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Aims and Scope

Educational Technology & Society is a quarterly journal published in January, April, July and October. *Educational Technology & Society* seeks academic articles on the issues affecting the developers of educational systems and educators who implement and manage such systems. The articles should discuss the perspectives of both communities and their relation to each other:

- Educators aim to use technology to enhance individual learning as well as to achieve widespread education and expect the technology to blend with their individual approach to instruction. However, most educators are not fully aware of the benefits that may be obtained by proactively harnessing the available technologies and how they might be able to influence further developments through systematic feedback and suggestions.
- Educational system developers and artificial intelligence (AI) researchers are sometimes unaware of the needs and requirements of typical teachers, with a possible exception of those in the computer science domain. In transferring the notion of a 'user' from the human-computer interaction studies and assigning it to the 'student', the educator's role as the 'implementer/ manager/ user' of the technology has been forgotten.

The aim of the journal is to help them better understand each other's role in the overall process of education and how they may support each other. The articles should be original, unpublished, and not in consideration for publication elsewhere at the time of submission to *Educational Technology & Society* and three months thereafter.

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Book review(s)

Paquette, G. (2007). An Ontology and a Software Framework for Competency Modeling and Management. *Educational Technology & Society*, 10 (3), 1-21.

An Ontology and a Software Framework for Competency Modeling and Management

Gilbert Paquette
LICEF Research Center, Télé-université, Montreal, Canada // Tel: (514) 840-2747 ext. 2818
gilbert.paquette@teluq.uqam.ca // www.licef.teluq.uquebec.ca/gp

ABSTRACT

The importance given to competency management is well justified. Acquiring new competencies is the central goal of any education or knowledge management process. Thus, it must be embedded in any software framework as an instructional engineering tool, to inform the runtime environment of the knowledge that is processed by actors, and their situation toward achieving competency-acquisition objectives. We present here some of our results in the last 10 years that have led to an ontology for designing competency-based learning and knowledge management applications. Based on this ontology, we present a software framework for ontology-driven e-learning systems.

Keywords

Ontology-driven e-learning system, Competency acquisition

A search on the Internet is sufficient to show the importance given to competency profiles in human resource management and education. Ministries of education, school boards, and teacher training institutes use competency profiles to define school programs or teachers' required qualities, especially in the use of technologies in education.

Consulting companies present their expertise by enumerating competencies, marketing their services in this way. Other companies offer services or computerized tools to help their prospective customers define or manage the competence of their staff. These services and tools are looked upon as the main asset of an organization from a knowledge management perspective. Governmental agencies or professional associations use competency-based approaches to define conditions to the exercise of a profession and to orient their vocational training programs.

To address the challenges of the knowledge society, we need to better support the process of competency acquisition in the context of lifelong learning, which is more and more required from every citizen. We need more flexible, adaptive learning systems, inside and outside public education systems, before, after, and during work. We need to respond to the huge demand for web-based resources for work and learn to cope with the exponential growth of information, by making the semantic web more and more a reality. We need to make educational modeling more widely used through powerful yet user-friendly tools and methods. Finally, we need to provide citizens with the tools to personalize their learning processes based on evaluation of their competencies.

Explorations in competency management

In this introductory section we will survey a set of applications related to competency management. These applications have been built in various projects we have achieved since 1992. It is important to note that we have started these projects with a clear definition of a competency that has been essentially confirmed and refined by many projects, some of which will be presented in this section.

Our definition is founded on the relation between specific knowledge in an application domain and generic skills. *Competencies are statements that someone, and more generally some resource, can demonstrate the application of a generic skill to some knowledge, with a certain degree of performance.*

For example, suppose we say that a technician can *diagnose the faults in a car engine, for all kinds of car*. This is a competency in which a technician applies the generic skill of *diagnosis* to his knowledge of *faults in a car engine*, with a degree of performance that involves *all kinds of cars*. A lower level of competency would be to *"sometimes identify that there are some faults in a car engine"* because "identify" is a simpler generic skill than "diagnose" and “sometimes” is less demanding than “all the time.” These kinds of relationships between competencies are very important for instructional engineering, as we will show later on.

In this section, we will present applications where we have used this definition to help develop and validate the ontology that will be presented in the second section, which gives a more precise meaning to the concept of competency. Then, based on this ontology, we shall define tools and services for a software framework for competency management, which is the subject of third section.

Competency in an Instructional Engineering Method (MISA)

As early as 1992, we started to integrate knowledge and competency modeling within the MISA Instructional Engineering method (Paquette, Crevier, & Aubin, 1994; Paquette, 2002a, 2003). Competency ontologies are central to any instructional engineering methodology. They are important before, during, and after delivery. Before delivery, Competencies serve to guide the design or adaptation of a learning environment. During delivery, they guide the action of facilitators for learners’ assistance. After delivery, they help assess the learning results and the evaluation of the quality of a learning environment. We give here two examples of the use of competency modeling for instructional engineering that have served in many of our applications projects.

Guiding the definition of knowledge and activities using competency gaps

Figure 1 presents two of the tools in Atelier distribué d’ingénierie des systèmes d’apprentissage (ADISA)(translated from French as “Distributed Workbench for the Engineering of Learning Systems”), a web-based workbench to support the 35 main tasks of the MISA instructional design method. These tools are used to define a set of competencies associated with a knowledge model that defines the content for a course. In task/tool 212, the designer builds a graph of the knowledge that will be processed by learners and facilitators in an e-learning application, adding “P” labels to the knowledge elements that are important priorities for learning.

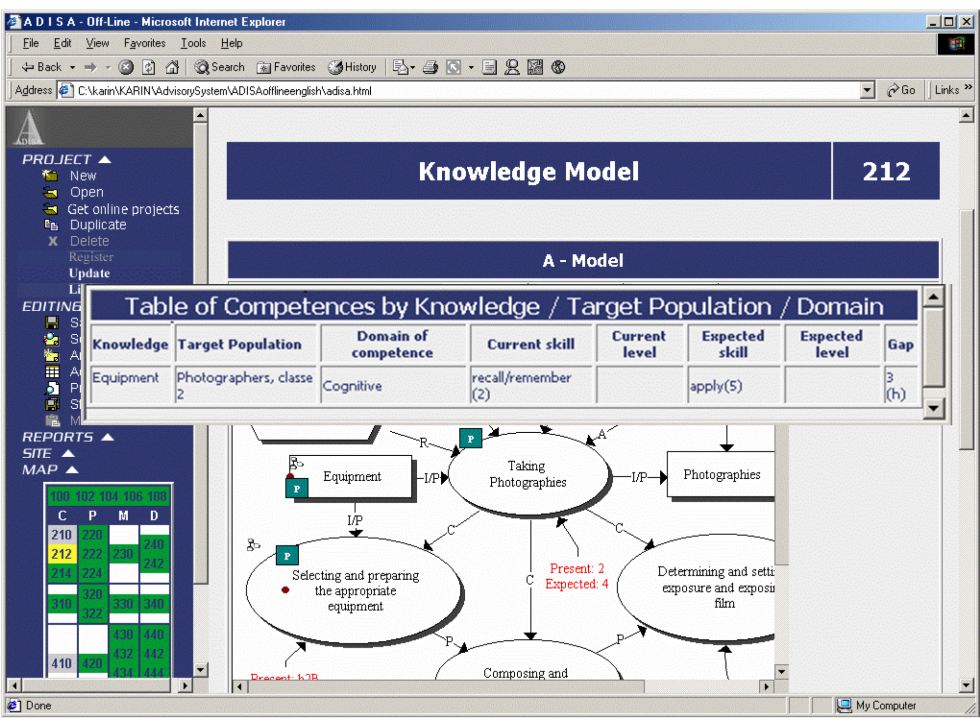

Figure 1. Associating competencies to the knowledge element

In task/tool 214, a list of these priority knowledge units is automatically transferred from the model and displayed to the designer in order for him to assign prerequisite and target competency statements for these knowledge elements. An example for the knowledge of photography, "Equipment," is shown in the figure. For each priority knowledge element and each target population of learners, the skill name and level and the performance name and level are entered for the prerequisite ("current skill" in the figure) and target or expected skill. Here, no performance level is shown: the spaces for current and expected levels are empty.

This data enables the system to calculate the gap between entry and target competency, which is defined here as the absolute value of the difference between the two skill levels. The notion of skill level is related to generic skills' taxonomies that will be explained later in table 4. Here the current or entry skill is "recall/remember," which is the second on a scale of generic skills of increasing complexity. The expected skill is "apply," which is fifth on the same scale. So the gap is simply $| 5 – 2 | = 3$. If the performance level had been defined, we would have been able to obtain a two-dimensional scale, such as the one in figure 8, to evaluate the gap more precisely.

The system can then display a table of the priority knowledge element versus the competency gap (shown on figure 1 for the knowledge entity "Equipment"). Using this table, it is possible to guide the further development of the knowledge model, going back to the modeling tool in task 212. For example, for a knowledge element with gap of 0, it is not necessary to develop the model further; in fact it shouldn't be a learning priority at all. On the contrary, for a knowledge element with a gap of 3 between the prerequisite: recall/remember (level2) and the target: apply (level 5), we should add more related knowledge in the model and thus more activities in the pedagogical model to acquire that knowledge.

Constructing an activity structure based on a generic skill

The generic skills on which a competency is based are processes acting on knowledge in an application domain. They can also be represented as process models (Paquette, 1999). On the left side of figure 2, there is a graph of a generic skill, to simulate a process, with its main operations (ovals) such as "produce examples of the input to the process" to be simulated, "identify the next applicable procedure" in the process, "apply this procedure," and finally "assemble the simulation trace" by collecting the products (rectangles) of these operations. On the graph, four groups of principles (hexagons) are added to constrain the products and/or control the operations of the generic simulation process. Note that this model is totally generic, applicable to any specific knowledge domain, such as Internet processes, manufacturing processes, or others.

The graph on the right side of figure 2 presents a corresponding learning scenario based on a generic skill model in which learners simulate a multimedia production process by performing learning activities that correspond to the main operations in the "simulate a process" skill. Such an activity structure is based on a graph almost isomorphic to the generic process, however, taking a "learning activity" viewpoint. The specific domain vocabulary is used, and the activities are formulated in an "assignment style" format.

This provides the skeleton of a learning design. To complete the process, we need to add resources to help learners achieve their tasks. The important thing here is that the generic process in a target competency provides the structure the learner's assignments. In that way, it is possible to make sure that the learner works at the right skill level, in this case "simulating a process," while at the same time processing a specific knowledge domain.

Constructing a professional training program

We have used the instructional engineering tools and the principles presented above to develop a complete professional training program. In 2003, we were contracted by a Montreal-based company to apply our competency engineering approach and our taxonomy of generic skills, in order to re-engineer a training program offered by the School of the Quebec Bar. This one-year program serves to habilitate every new lawyer in Quebec to professional practice. Working meetings of our team members with an expert committee, composed of 12 experienced lawyers, allowed us to build a relevant knowledge model for the domain of law practice. In a second step, we identified cognitive and socio-affective skills associated with this knowledge, as well as the conditions of performance that are required from novice lawyers to be able to start professional practice.

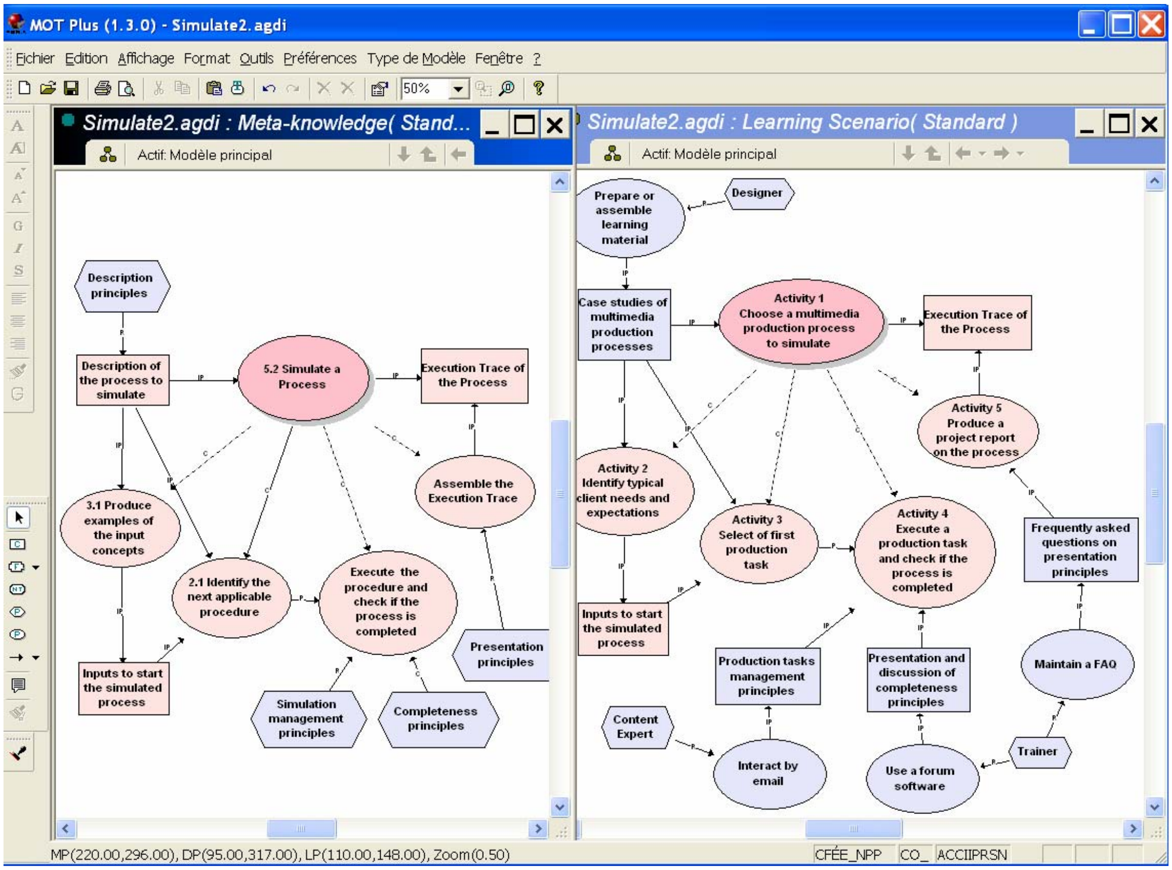

Figure 2. From generic skill to learning scenario definition

Data on these elements was collected during group sessions with the expert committee, and individual face-to-face sessions with some of its members. Questionnaires were filed in by all members. The consultation of different content documents used in the program served to enrich the information. Systematically, the analysis of obtained data led to a document synthesizing a competency profile, which was validated by the Committee and which brought new elements to advance the work and complete the models. The iterative revision of the different versions of the competency profile led to a list of 35 main knowledge elements with their associated target competencies.

Table 1 presents a sample of some of these competencies. Each competency is expressed by a statement specifying the generic skill (in bold italic) that the novice lawyer has to apply to a knowledge element (in italic) according to particular performance conditions expressed in the rest of the competency statement.

Competencies were grouped in five domains based on the knowledge model: A — law concepts, regulations, and standards of the profession; B — communication with the client; C — establishment of a diagnosis; D — elaboration, assessment, and application of a solution; E — management of case data and quality control. The four last categories show that the knowledge model was mainly procedural, describing the main element of law practice as a sound decision for a professional program. The committee attributed a priority to each of the competencies shown in the priority column of table 1.

To plan the new program, it was important to identify, for every competency, the distance between the prerequisite competency that the students should possess before entering the program and the target competency to be acquired by the end of the program. The levels of the target generic skill were first identified by the expert committee, and entry levels were set in the second phase by trainers in the program. The difference between the two is the gap shown in the last column of table 1.

Table 1. A sample of the 35 competencies for the law training program

ID	*Group A — Law concept, regulations, and standards of the profession*	*Priority*	*Entry*	*Gap*
A1	***(6) Analyze*** the *applicable texts of law* to a situation, without help for simple and average complexity situations, with help in complex ones	1	(2)	4
A3	**(3)** ***Specify*** the applicable law regulation autonomously, in any case	2	(1)	2
A8	***(5) Apply*** *pertinent proofs and procedures*, without help for simple and average complexity situations.	1	(2)	3
ID	*Group B — Communication with the client*	*Priority*	*Entry*	*Gap*
B1	***(6) Analyze*** *interactions with the client*, without help in any communication situation.	2	(2)	4
B2	***(9) Evaluate*** the quality of one's capacity *to listen to the client*, without help in any communication situation	2	(1)	8
B4	***(4) Transpose*** in one's social and affective interactions with the client *principles of communication* and *human behaviour*, without help in average complexity situations.	2	(1)	3

Once stabilized, the competencies, their groupings, and the estimated competency gap contributed to define the structure of the new program. As shown in table 2, competencies were distributed in learning units (called courses), taking in account groupings, priorities, and the competency gap between entry and target levels.

The gap between the entry and target competency levels proved to be very important for the construction of the program. There were 9 competencies with a gap from 1 to 3, 18 with a gap of 4 or 5; 5 with a gap of 6 or 7; and 5 with a gap of 8. The competencies were distributed in a spiral approach into four sequential learning units (courses 1 to 4) according to the gap. For example, the B2, and E4 to E7 competencies (with a gap of 8) were integrated in all four courses to increase progressively the generic skill and performance levels of the learners. Competencies A1 and others were distributed only in the first two courses because they are easier to acquire. Competencies A3 and others were included only in the first learning unit, which seems to be sufficient for their acquisition. The target competencies in the courses serve as learning objectives to be measured by exams and other means of evaluation. The following phases of the project have focused on building learning scenarios for each learning unit or sub-unit based on the generic skills in the associated competencies.

Table 2. Distribution of competencies into courses of the program

Gap	Competencies	Course 1	Course 2	Course 3	Course 4
1-3	A3, A4, A5, A6, A7, A8, B4, C2, C6	x			
4-5	A1, A2, A9, A10, B1, B3, C1, C3, C5, D2, D5, D6, E1, E2, E3, E8	x	x		
6-7	C4, D1, D3, D4, E9	x	x	x	
8	B2, E4, E5, E6, E7	x	x	x	x

Integration in an LCMS (Explor@-2)

The same general approach to competency modeling has been integrated in an e-learning delivery system called Explor@ (Paquette & Marino, 2005). Unlike most LCMS, Explor@ is built around two structures: the activity structure (or learning design), which breaks down a program or course into smaller activity structures, activities, and resources, and the knowledge/competency structure, which presents a hierarchy of concepts in an application domain, with their associated entry and target competencies. Figure 3 presents the tools that help create and manage these two structures.

The large window on the left presents a tree of concepts from a lightweight ontology in a subject-matter domain (in this case, eco-agriculture). The nodes of this tree are concepts from the domain ontology and the leaves serve to select a generic skill associated to its parent node. When selecting a leaf like "Analyze-6" with parent node "agriculture practice," the right part of this window enables a designer to document corresponding competencies, while writing the target competency statement. The knowledge and skill elements are copied automatically from the tree structure. The designer then adds the meta-domain (here "cognitive," but this could also be "affective" or "psycho-motor"). The performance level is set by selecting some or all of the "performance criteria" in an auxiliary window, criteria that are combined by the system into A, B, C, or D level (here B-Familiarity). The rest of the right side of the window is to fix similar elements for the entry competency on the same knowledge, based here on the "Apply-5" generic skill.

The lower right side of the window serves to associate these competencies with activities and resources in the activity structure shown in the other window. This is done by simply selecting activities or resources from this window; resources are on the leaves of this tree below the activity or activity structure where they are used or produced.

Another auxiliary tool (not shown on figure 3) displays a summary table of competencies at different levels of the activity structure, enabling designers to distribute relative weights to compose a global evaluation. From this data, it is possible to generate automatically a self-diagnosis questionnaire like the one in figure 4 below, where learners can self-assess their competencies and select proper activities and resources to help improve them. Similar interfaces can be generated for trainers to help them evaluate the students' progress.

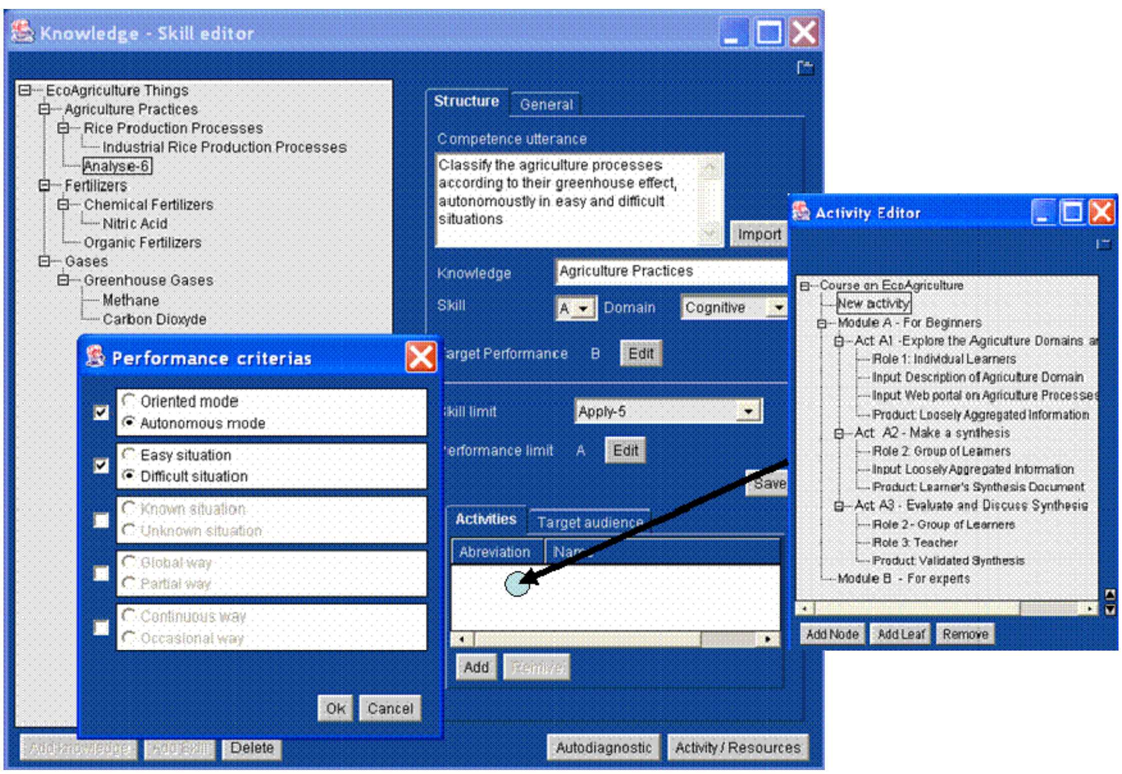

Figure 3. Competency management in Explor@

Emergent self-composed training programs for life-long learning

Figure 4 shows screens of a user-friendly self-diagnosis web tool that can help students diagnose their competency and compose their own training programs with or without the help of a trainer or facilitator (Ruelland, Brisebois, & Paquette, 2005). The tool comprises three steps displayed in the three windows of the figure.

On the first page, a list of competencies imported from a competency editor is presented to the user (learner or trainer). For each competency, the user selects his/her actual performance level from among four levels.

On the second page, a global summary of these combined levels is displayed in the form of a bar graph of the gaps between actual and target competencies, to identify strengths and weaknesses.

On the third page, recommendations for a plan of action are provided in the form of resources associated with each competency or competency group. Access is given to these resources through a hyperlink to enable user navigation between the resources. The resources can be any document, website, online or blended learning course, or address of a resource person that have been previously associated with one or more competencies. The association tools between competencies and resources can be made available to students as well as trainers to enable the composition of a training program for lifelong learning. In that case, federated search tools in learning object repositories can be used to find appropriate resources and link them to competencies.

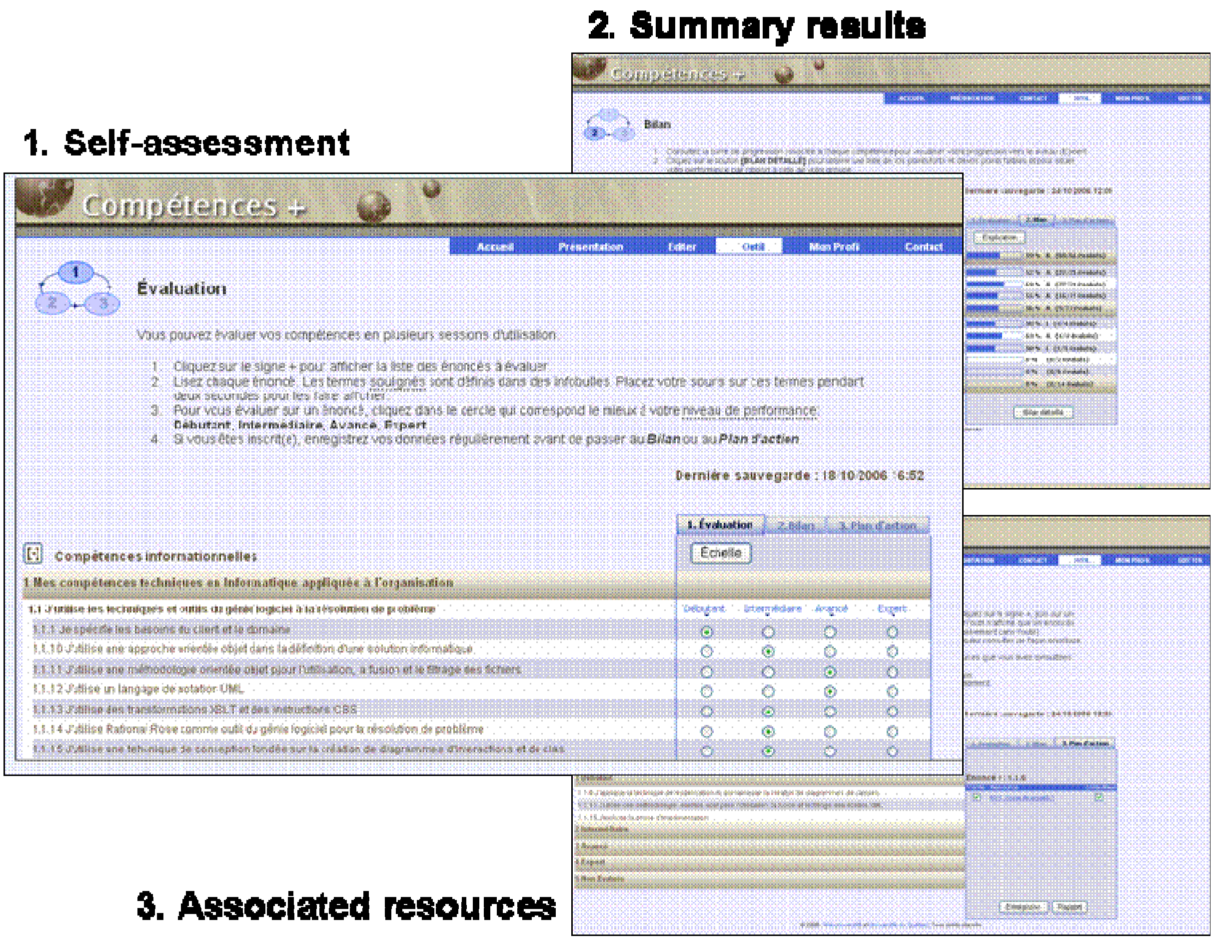

Figure 4. A competency self-assessment tool

An ontology for competency modeling

Drawing on the previous work and the experience gained in numerous projects, we now present an ontology for competency modeling that combines the concepts of knowledge, skill, attitudes, and performance. It is rooted in different fields of research such as instructional design, software engineering, and artificial intelligence. It provides ways to annotate semantically resources in e-learning and knowledge management environments, in particular to define competencies of individual actors, prerequisites and goals for activities and resource content, evaluation criteria, and personalization capabilities for e-learning and knowledge management applications.

Beyond the textual competency statement

Most often, competencies are expressed as simple, plain-language sentences, stating informally that a group or person has the capacity or the knowledge to do certain things. Competency profiles are, in general, loosely structured collections of such texts that are not always easy to interpret, communicate, or use, especially if the goal is to plan learning events to support the acquisition of new competencies.

Efforts are being made to facilitate the use of competencies in education and training. For example, the IMS organization, involved in defining e-learning standards, produced in 2002 a specification for a Reusable Definition of Competency or Educational Objective (IMS-RDCEO 2002). It defines an information model for describing, referencing, and exchanging definitions of competencies, primarily in the context of online and distributed learning. Its goal is to enable the interoperability among learning systems that deal with competency information by providing a means for them to refer to common definitions with common meanings.

As stated in this RDCEO documents, “the word competency is used in a very general sense that includes skills, knowledge, tasks, and learning outcomes.” Furthermore, **“**the core information in a RDCEO is an unstructured textual definition of the competency that can be referenced through a globally unique identifier.” The RDCEO does not provide any structured model for a competency, but it mentions that “this information may be refined using a user-defined model of the structure of a competency.”

As we pointed earlier (Paquette & Rosca, 2004; Paquette & Marino, 2005), a crucial area where a learning design specification like IMS-LD needs to be improved is knowledge representation. Actually, the only way to describe the knowledge involved in a learning design is to assign *optional* educational objectives and prerequisites to the unit of learning as a whole and/or to some of the learning activities.

Without a structural model for a competency, these entry and target competencies will be unstructured pieces of text, which are difficult to use in e-learning systems, forbidding, for example, consistency checking between different levels of the LD structure, and even at the same level between the content of learning activities, their related resources, and the learners’ competency. In fact, in IMS-LD the knowledge in learning resources is not described at all, and the actors’ knowledge and competencies are indirectly defined by their participation in learning units or activities only if educational objectives are associated.

Without a good representation of the knowledge and competency to be processed, a delivery system will be unable to help its users according to their present and expected competency state. In other words, the system will be unable to provide personalized learning activities for its users. What we need is both a qualitative structural representation of knowledge in activities and resources, but also a quantitative one providing a metric for evaluating competency gaps during the learning process. The association between learning objects (documents, tools, actors, activities) within a unit of learning, and the knowledge and competencies they possess, contain, or process is a key concept for semantic web application (Berners-Lee, Hendler, & Lassila, 2001).

The knowledge domain in an e-learning or knowledge management application can be structured in many ways: dictionaries, thesaurus, book summary, library catalog, indexes and metadata, knowledge graphs, ontologies, etc. The tree organization of a knowledge domain is an important property that can significantly reduce the processing, but it is insufficient to describe the rich network of relations that ties the concept structures. It needs to be complemented with relations betweens concepts and axioms in order to sustain more refined mechanism of conceptual matching and inference. In other works, we need to use some form of domain ontology (Davies, van Harmelan, & Fensel, 2002, Breuker, Muntjewerff, & Bredewej, 1999).

But if we use only domain ontologies without defining mastery levels for the knowledge, we limit ourselves to weak semantic management capabilities, both by human facilitators and computer support systems. We can use different mastering scales: simple quantitative percentage, levels in Bloom taxonomy, and combinations between generic skills taxonomies and performance levels, which is our proposal. The description of knowledge mastery must be reasonably simple to be manageable. Still, the levels must correspond to clearly identified generic processes such as applying, synthesizing, or evaluating knowledge.

Combining the preceding requirements suggests that a good candidate for the semantic indexing of educational resources, actors, and activities will be a combination between domain ontologies and a simple and expressive generic skills ontology.

A competency ontology

The basis for the competency ontology we will now introduce can be found in many related fields, such as mathematical logic (Thayse, 1988), science methodology (Popper, 1967), problem solving and its teaching (Polya, 1957), educational technology (Romiszowski, 1981 Merrill, 1994), software and cognitive engineering (Breuker & Van de Velde, 1994; Steels, 1990), and artificial intelligence (Pitrat, 1991).

Our definition is founded on the relation between specific knowledge and generic skills. In his work on artificial intelligence, Jacques Pitrat (1991) produced an important synthesis in which he distinguishes several meta-knowledge categories and proposes the following definition: "Meta-knowledge is knowledge about knowledge, rather than knowledge from a specific domain such as mathematics, medicine or geology."

In the education sciences, Romiszowki (1981) expresses very well the simultaneous phenomenon of knowledge acquisition in a particular domain and the meta-knowledge building of generic skills: "The learner follows two kinds of objectives at the same time — learning specific new knowledge and learning to better analyze what he already knows, to restructure knowledge, to validate new ideas and formulate new knowledge." The same idea is expressed by Pitrat: "Meta-knowledge [generic skills] is being created at the same time as knowledge." In other words, meta-knowledge or generic skills develop while they are applied to knowledge in a particular field. Anybody learning new knowledge uses generic skills (at least minimally) without necessarily being aware of it. However, using generic skills should really be a learner's conscious act.

On a more practical ground, we studied (Paquette, 2002b) a sample of competency profiles in diverse sectors including large companies (such as Hydro-Quebec), the Public Service Commission of Canada, professional requirements, high school curricula, libraries, and information processing. We find a large diversity of goals, uses, and even explicit or implicit conceptual framework differences. Our goal is to find unity behind that diversity to be able to extract models of competency that can be used at an operational e-learning framework.

Competencies are statements that link together skills and attitudes to knowledge required from a group of persons and, more generally, from resources. Some examples integrate elements apart from these or ignore some of them. For example, the competency profile of the Public Service Commission of Canada presents a model that lies partly outside the realm of the competency definition, taking in account the interests and beliefs of the public servants. At the other end, statements like "ability to plan work," "openness to critique," and "some knowledge of creation tools" in a competency profile for multimedia producers seem insufficiently precise, describing respectively a generic skill, an attitude, and a knowledge element that are part of a competence but insufficient to describe it.

In most competency profile definitions however, a competency is defined as a combination of skills, attitudes, and knowledge that enable a group or person to fulfill a role in an organization or society, for example, to act as a lawyer, nurse, technician, teacher, information seeker, media producer, or any other profession. Such roles require general competencies that might be shared with other roles, as well as more specific competencies required by specific task, context, and problems they will have to solve. For example, the role of a nurse will not be the same in a developing country as in a society where there exists a highly organized, sometimes bureaucratic, health system.

Figure 5 presents the top level of the ontology that we propose, defining the main competency concepts that will be explained and expanded upon later on.

Competencies serve to annotate resources, human as well as media resources, giving them a semantic meaning as to the knowledge and skills they own or contain. These annotations can represent prerequisites to achieve a task, or to be attained as a result of a task. They can also be declared as actually owned by the resource they annotate. Each competency is composed of a single competency statement, exactly one generic skill that may require precision using performance indicators, and at least one knowledge entity. The competency statement is a plain-language phrase that refers to the other components, stating that the generic skill (with optional performance indicators) can be applied to the knowledge.

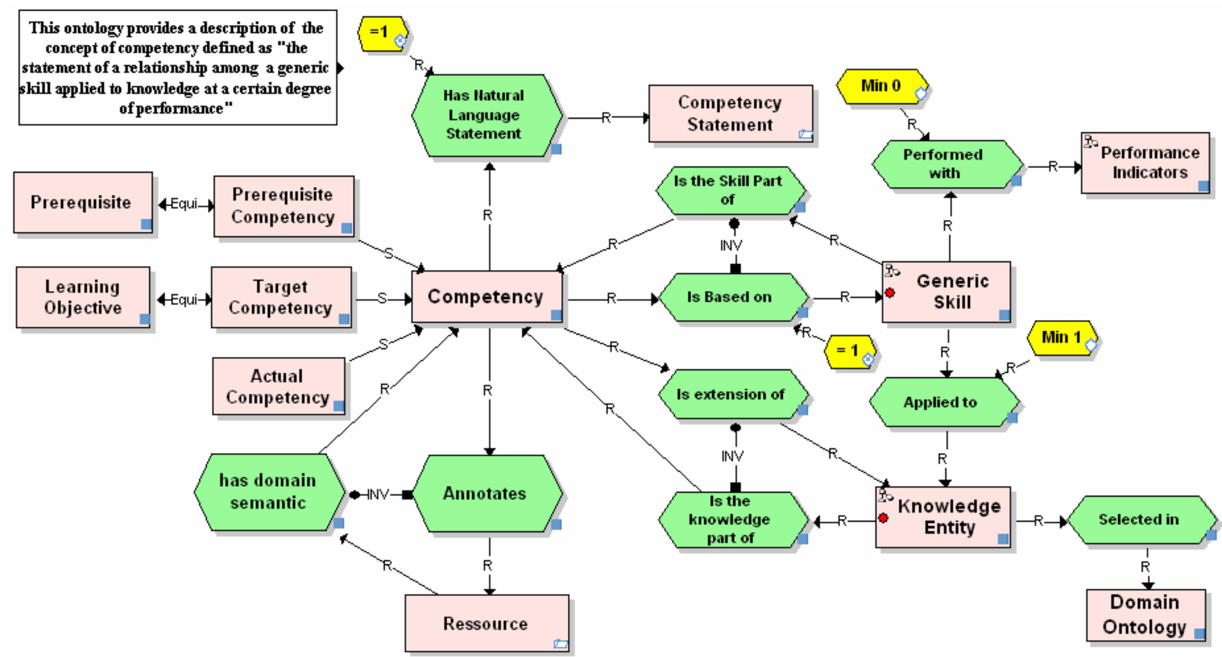

Figure 5. Top-level ontology for competency definition

[*Note.* This graph uses MOT + OWL graphic syntax that covers all OWL-DL primitives (W3C 2004). Rectangles represent classes, and hexagons represent properties linked to their domain and co-domain by incoming or outgoing R links. S links from one class to another means that the first is a sub-class of the second.]

The knowledge part of the competency can be a concept, a procedure, a principle or a fact that is selected in a domain ontology. In a competency profile for a profession such as nursing, this knowledge part will be selected in a healthcare-structured description of facts, concepts, procedures, or principles. In a competency profile for media producers, the knowledge entity will be one of the techniques, methods, objects, or products from the multimedia domain. In general, we will consider that the competency ontology is extended by an application domain ontology from which the knowledge part has been selected as a class (concept) or an individual of the ontology.

A generic skill is a process that can be applied to knowledge in more than one application domain, for example to perceive, memorize, assimilate, analyze, synthesize, or evaluate knowledge items. A generic skill is described by an action verb, sometimes with performance indicators such as “in new situations” or “without help” that serve to make the skill more specific, while remaining independent from any application domain. For example, a generic skill like “establish a diagnosis,” or “establish a diagnosis in new situations without help” can be applied in diverse application domains to knowledge items such as “skull fracture,” “car motor failure,” or “exam failure risk.” A generic skill is also selected from a generic skill’s ontology, which is considered an extension of the competency ontology.

Table 3 gives a sample of competencies from different sources showing how this competency ontology can be applied. Note that the fourth and fifth examples are merely expressions of a generic skill without a knowledge part, so we have concluded that implicitly it was meant to cover all knowledge in the application domain ontology. The fifth one is in fact two competencies that should be separated because a competency contains only one generic skill. Note also that the second and the fifth competencies have a performance indicator, respectively “accurately” and “in everyday life.”

Table 3. A sample of competency statements in different fields and their breakdown

Source	Competency Statement	Generic Skill	Knowledge Entity
ANCI profile for nurses (1)	Demonstrates knowledge of legislation and common law pertinent to nursing practice	Apply	Australian law related to nursing practice
ANCI profile for nurses (1)	Analyzes and interprets data accurately	Analyze without error	Patient healthcare data
Multimedia Producer (2)	Ability to evaluate project's feasibility	Evaluate	Project description
Multimedia Producer (2)	Ability to convince others	Influence	Team members and clients
MEQ — Student Competencies (3)	Analysis and synthesis capability	Analyze Synthesize	All subject matter in the curricula
MEQ — Student Competencies (3)	Apply in everyday life, rules of life in society	Apply in everyday life	Rules of life in society
Teaching Competencies (4)	Operates within the framework of law and regulation	Apply	Laws regulating the teaching profession
Teaching Competencies (4)	Plans purposeful programs to achieve specific learning outcomes	Synthesize	Programs addressing specific outcomes
Information Literacy Profile(5)	Identifies a variety of types and formats of potential sources for information	Identify	Types and formats of information sources
Information Literacy Profile(5)	Determines whether the initial query should be revised	Evaluate	Query for information

Extended examples of these competency profiles can be found in Paquette (2002 b):

Generic skills sub-ontology

We will now expand the competency ontology for the generic skill component of a competency requirement. The backbone of this sub-ontology is a generic skill taxonomy that presents more and more specialized classes of intellectual processes (such as memorize, transpose, analyze, or evaluate) that can be applied in different knowledge domains. Each generic skill class groups individual knowledge-processing activities.

Possessing a generic skill means that a learner can solve a corresponding class of problems (Chandrasekaran, 1987; McDermott, 1988; Steels, 1990). For example, if a learner possesses a diagnostic or classification skill, it implies that this learner is able to solve some diagnostic or classification problems with a certain degree of proficiency. Another view is to see cognitive skills as active, procedural meta-knowledge (generic processes) that can be applied to knowledge (Pitrat, 1991) A third view considers the association between cognitive skills and application knowledge as objects to be learned together, such as educational objectives (Bloom, 1975; Krathwohl, Bloom, & Masia, 1964; Reigeluth, 1983; Martin & Briggs, 1986). Integrating all three viewpoints gives us a solid foundation for a generic skills taxonomy.

Basic hierarchy of generic skills. Table 4 presents an overview of the proposed skills taxonomy. This table displays a loose correspondence between an artificial intelligence taxonomy (Pitrat, 1991), a software engineering taxonomy (Breuker & Van de Velde, 1994; Schreiber, Wielinga, & Breuker, 1993), and two educational taxonomies (Bloom, 1975; Romiszowski, 1981). Although the terms are not in direct correspondence, table 2 distributes them into 10 levels that lay the foundation for our taxonomy (Paquette, 1999; 2003), shown in the left part of table 2. It portrays three layers, from left to right and from generic to specific. It could be expanded to more levels for additional precision.

We will now discuss some of the properties of this taxonomy. Contrary to the behaviourist view on learning objectives, intellectual skills are viewed here from a cognitivist viewpoint as processes that can be described, analyzed, and evaluated by themselves or in relation to various knowledge domains.

Table 4. Generic Skills Processes compared to processes in other taxonomies

Generic Skills Classes			Active meta-knowledge (Pitrat)	Generic problems (KADS)	Cognitive objectives (Bloom)	Skills cycle (Romiszowski)
1	2	3				
Receive	**1. Acknowledge**					Attention
	2. Integrate	2.1 Identify 2.2 Memorize			Memorize	Perceptual acuteness and discrimination
Reproduce	**3. Instantiate/Specify**	3.1 Illustrate 3.2 Discriminate 3.3 Explain	Knowledge Search and Storage		Under-stand	Interpretation
	4. Transpose/ Translate					Procedure Recall Schema Recall
	5. Apply	5.1 Use 5.2 Simulate	Knowledge Use, Expression		Apply	
Produce/Create	**6. Analyze**	6.1 Deduce 6.2 Classify 6.3 Predict 6.4 Diagnose	Knowledge Discovery	Prediction, Supervision, Classification, Diagnosis	Analyze	Analysis
	7. Repair			Repair		Synthesis
	8. Synthesize	8.1 Induce 8.2 Plan 8.3 Model/Construct		Planning, Design, Modeling	Synthesize	
Self-manage	**9. Evaluate**		Knowledge Acquisition		Evaluate	Evaluation
	10. Self- control	10.1 Initiate/Influence 10.2 Adapt/Control				Initiation, Continuation, Control

Table 5 presents process definitions to compare generic skills in the first layer. For each class of generic skills, it shows input and products, as well as examples in the class. These definitions support the hypothesis that skills in the first layer are ordered from simple to complex. Self-management skills involve explicit meta-cognitive operations for evaluation and decisions; this entails the need for production/creation operations to be performed. Creation or production of new knowledge from more specialized knowledge entails the use of reproduction skills. Reproduction skills are essentially instantiation or translation from more general knowledge that requires reception skills. Finally, reception skills involve only attention and memory operations that are needed in reproductive processes.

Generic skill's complexity. We provide here a definition of a generic skill's complexity: Skill A is more complex than skill B if for any generic process P in class A, there exists a generic process in class B acting as a sub-process of P.

We have provided elsewhere (Paquette, 2002b) evidence of a complexity ordering for the 10 classes in the second layer of our taxonomy by constructing process graphs of these generic skills. For example, the "simulate" skill (level of complexity 5.2) can be broken down into four sub-processes: produce examples of the input concept (instantiate: level 3), identify the next applicable procedure (identify: level 2), execute the procedure applying its control principles (apply: level 5, in a simpler way), and finally assemble the simulation trace (transpose: level 4). This shows, according to our definition of complexity, that "simulate" is more complex than skills at levels 2, 3, and 4.

Meta-domain. Generic skills, being processes acting on knowledge, can be classified according to the kind of input they process or produce. For example, "to persevere and to adapt a course of action in a project" is a process in which affective and social input and output are essential. In Paquette, 2002b, we built a complete table showing examples in the cognitive, affective, social, and psycho-motor meta-domains for each of the 10 major skills in the second layer of the taxonomy. This shows that this taxonomy can be interpreted in each of the four meta-domains: cognitive, psycho-motor, affective, and social. For example, we can repair theories and movements, as well as attitudes or social relations. What differentiate these four meta-domains is essentially the type of input to a skill and its resulting outputs. If the stimuli or the result concerns rational thought, motor capacities, affective attitude, or social interactions, we will label the skill to be cognitive, psychomotor, affective, or social, respectively.

Table 5. Comparison of generic skills, from simple to complex (first layer)

Name of skill	Definition	Examples
Receive	Input = internal or external stimulus; Product = facts or knowledge found or stored in memory	Pay attention to an event, to a movement, to an emotion, to a social context; Identify knowledge, associated impressions; Memorize knowledge, impressions.
Reproduce	Input = knowledge and models; Products = facts obtained through instancing or knowledge obtained through reformulation	Use examples to explain or illustrate a concept, a procedure, or a principle; Use a model to explain facts; Simulate a process.
Produce/ Create	Input = knowledge and models; Products = new knowledge or models resulting from analysis and synthesis	Classify objects according to a taxonomy; Repair defective system components ; Plan a project; Model and build a system.
Self-manage	Input = knowledge, models, values; Product = knowledge, models, meta-knowledge (values or generic skills) linked to domain model	Assess knowledge validity or self competence; Initiate a change process after assessing the situation; Apply a generic strategy to improve learning and performance.

Sub-ontology for generic skills. Figure 6 summarizes the preceding discussions on the generic skill's properties, presenting the resulting sub-ontology for generic skills.

The taxonomy is ordered by layers (using specialization S links) from left to right and from general to more specialized skills. The first layer shows a "C" property between the four classes of skills. This property reads from bottom to top as "is more complex than." We add here a transitivity axiom for the C property by adding an arrow label on its graphic symbol. This property also exists between skills of the second layer. Only some of C property symbols are shown in figure 6 to ease the graph's readability, but there is one, for example, from synthesize to repair and from repair to analyze. On the other hand, there are no direct C properties between skills of the third layer, only through their second-layer parent classes.

This MOT + OWL graph shows a third type of OWL objects representing individuals. It serves to assert that generic skills have a meta-domain property that can have as a value "cognitive," "affective," "social," or "psycho-motor", as well as any combination of these values (the "max 4" cardinality axiom affecting the property). It also shows that, based on the second layer's total ordering by complexity, we can assign one and only one number from 1 to 10, representing the complexity level of a generic skill. In OWL terminology, it means that the "has skill level" property is functional. A corresponding axiom is added by a label on the hexagon representing this property.

Performance indicators and levels

We now complete the competency ontology by developing a sub-model for the "performance indicator" class shown in figure 5. There are many possible performance indicators that are used by practitioners and some that we have explored in our own projects in the last 10 years. The ones shown in figure 7 have been found most frequently useful.

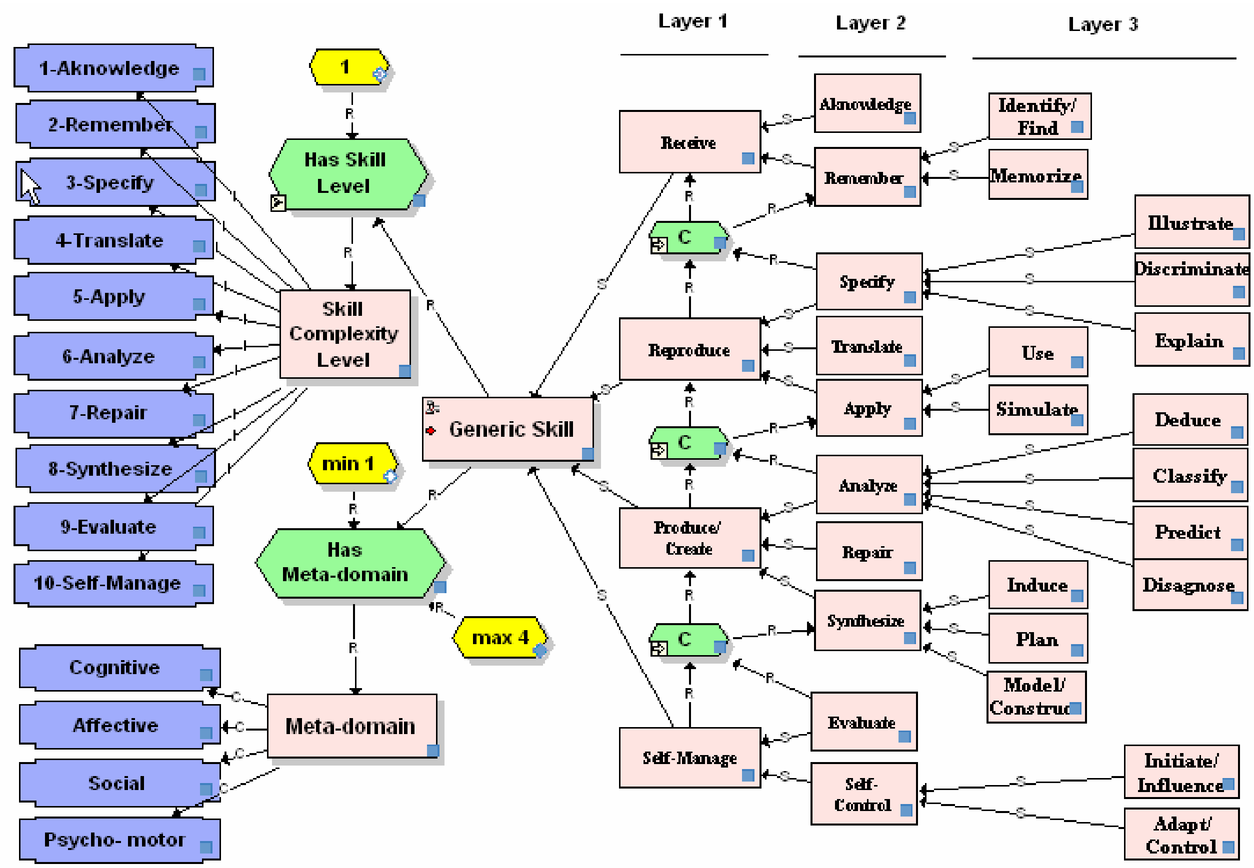

Figure 6. Extension of the competency ontology to generic skills

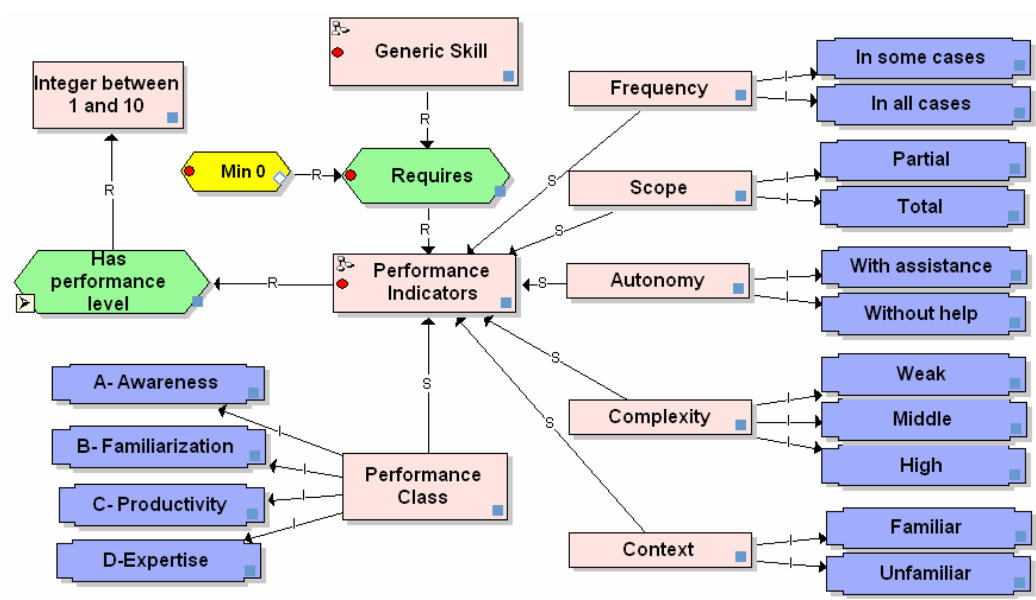

Figure 7. Extension of the competency ontology to performance indicators

For any generic skill, it is possible to add performance indicators such as frequency, scope, autonomy, complexity and/or context of the use. For example, a competency like “diagnose the source of malfunction of a car engine” could be made more precise by adding at the end performance indicators such as “in all cases” or “in the majority of cases” (frequency), “for part of the causes” or “for all causes” (scope), “without help” or “with little assistance” (autonomy), “for high complexity engines” (complexity), or “in unfamiliar cases” (context of use). Some of these values are shown in figure 7 as instances of the ontology. Other individuals and other values could be added to extend the ontology. The usefulness of such indicators is to help build ways to assess the competency, for example, to design exam questions or to register student actions in some model of his or her progress.

Table 6. Performance Categories or Levels vs. Other Indicators

CRITERIA	PERFORMANCE LEVELS Awareness 0.0 – 2.5	Familiarity 2.5 – 5.0	Mastery 5.0 – 7.5	Expertise 7.5 - 10
Frequency	Sometimes	Always	Always	Always
Scope	Partial	Partial	Partial	Total
Autonomy	With assistance	With assistance	Without help	Without help
Complexity	Weak	Weak	Middle	High
Context	Familiar	Familiar	Familiar	Unfamiliar

Alternative and more simple performance indicators classify performance for a generic skill in four broad categories: “awareness,” “familiarization,” “productivity,” or “expertise,” or simply by a number on a 1–10 scale for the performance level. These categories or levels can be direct evaluation results, or they can be calculated from the other indicators. One way to combine indicators or criteria to define performance classes or levels is shown in table 6.

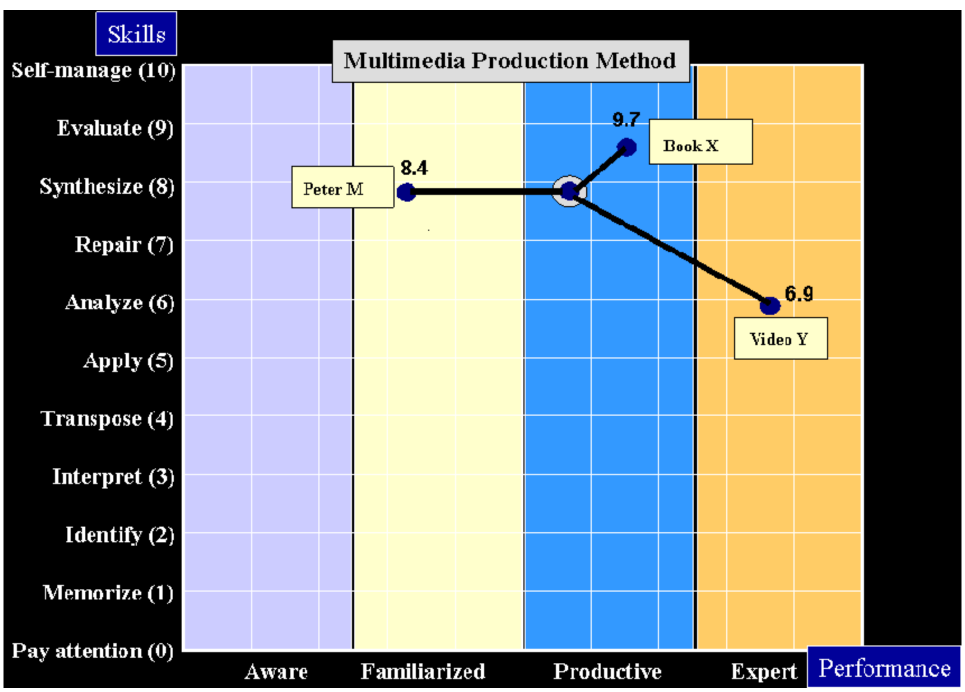

Figure 8. Situating resources on a skills/performance scale

Competency scale

By combining the generic skills' levels with performance levels, we can design a two-dimensional competency-based scale that will help situate resources according to their competency for a certain knowledge item. For example, figure 8 shows such a competency scale for the knowledge of a "multimedia production method." It shows a course having a target competency of 8.6, which means it aims to "synthesize productively a multimedia production method." For that course, Peter M has an actual competency of 8.4, which means he is "familiar with synthesizing a multimedia production method." Video Y, at a level of 6.9, may not be very useful for that course, except maybe as a refresher, because it focuses on "analyzing at expert level a multimedia production method," which is at a lower generic skill level.

A software framework for competency management in TELOS

This concluding section will summarize part of the actual research we are conducting within the LORNET research network to generalize and integrate the concepts presented above into the architecture of the TelELearning Operating System (TELOS).

TELOS: An ontology-driven architecture

TELOS is basically an assembly-and-coordination system. The term "TelE-Learning Operating System" means that TELOS is planned essentially as a set of coordination and synchronization functionalities supporting the interactions of persons and computerized resources that compose a learning or knowledge management system. It integrates human and computer agents using two basic processes: semantic representation of resources and resource aggregation.

An important goal is to help the system survive the rapid evolution of technologies by embedding in the system technology-independent models expressed as ontologies. The TELOS system is able to reuse ontologies as "conceptual programs." In this vision, the conceptual models are not just prerequisite to building the TELOS system; they are part of the system and its most fundamental layer.

Global view of the TELOS competency management framework

The TELOS Competency management framework is composed of the 10 major tools shown in figure 9. The tools in the first column serve to design fundamental elements of a TELOS Learning and Knowledge Management Application (LKMA).

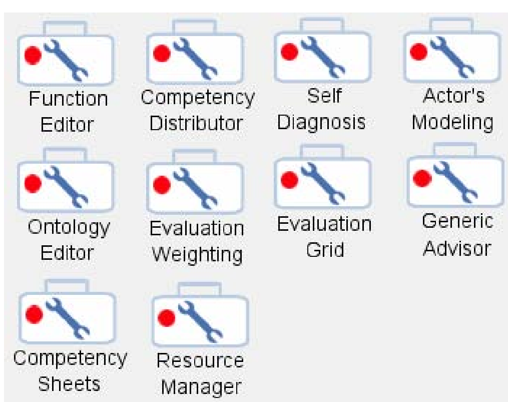

Figure 9. TELOS Competency Framework

A Scenario Editor defines the flow of control and data between actors, activities, and the resources used and produced by the actors in the activities of learning design or workflow. In particular, the graphic design can be translated in an XML file compliant with the IMS-LD specification (2003).

The Ontology Editor defines a domain semantic structuring as the main concepts, properties, and individuals to be studied in an application domain. It is complemented by a Competency Sheets tool that adds competency definitions to some of the knowledge entities in the domain ontology. The form-based interface of the competency sheets is configured by a competency ontology such as the one presented in the second section.

These editors define two structures, the first one related to actors' tasks and productions and the second one to the domain knowledge and competencies being processed by the actors. The next two tools, Competency Distributor and Evaluation Weighting serve to define associations between the two structures. Also, a Resource Manager can be used with knowledge and competencies to find and associate complementary resources not in the scenario.

These associations will be used to parameterize the evaluation tools. The Self Diagnosis tool can be used by any LKMA actor (learners, trainers, content experts, technical support, evaluators, etc.) to assess their own competencies linked to appropriate resources that they can use for support or learning. The Evaluation Grid is a tool for learners' evaluation by an assessment actor.

Finally, some of these evaluation results produced by the runtime actors can be integrated into an actor's model and/or into an e-portfolio, which is also called a learning and knowledge management product (LKMP). Competency evaluation results and the products of an actor's activities form the basis of their user model. The Actor's Model Integration tool serves to integrate and define the access to the LKMP data, according to a predefined policy that configures this tool. Then the actors' models can be exploited by a Generic Advisor tool that provides personalized assistance to the actors.

Figure 10 presents a global view of a competency management workflow in which these tools/services are used. It shows three phases. In the first phase, designers edit the LKMA basic components: a scenario workflow and a domain ontology (including entry and target competency). In the second phase, designers configure some evaluation tools that will be used by the scenario actors at delivery time. The last phase is when the evaluation of actual competencies is done and its results are integrated into actors' models and e-portfolios (LKMP). This is also where assistance data is added to the activity definition in the learning scenario.

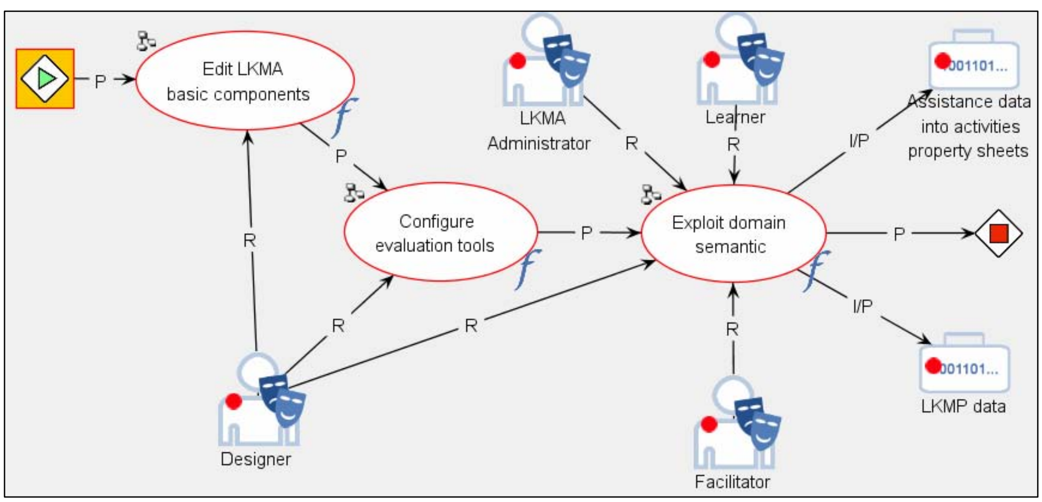

Figure 10. Global view of the Competency Management Workflow

Scenario and knowledge/competency design

Figure 11 describes in more detail the first phase. It shows the LKMA Designer's task using the scenario editor and the ontology editor with competency-property sheets. These edition activities produce on one hand a list of actors, activities, and resources present in the LKMA scenario, sorted by type, and on the other hand a list of competencies with their components. Both lists will serve to parameterize the competency distribution and evaluation weighting tools in the next phase. They can also serve, in the third phase, to design personalization rules based on competency gaps that will be triggered at runtime to provide to learners advice on resources to use, activities to complete, actors to consult, or simply on how to adapt their learning or knowledge management environment.

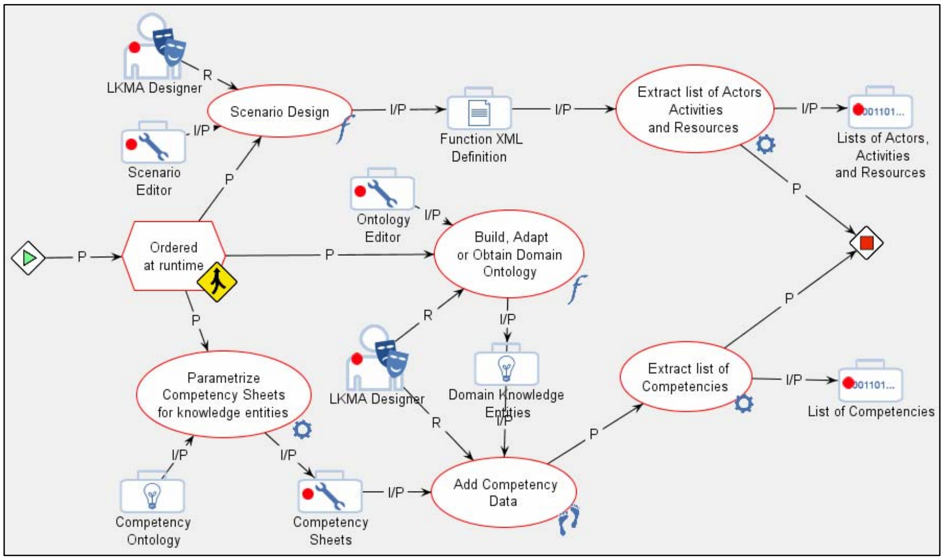

Figure 11. Design sub-processes for competency management

Knowledge and competency association

Figure 12 shows the second sub-process or phase of the competency management process.

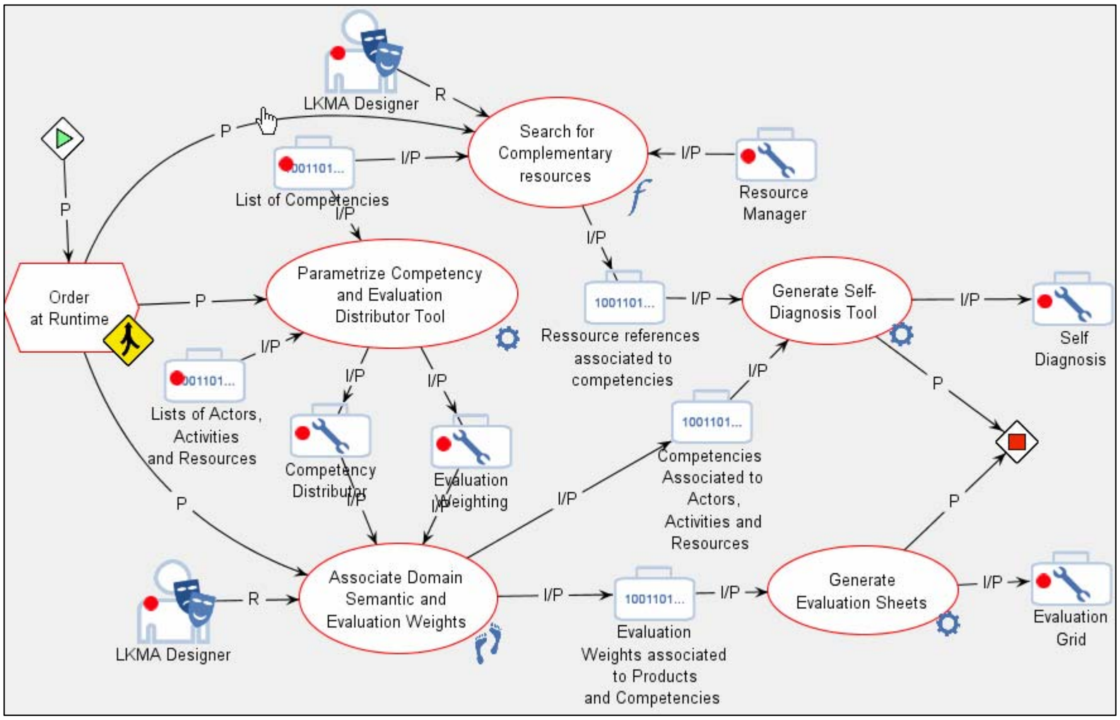

Figure 12. Knowledge and competency association sub-process

It is possible to annotate a scenario component directly by selecting it and opening a domain semantic interface showing the ontology editor and its competency sheets. But doing this in a piecemeal fashion is not the best way to design a coherent application.

To improve this, we need more synthetic association tools, such as the competency distributor and the evaluation weighting tools shown in figure 12. Basically, they take the form of two-dimensional tables with lines filled by a list of competencies already defined in the ontology editor. Column headings indicate the activities, the input resources, the products, or the actors in the scenario.

In the case of the evaluation weighting tool, only the learner products marked for evaluation by a designer are displayed in the columns. This tool enables the designer to distribute weights between them and, for each product, between target competencies for the product.

Competency evaluation sub-process

The above operations require a certain amount of effort by the application's designers that will be rewarded by the automatic production of corresponding tools for learners and facilitators to use at runtime for competency evaluation. The tools/services presented in figure 13 are called "competency evaluation tools" because they use the association of knowledge and competencies with actors, activities, and resources to provide evaluation and personalization functionalities.

The self-diagnosis tool used by learners (and possibly by facilitators), help these actors assess their own actual competencies with regard to target competencies defined by designers in the preceding phase of the process. The evaluation grid is used by facilitators to evaluate the actual competencies of learners.

Both tools output evaluation data that can be integrated into an actor's model and/or e-portfolio. This is done according to an administrative ontology (possibly including a digital rights management component) that defines how this data can be integrated into an actor's model and e-portfolio, and also what persons or computer agents will have access to it. The resulting LKMP data can be used to trigger personalization rules previously designed by a generic advisor. This assistance data will serve to control the flow of activities at runtime based on differences between actual competencies (stored in evaluation data) and target competencies set by the designers using the competency association tools.

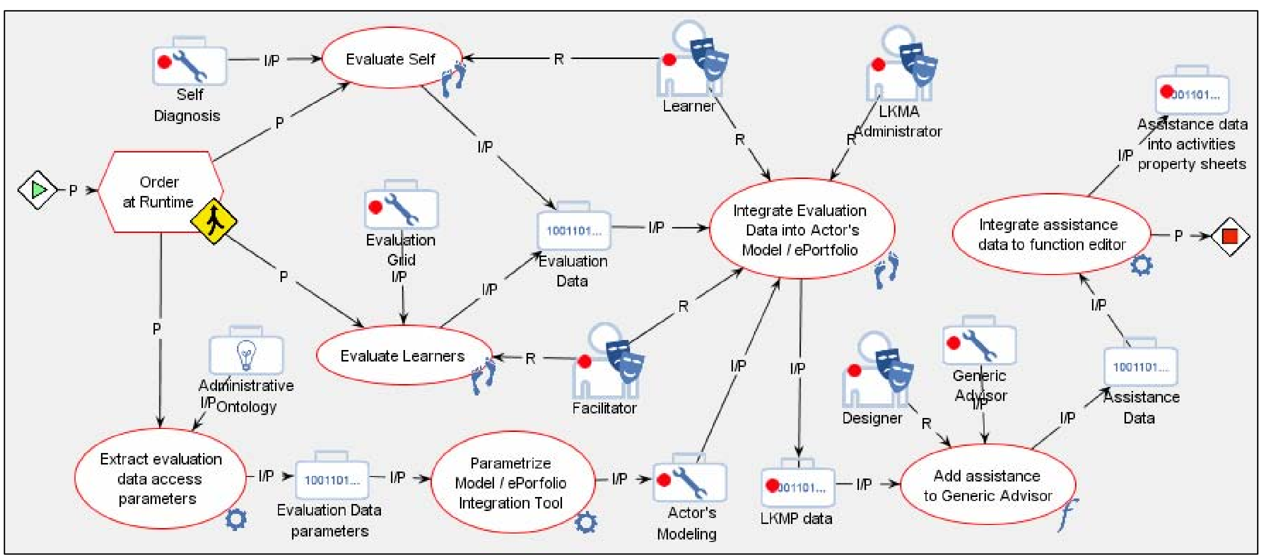

Figure 13. The competency evaluation sub-process

Conclusion

The importance given to competency management is well justified. Acquiring new competencies is the central goal of any education- or knowledge-management process. Thus, it must be embedded in any software framework as an instructional engineering tool, to inform the runtime environment of the knowledge that is processed by actors and their situation towards achieving competency-acquisition objectives. At runtime, the actual competency of actors must be evaluated in different ways, and this data can be integrated as a central piece for learners' e-portfolios and models. This data maybe scarce or elaborated, but it can be used by human facilitators or software agents to assist learners in acquiring new competency, and to adapt the learning environments to the learners' characteristics.

We are not too far away from releasing most of the tools presented in this framework. Most of them have already been built in the past, but the major challenge is to integrate them in a coherent, flexible, user-friendly, and scalable way, within the new context provided by the semantic web and the ontology-driven architecture of TELOS. What is yet to be proven is that the general approach presented here can be used at different level by average design practitioners and learners.

References

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). The semantic web. *Scientific American, May*, Retrieved June 7, 2007, from, http://www.sciam.com/article.cfm?articleID=00048144-10D2-1C70-84A9809EC588EF21.

Bloom, B. S. (1975). Taxonomy of Educational Objectives: the Classification of Educational Goals, New York, NY: D. McKay.

Breuker, J., & Van de Velde, W. (1994). *CommonKads Library for Expertise Modelling*, Amsterdam: IOS Press.

Breuker, J., Muntjewerff, A., & Bredewej, B. (1999). Ontological modelling for designing educational systems. *Paper presented at the AI-ED 99 Workshop on Ontologies for Educational Systems*, July 18-23, 1999, Le Mans, France.

Chandrasekaran B. (1987) Towards a functional architecture for intelligence based on generic information processing tasks*. IJCAI-87 Proceedings* (pp. 1183–1192). Milan, Italy.

Davies, J., van Harmelen, F., & Fensel, D. (2002). *Towards the semantic web: Ontology-driven knowledge management*. New York, NY: John Wiley & Sons.

IMS-RDCEO (2002). *IMS Reusable Definition of Competency or Educational Objective Best Practices*. [Version 1.0, final specification]. IMS Global Learning Consortium, Inc. Retrieved June 7, 2007, from, http://www.imsglobal.org/competencies/index.html.

IMS-LD (2003). *IMS learning design: Information model, best practice and implementation guide*. [Binding document, schemas]. Retrieved June 7, 2007, from, http://www.imsglobal.org/learningdesign/index.cfm.

Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). *Taxonomy of educational objectives: The classification of educational goals*, New York, NY: Longman.

Martin, B. L., & Briggs L. (1986). *The affective and cognitive domains: Integration for instruction and research*, Eaglewood Cliffs, NJ: Educational Technology Publications.

McDermott, J. (1988). Preliminary steps towards a taxonomy of problem-solving methods. In S. Marcus (Ed.), *Automating knowledge acquisition for expert systems* (pp. 225–255). Boston, MA: Kluwer Academic Publishers.

Merrill, M. D. (1994). *Principles of instructional design*, Eaglewood Cliffs, NJ: Educational Technology Publications.

Paquette, G. (1999). Meta-knowledge representation for learning scenarios engineering. In S. Lajoie & M. Vivet (Eds.), *Proceedings of AI-Ed ’99 in AI and Education: Open learning environments*, Amsterdam: IOS Press.

Paquette, G. (2002a). L’ingénierie pédagogique: Pour construire l’apprentissage en réseau. Montréal: Presses de l’Université du Québec.

Paquette, G. (2002b). Modélisation des connaissances et des compétences, un langage graphique pour concevoir et apprendre. Montréal: Presses de l’Université du Québec.

Paquette, G. (2002c). TeleLearning systems engineering: Towards a new ISD model. *Journal of Structural Learning, 14*, 1–35.

Paquette, G. (2003). *Instructional engineering for network-based learning*, Pfeiffer/Wiley Publishing Co.

Paquette, G., Crevier, F., & Aubin. C.(1994). ID knowledge in a course design workbench. *Educational Technology, 34*(9), 50–57.

Paquette G., & Marino, O. (2005). Learning objects, collaborative learning designs and knowledge representation. *Technology, Instruction, Cognition and Learning, 3*, 85–108.

Paquette, G., Marino, O., De la Teja, I., Léonard, M., & Lundgren-Cayrol, K., (2005). Delivery of learning design: The Explor@ System’s case. In R. Koper & C. Tattersall (Eds.), *Learning Design: A Handbook on Modelling and Delivering Networked Education and Training* (pp. 311–326), Berlin: Springer Verlag.

Paquette, G., & Rosca, I. (2004). An ontology-based referencing of actors, operations and resources in eLearning systems. *SW-EL 2004 Workshop*, August 23, 2004, Eindhoven, The Netherlands

Pitrat, J. (1991). Métaconnaissance, avenir de l’Intelligence Artificielle, Paris: Hermès.

Polya, G. (1957). Comment poser et résoudre un problème? Paris: Dunod.

Popper, K. R. (1967). *The logic of scientific discovery*, New York, NY: Harper Torchbooks.

Reigeluth, C. (1983). Instructional theories in action: Lessons illustrating selected theories and models, Hillsdale, NJ: Lawrence Earlbaum.

Romiszowski, A. J. (1981). *Designing instructional systems*, New York, NY: Nichols Publishing.

Ruelland, D., Brisebois A., & Paquette, G. (2005). Supporting self-assessment in a competency approach to learning, *E-Learn 2005 Conference*, October 15-19, 2005, Vancouver, BC, Canada.

Schreiber, G., Wielinga, B., & Breuker, J. (1993) *KADS: A principled approach to knowledge-based system Development*, San Diego, CA: Academic Press.

Steels, L. (1990). Components of Expertise. *AI Magazine, 11*(2), 30-49.

Thayse, A. (1988). Approche logique de l’intelligence artificielle, Paris: Dunod.

W3C (2004). *OWL Overview Document*, Retrieved June 7, 2007, from, http://www.w3.org/TR/2004/REC-owl-features-20040210/.

Ainsworth, S. (2007). Using a Single Authoring Environment across the Lifespan of Learning. *Educational Technology & Society*, 10 (3), 22-31.

Using a Single Authoring Environment across the Lifespan of Learning

Shaaron Ainsworth
School of Psychology and Learning Sciences Research Institute, University of Nottingham, UK
Tel: +44 115 9515315 // Fax: +44 115 9515324 // Email: Shaaron.Ainsworth@nottingham.ac.uk

ABSTRACT

For a single authoring environment to be sufficiently general to be applicable to contexts across the whole lifespan of learning, some of the benefits that come from knowledge-rich domain specificity have to be sacrificed. Consequently, it is an open question as to whether it is possible to achieve effective learning environments from a generic tool. REDEEM is an authoring environment that aims to achieve this by creating adapted and interactive learning environments from existing courseware. In this paper, a 10-year research program is described that has assessed the usability, functionality, and effectiveness of REDEEM's approach.

Keywords

Authoring environments, Evaluation, Usability, Pedagogy, Learning outcomes

Introduction

The goal of authoring environments is to make the creation of effective learning material easier. This could have a range of benefits: for example, authors without technical skills but with relevant pedagogical knowledge could create learning environments; the time taken to create learning environments could be reduced (as creation of learning environments is variously estimated at between 200 and 1000 hours per hour of learning); learners and authors could benefit from consistent interfaces across a wide range of courses; and good practice could be supported by providing tools that encourage (or enforce) specific designs.

To achieve these benefits for authors and learners, it is apparent that the authoring tool must be sufficiently general to adapt to different domains and potentially different types of learners. And this raises a problem. Typically authoring tools that are the most generic are only capable of creating learning environments with the least depth of knowledge and power (Murray, 1996; 2003). Consequently different authoring environments have taken different positions of the generality/depth continua. A system such as the LEAP Authoring Tool (Sparks, Dooley, Meiskey, & Blumenthal, 2003) is very specialized. Its purpose is to create material to train telephone operators to handle customer requests over the telephone. As a consequence of this domain specificity, however, the system can rely upon conversation grammars. These contain a description of all the individual actions that the actors in the conversation may take, as well as hints for each step of the conversation, and audio recordings and textual representations of actions. DIAG (Towne, 2003) is another specialized authoring system, this time for fault finding and diagnosis. It does not solely rely on general troubleshooting principles but instead uses domain-specific reasoning to monitor students' undertaking fault diagnosis on specific simulated equipment, demonstrating and explaining expert performance. Aleven et al. (2006) discuss the CTAT authoring system. A powerful authoring tool is available for authors with artificial intelligence programming skills, but for those without such knowledge, simpler intelligent tutoring systems can be built where authors create user interfaces by direct manipulation and then use a behavior recorder tool to demonstrate alternative correct and incorrect actions. Other authoring tools such as RIDES (Munro, 2003) and SIMQUEST (van Joolingen & De Jong, 2003) create powerful simulations to support discovery learning and guided practice.

In contrast, the authoring environment described in this paper (REDEEM) takes the opposite position of the generality/depth continua. REDEEM has shallow depth of knowledge and has only a limited range of tutoring actions, but can be applied in a very time-efficient manner to many different domains and learners. It remains, therefore, an open question: Can a single authoring environment that is sufficiently general to adapt to contexts across the whole lifespan of learning still have sufficient power to deliver effective learning experiences? Consequently, in the remainder of this paper, a brief system description will be provided (see Ainsworth, et al., 2003, for more details) and then the 10-year research program with REDEEM will be reviewed to examine the strengths and the weaknesses of taking this approach to lifelong learning.

System description

The REDEEM authoring environment was developed in Click2Learn ToolBook Instructor and runs on Windows 95+. It consists of two main pieces of software (authoring tools and REDEEM shell) through which authors and learners interact with courseware. This is one of the most unusual features about REDEEM: courseware is not created within the system but instead remains external to application and is delivered through REDEEM. For example, courseware can consist of pages of either Click2Learn ToolBook or HTML/Gifs/JPEGS etc. and can contain multimedia, simulations, animations, questions, and exercises. Examples of material used to date include existing ToolBook courses on topics such as genetics, communication and information systems, PCs and networking, html courses on statistics, and principles of photography. This decision significantly reduces the time needed to author learning environments and allows reuse of much existing material but obviously limits the tutorial actions available to REDEEM.

Authoring tools

REDEEM's authoring tools use simple graphical interfaces to allow authors to describe how they want the computer-based teaching (CBT) to be taught for different learners. There are four main tools: domain tools (which describe the material and add interactivity); student tools (to describe student categories); strategy tools (to develop different teaching strategies); and macro-adaptation tools (which assign particular domain materials and teaching strategies to the categories of students).

Domain tools

The first major task that needs to be performed is to describe the domain material, which ultimately the system will use to make decisions about how to present material to the learners. Sections are created by combining pages, which need not consist of contiguous pages in the underlying courseware. Pages can also be in multiple sections. Sections are then described upon a number of dimensional ratings, (i.e., familiar, easy, general, or introductory). Authors describe relations between sections, for example, the prerequisite relation, which ensures that a section is not taught until prerequisite sections have been completed. Pages are then described using the same process, dimensional ratings are provided and, if required, prerequisites can be set.

The second major aspect of domain authoring is to add interactivity. Authors create questions (multiple choice, fill in the blank, multiple true, true-false, or matching questions) and provide feedback that will explain to the student why an answer is correct. Five different hints for each question can be created, which ideally increase in specificity. Authors describe a number of characteristics of the question that the shell uses to implement a specific teaching strategy (e.g., difficulty, pre- or post-test). Authors can also associate a reflection point (which means that students are prompted to take notes) or a non-computer task (which directs student attention to another activity) with a page.

Student tools

Student categories can be created at any degree of granularity, ranging from a whole class to an individual student. Authors typically have tended to use performance-based measures (e.g., high flyer, struggler) or task-based measures (e.g., revising) or have combined these (e.g., high reviser). But, it is possible to use any dimension that authors find appropriate and that the domain material will support (e.g., maths phobe, visualizer). The validity of performance-based categories can be evaluated against students' question performance. The shell can then automatically change the category as the overall standard of the student (as defined in the shell's student model) changes. If this occurs, then both content and teaching strategy may change as the system macro-adapts to the new category.

Strategy tools

REDEEM allows authors to create multiple teaching strategies. Different instructional principles can be embodied in various strategies by manipulating graphical sliders. Each slider in Figure 1 has three discrete positions that result in different instruction. For example, slider 7 (post-test) allows authors to describe if questions should be asked after each page, at the end of the section, or at the end of a course; and slider 5 sets the way that help is provided to either help on error and request, help on error only, or no help at all. By combining these different settings, different strategies can be created. For example, an author might create a "Free Discovery" strategy where students choose the material they see and the questions they answer, and the number of attempts allowed for each question is unlimited; they can chose to receive help and whether to perform non-computer-based tasks. In total, REDEEM can offer nearly 10,000 different teaching strategies, each (very) subtly different to each other, although to date no author has created more than eight for a particular class of students.

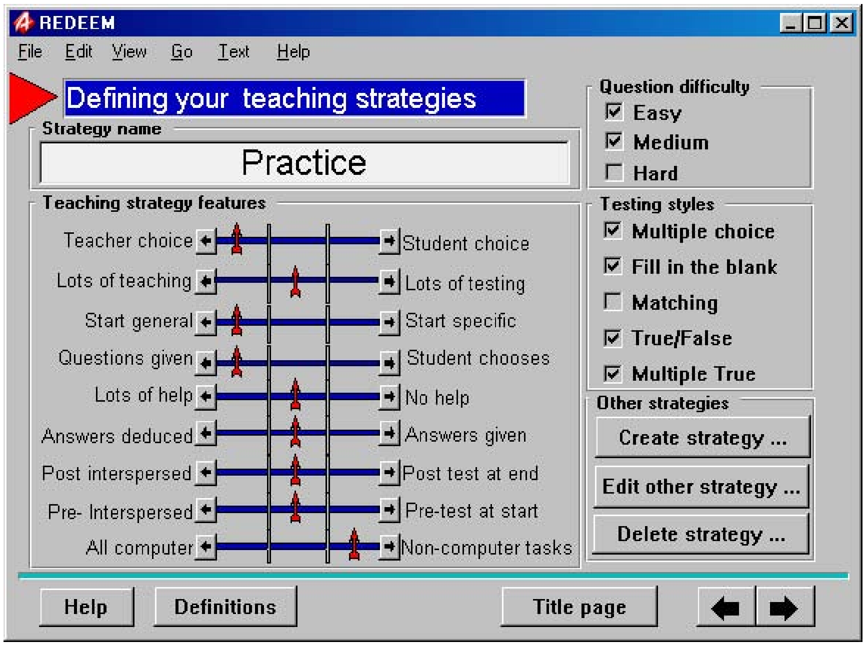

Figure 1. Strategy Authoring

Macro-adaption tools

Macro-adapting the material is achieved through the use of student categories, as content and strategies can be associated with a specific category. By default, learners see all the material, but the author can choose to remove sections for a particular category (e.g., to focus on introductory material for learners who need more help or include extension activities for students who could benefit from more challenging tasks). Each student category is also given a teaching strategy (e.g., high flier with free discovery). To date, authors have varied from creating a single preferred strategy to creating a unique strategy for each group or even for an individual student.

REDEEM shell

The REDEEM shell uses the output of the authoring tools, together with its own default teaching knowledge, to deliver adapted (occasionally adaptive), interactive courseware. The main role for the REDEEM shell is to deliver the course material to each student in the way that the teacher specified with the authoring tools. Tutorial actions available to the shell (depending upon the teaching strategy) are: teach new material; offer a question (and help if appropriate); suggest that students make notes on the online tool; offer a non-computer-based task and by means of password protection check that is has been completed; change student category; or summarize students' progress. To achieve this REDEEM uses a basic overlay model that records the system's understanding of the student's knowledge of an area. The values of the model change over the course of a session as the student sees new material and answers questions. If student categories are performance-based, then the student model is used to determine if learner should change category. The shell also maintains a student history. This is used to offer reports to the author either on an individual student's progress, a student category's progress, or to give a report on the course.

Mixed-initiative REDEEM

The version of REDEEM described above has been used in situations where a teacher is available who wishes to take responsibility for macro-adapting REDEEM (i.e., assigning material and strategies to learners via student categories). This has been the way REDEEM has been used in conventional classrooms (primary, secondary, and military). However, not all learning situations are teacher-led, and to allow REDEEM to be useful in informal and student-led learning, it seemed appropriate to create a version where learners macro-adapt REDEEM to suit themselves. Consequently in the mixed-initiative version of REDEEM, authors use the domain tools and strategy tools as described above, the student tools set up categories (but do not assign students to categories), and the macro-adaption tools prescribe a default strategy and a range of available strategies per category. Now when the students log in, they select one of the learner categories, and this now results in a default teaching strategy, which they can change to any of the other strategies that are available. For example, for a statistics revision unit available to university students, we created four categories (confident learner/reviser and unconfident learner/reviser). Each category was assigned a default strategy (e.g., confident reviser received "challenge me") but could choose to one of six other strategies). This design is a trade-off between giving students significant choice yet only requiring minimal interaction (less than 30 seconds typically) to utilize this functionality.

Empirical Studies

To examine whether REDEEM could achieve its objective to be general across a range of domains and users and still be effective educationally, we needed to analyze both the authors' and the learners' experiences. Each type of user has different requirements and consequently the type of analysis needed to differ as well. Table 1 summarizes the main studies that have been conducted.

Table 1. Description of REDEEM studies

Study	Purpose	Subjects	Course	Location	Author	Primary Reference
1. Primary Shapes	Usability, Functionality	3 teachers, 1 teacher trainer	Introduction to shape and area	University	Teachers, Lecturer	Ainsworth, Grimshaw, & Underwood, (1999)
2. Naval authors	Usability, Functionality	2 trainers	Comm. & Info Systems Protocols	University & naval sites	Trainers	Ainsworth, Williams, & Wood, 2001).
3. Genetics at Uni.	Learning effectiveness	86 students 14–16yrs	Genetics	University	Teacher	Ainsworth & Grimshaw (2004)
4. Genetics in School	Learning effectiveness	15 students, 14–16 yrs	Genetics	Secondary School	Teacher	Ainsworth & Grimshaw (2004)
5. Navy full time	Learning effectiveness	19 students 17–22 yrs	Comm. & Info Systems Protocols	HMS Collingwood	Trainer	Ainsworth et al. (2003)
6. Undergrad	Learning effectiveness	25 students, 20–28 yrs	PC & Networking	University	Researcher	Ainsworth, Williams & Wood (2003)
7. RAF	Learning effectiveness	16 students, 20–45 yrs	PC & Networking	RAF Waddington	Researcher	Ainsworth & Fleming (2006)
8. Undergrad Mixed Initiative	Functionality, Learning effectiveness	167 students, 18–20 yrs	Statistics	University	Lecturer	Ainsworth & Fleming (2005)

Author-focused studies

Studies 1 and 2 were the main author-focused studies and they were primarily concerned with usability and functionality. Primary (K–12) and secondary (high) school teachers, lecturers, and military instructors found it easy to use the tools to express, represent, and assess their teaching knowledge to create a learning environment within a feasible time scale.

REDEEM's usability has been assessed by asking authors to create learning environments either for their own class of learners or a set of hypothetical learners. Then teachers were interviewed throughout the process of creating the environments and about their satisfaction with the outcome. Initial training in the use of the REDEEM tools required between one and two hours. No author found the overall decomposition of the teaching process incompatible with his or her approach. REDEEM's use of graphical and form-fill style interview tools has mostly proved simple and easy for authors to use. Time taken to author (once an existing suitable course has been found) has been acceptable, ranging from between 6 and 11 hours to author the four-hour course, Understanding Shapes (Study 1). In Study 4 a teacher took less than 25 hours to create two environments (around eight hours of instruction). Navy authors began by requiring 10 hours per chapter (around 6:1), which dropped to 6 hours by the end of authoring (around 3:1) (Study 2). It is not unrealistic to claim that creation of a REDEEM learning environments from an existing course can be done at a ratio of under five hours development per hour of instruction.

In terms of functionality, overall, authors were pleased with the functionality that REDEEM offered. Compared to the original courseware or to courses authored by others, they all felt their learning environments were more suitable for their classes' needs.

Classroom teachers and military instructors used REDEEM in very different ways, with teachers focusing more on personalization. The teachers wanted to structure the domain material in ways that reflected their own beliefs and to create multiple student categories with unique strategies. In contrast, the military authors used REDEEM to create a single teaching strategy that reflected their own preferred strategy rather than the courseware designer's strategy. What both groups had in common was the value they placed on increasing interactivity by adding questions and reflection points.

However, these studies have revealed some interesting dilemmas about REDEEM's design. Firstly, REDEEM requires users to shift from storyboarding to knowledge-based authoring. The most problematic part of this is domain sequencing, with authors describing characteristics of a page (e.g., familiarity and complexity) and the shell computing a route. However, this proved too time-consuming, was difficult for authors to visualize, and so was unpopular and resisted. Unfortunately, knowledge-based authoring ignores the important role that narrative plays for authors and learners when they are interacting with new material. In retrospect, we would stick to knowledge-based authoring for interactivity but use a more narrative-based approach to structure the domain content.

The second concern is with the adaptive features of REDEEM, which allow the shell to compute its own route through material and to change student category (if desired), and so allow students to receive different teaching strategies. This proved very unpopular with all authors as they were reluctant to surrender control to the system. This limits the functionality that REDEEM can offer, turning it into a courseware authoring tool rather than its original intended goal of intelligent tutoring system authoring tool.

The final concern is time efficiency. Authors need to create learning environments in a time-efficient way. REDEEM achieves a ratio of around three to five hours of authoring to one hour of instruction when a trained author, familiar with the domain and with teaching, creates an environment from imported domain material. But it does not include time to locate the domain material that meets their needs. However, many authors felt that the 5:1 ratio was not fast enough. If authors had been happy to leave decisions to REDEEM, some of this time could have been reduced (e.g., authors often hand-coded a sequence of material when the shell would have produced the same route automatically). Authors also often spent a considerable amount of time on details that potentially may not have been too important (e.g., one teacher edited every help message to include a full stop after each message). However, on the positive side, one of the features that teachers appreciated most was the way that REDEEM allows quick assignment of different strategies and content to different student categories. Analysis of authoring times suggests that this is normally achieved in less than 30 minutes, irrespective of the size of the course.

Learner-focused studies

Two types of studies were conducted to explore whether REDEEM helped students learn: experimental studies conducted in either in the laboratory or in a semi-naturalistic setting (studies 3 to 7) and quasi-experimental studies conducted in a real-world setting (study 8). Studies 7 and 8 also included questionnaires to assess learners' satisfaction with the environment.

The experimental studies all had the same basic design and employed the same comparison. Learning outcomes from students working with the original courseware (which had been developed prior to the studies and was already in use in classrooms) was compared to those from the REDEEM-enhanced version of the CBT. In all cases a partial crossover design was employed —– half the participants received REDEEM then the original CBT, and half the original CBT and then REDEEM. If learning outcomes are higher with REDEEM, then the conclusion that the REDEEM/Author partnership in the situation provided better support for learning than the original courseware is warranted.

Table 2. Experimental Studies

Study	Authoring	Gain	Effect size
3. Genetics at University	5 student categories based on teacher views of ability in which each received a unique teaching strategy and content	RED = 10% CBT = 8%	.21
4. Genetics in School	3 student categories based on school sets which varied content but not strategy	RED = 16% CBT = 8%	.82 *
5. Navy full time	1 student category/teaching strategy	RED = 21% CBT = 22%	–.04
6. Undergrad	1 student category/teaching strategy	RED = 53% CBT = 44%	.82*
7. RAF	1 student category/teaching strategy	RED = 47% CBT = 32%	.76*

Table 2 shows the learning outcomes of the five experimental studies. Overall it shows that REDEEM could be used to create learning environments that are more effective than the CBT they are based on. On average, REDEEM led to a 30% improvement from pre-test to post-test, whereas CBT increased scores by 23%. This advantage for REDEEM translates into an average effect size of .51. This compares well to non-expert, human, individual tutors (an average of .4 sigma [Cohen, Kulik, & Kulik, 1982]) but is significantly below that of expert human one-to-one tuition at 2 sigmas (Bloom, 1984). However, given the efficiency of creating REDEEM courseware and the fact that the comparison was CBT which was already in use, this overall increase in effectiveness is highly satisfactory.

Given REDEEM's proven effectiveness in experimental settings, we felt justified in using it in a real-world situation. In 2005 a semester of a statistics courses at the University of Nottingham was REDEEMed. Ten lectures (originally in PowerPoint) were imported into REDEEM, and additional interactivity was authored. Four learner categories were created: non-confident learner (NCL), confident learner (CL), non-confident reviser (NCR), and confident reviser (CR). Four default teaching strategies were created (Table 3) and four optional strategies were devised that provided contrasting experiences such as using REDEEM in "exam style" or in "pre-test" mode (test me after the course, before section, or course).

These lectures were made available over the intranet for students to use on a completely voluntary basis. At the end of the year, students took an exam, which assessed their understanding of this course, and a prerequisite first-semester statistics course. Over the year, we kept process data that recorded which students used REDEEM on which lectures and asked students to complete questionnaires assessing their experience with REDEEM.

Analysis of this data is complex, given the quasi-experimental nature of the research (see Ainsworth & Fleming, 2005), but demonstrates a clear benefit of REDEEM. Those students who used REDEEM scored more highly on their second semester exam scores. But, this could be because students who were more motivated or of a higher ability chose to use REDEEM. Happily, this explanation is unlikely as these students did not also have higher performance on the first semester scores (for which REDEEM was unavailable). Furthermore, a stepwise linear regression showed that students were predicted to do 1% better for each REDEEM lecture they completed, allowing them to improve by 10%. Finally, we examined performance specifically on those lectures the students had studied with REDEEM and related that to particular exam questions. Using REDEEM increased performance only on the exam questions that corresponded to the lectures that a student had studied with REDEEM (students scored an average of 64% on those lecture's questions versus 54% on those they had not studied).

Table 3. Teaching Strategies

Name	**Default**	**Description**
Simple Introduction	NCL	No student control of material or questions; easy/medium questions (max one per page), 2 attempts per question, help available. Questions after page.
Guided Practice	NCR	No student control of material/questions; easy/medium questions (max one per page). 5 attempts per question, help is available. Questions after section.
Guided Discovery	CL	Choice order of sections but not questions. 5 attempts per question, help only on error. Questions after section.
Free Discovery	CR	Choice order of sections and questions. 5 attempts per question, help available
Just Browsing		Complete student control of material. No questions.
Test me after the course		No student control of material or questions. All questions at the end, 1 attempt per question, no help.
Test me before each section		Choose order of sections. Questions are given before each section. 5 attempts per question and help available on error.
Test me before the course		Student control sections All questions at the start. 5 attempts per question. Help is available.

Students views about the usefulness of REDEEM for supporting their learning was generally positive. They considered it to be less useful than lectures for learning statistics, but more useful than tutorials, textbooks, or working with friends. They reported they would definitely use REDEEM for the 2nd year statistics course if it was available (4.47/5) and would recommend REDEEM to next year's first years (4.45/5). Only one respondent (out of 99) would not use or recommend REDEEM. We also asked students why REDEEM helped them learn and they ranked REDEEM's features in the following order of usefulness: Questions, Hints & Explanations of Answers, Choice of Strategy, Review facilities, Student History, and Notes tool.

Overall then, REDEEM was appreciated by students and had a noticeable impact on exam performance (equivalent to a whole degree class in the UK system) for students who studied with it, even when we factor explanations based on differential use of REDEEM by motivated or higher ability students.

Conclusions

This program of research has been aimed at exploring whether a single authoring environment could be sufficiently general to be used across many learning contexts but still be able to create effective learning environments. We proposed that in order to meet its goal the system must have high usability, appropriate functionality, and enhance learning outcomes. Eight different studies have been conducted to explore if REDEEM meets its goals.

In terms of usability, the results were encouraging. Authors across all the observed contexts found the system easy to learn and could create learning environments in a time-efficient way. This could be substantially improved if we changed the model of content structure and sequencing from knowledge-based to storyboarding. Further improvements could come from making question authoring more efficient, for example, using generalization features similar to those found in CTAT (Aleven et al., 2006) and from reusing existing authoring. However, to truly calculate how long it would take to create a course we should include how long it would take authors to locate suitable domain material and, in the case of content with its own structure, strip this structure out. REDEEM has been described as one of the most usable ITS authoring tools (Murray, 2003), and our results tend to support this conclusion.

REDEEM's functionality has been assessed by examining how well it fitted the needs of primary (K–12), secondary (high school) teachers, university lecturers, and military trainers. For classroom teachers, the most important tool that REDEEM offered above existing courseware was the opportunity to personalize it to their specific needs. The teachers felt that the trouble with trying to use much courseware was that it contained material that was not required by their students or that the material was organized in ways that did not match with their curriculum. REDEEM allowed them to exclude material they did not want extremely easily (if you don't name a page, REDEEM won't offer it to students) and they could reorganize the structure of the material to meet their desired goals. The other feature that was welcomed was the opportunity to macro-adapt the material to different student categories. This allowed teachers to give all their students the opportunity to interact with (apparently) the same material but in ways that stretched their more able students and supported their struggling students. Some teachers chose only to macro-adapt content, whereas others adapted content and strategies.

The navy authors did not use this feature at all, but did like the opportunity to add additional interactivity. They felt that the courseware they were provided with was not sufficiently interesting for their students and liked to use questions to focus students' attention. However, they did see a potential role for macrodaption in adapting to role (e.g., initial training, skill updating). The naval author who worked in reserve training was also more enthusiastic about macro-adapting, saying it would help him deal with his varied learner population (from medical officers to 16-year-old trainees).

Finally, the university lecturer particularly liked the way that REDEEM could be available to support students in times and ways that teachers could not. Because 200 students take the statistics course that we REDEEMed, giving individual feedback on their performance is not normally possible. Furthermore, the majority of use of REDEEM happened after teaching had ended — approximately 66% of REDEEM use occurred after the end of term and 25% of total use occurred in the 36 hours prior to the exam!

REDEEM was shown to improve learning outcomes in both experimental and non-experimental situations. The average effect size is a very respectable 0.51. The benefit of REDEEM was observable even in real-world situations where other factors such as aptitude or effort might be expected to dilute its impact. However, the variability in the outcomes is very large and there is no consistent relationship between whether the course was authored by a researcher or a practitioner, the topic taught, whether the study was conduced in an artificial situation or in a realistic context, and whether REDEEM's macro-adaptive features were used to create learning environments for specific learner categories. We propose that one of the explanations for this variability lies in the behaviour of the learners in the study, which we can observe by inspection of the process data. The two studies without a significant REDEEM benefit were also the ones with the highest number of students who were least interested in learning this material. Analysis of the process logs suggests a wide variation in how much these learners interacted with the system. Adding features to enhance learning can only impact when learners chose to engage with them.

Consistent with this analysis is our view about those aspects of REDEEM which most helped learning. Students indicated they felt that questions and hints were the most useful features, and analysis of the process logs also confirms this view. These results suggest that any advantage of REDEEM was due more to increasing interactivity than to macro-adaptation. That degree of interaction predicted learning outcomes does not seem contentious, but the question that remains is why benefits from macro-adaptation were not observed. This may be because inappropriate categories were used (authors chose only to use ability) or that strategies were not assigned appropriately. Moreover, from this design benefits might be difficult to identify. For example, if an author assigned a unique teaching strategy to every category of learner and they all made equal gains, does this mean that the strategies were ideally targeted or that they had no effect? Consequently, further research is needed to examine the educational significance of macro-adaptation and to consider which are the most important learner characteristics and strategy dimensions. In terms of learners themselves, macro-adapting this was a popular feature with students, who chose strategies that were appropriate to their context (for example, a large amount of "test me before the course" was observed as students crammed just before the exam).

In terms of using a single authoring environment across all learning contexts, we did not quite achieve our goal. The versions used in schools and for the military had identical functionality; however, we changed the interface (friendly primary colours and larger fonts in school). The mixed initiative version used at university could be used in a large number of contexts where learning is more under control of learners themselves and may be less suitable to some of the school and military situations.

REDEEM is now a senior citizen in the world of authoring environments. It was developed well before the importance of meta-data standards were envisaged and even before the use of the web was commonplace in learning environments. As such, it is now time for the system to retire. It requires its own learning management system to be installed onto each computer and does not create learning environments that are SCORM compliant. However, some of the ideas pioneered by REDEEM are only now becoming standard. In particular, the central design concept of REDEEM is that information and pedagogy are kept separate, and REDEEM focuses on allowing authors to describe how they want the content taught (rather than the content itself). This focus on pedagogy is still far from common, although its importance for the use (and reuse) of learning objects is recognized (Sloep, 2004). Recent projects such as Educational Modelling Language (Koper & Manderveld, 2004) and its successor IMS design, (see IMS, 2003)) are demonstrating the importance of pedagogical meta-data.

In conclusion, we acknowledge that there are many situations in which learning environments with more knowledge or power than REDEEM will be needed, for example, in simulation-based learning. However, we propose that the REDEEM approach of usable authoring tools to create adapted and interactive courseware over a large range of learning contexts has been a success.

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References

Ainsworth, S. E., & Fleming, P. F. (2005). Evaluating a mixed-initiative authoring environment: Is REDEEM for real? In C. K. Looi & G. McCalla & B. Bredeweg & J. Breuker (Eds.), *Proceedings of the 12th International Conference on Artificial Intelligence in Education* (pp. 9–16). Amsterdam: IOS press.

Ainsworth, S. & Fleming, P. F. (2006). Evaluating authoring tools for teachers as instructional designers. *Computers in Human Behavior, 22*(1), 131–148.

Ainsworth, S. E., Grimshaw, S., & Underwood, J. (1999). Teachers implementing pedagogy through REDEEM. *Computers & Education, 33*(2–3), 171–187.

Ainsworth, S. E., & Grimshaw, S. K. (2004). Evaluating the REDEEM authoring tool: Can teachers create effective learning environments? *International Journal of Artificial Intelligence in Education, 14*(3/4), 279–312.

Ainsworth, S. E., Major, N., Grimshaw, S. K., Hayes, M., Underwood, J. D., Williams, B., & Wood, D. J. (2003). REDEEM: Simple intelligent tutoring systems from usable tools. In T. Murray, S. Blessing, & S. E. Ainsworth (Eds.), *Tools for Advanced Technology Learning Environments.* (pp. 205–232). Amsterdam: Kluwer Academic Publishers.

Ainsworth, S. E., Williams, B., & Wood, D. (2001). Using the REDEEM ITS authoring environment in naval training, *Proceedings of the IEEE International Conference on Advanced Learning Technologies* (ICALT 2001) (pp. 189–192). Los Alamitos, CA: IEEE Computer Society.

Ainsworth, S. E., Williams, B. C., & Wood, D. J. (2003). Comparing the learning effectiveness of REDEEM and CBT. In U. Hoppe & F. Verdejo & J. Kay (Eds.), *Proceedings of the 11th International Conference on Artificial Intelligence in Education* (pp. 123–130). Amsterdam: IOS Press.

Aleven, V., Sewall, J., McLaren, B. M., & Koedinger, K. R. (2006). Rapid authoring of intelligent tutors for real-world and experimental use. In Kinshuk, R. Koper, P. Kommers, P. Kirschner, D. G. Sampson, & W. Didderen (Eds.), *Proceedings of the 6th IEEE International Conference on Advanced Learning Technologies* (ICALT 2006), (pp. 847–851). Los Alamitos, CA: IEEE Computer Society.

Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13*(6), 4–16.

Cohen, P. A., Kulik, J. A., & Kulik, C. C. (1982). Educational outcomes of tutoring: A metaanalysis of findings. *American Educational Research Journal, 19*, 237–248.

IMS (2003). *IMS Learning Design Specification*. Retrieved March 29, 2007, from http://imsglobal.org/learningdesign/index.cfm

Koper, E. J. R., & Manderveld, J. M. (2004). Educational modelling language: Modelling reusable, interoperable, rich, and personalised units of learning. *British Journal of Educational Technology, 35*(5), 537–552.

Munro, A. (2003). Authoring simulation-centred learning environments with Rides and Vivids. In T. Murray, S. Blessing, & S. E. Ainsworth (Eds.), *Tools for Advanced Technology Learning Environments.* (pp. 61–92). Amsterdam: Kluwer Academic Publishers.

Murray, T. (1996). Having it all, maybe: Design tradeoffs in ITS authoring tools. In C. Frasson, G. Gauthier, & A. Lesgold (Eds.), *Proceedings of the Third International Conference on Intelligent Tutoring Systems* (pp. 93–101). Berlin: Springer-Verlag.

Murray, T. (2003). An overview of intelligent tutoring system authoring tools: Updated analysis of the state of the art. In T. Murray, S. Blessing, & S. E. Ainsworth (Eds.), *Tools for Advanced Technology Learning Environments.* (pp. 491–544). Amsterdam: Kluwer Academic Publishers.

Sloep, P. B. (2004). Reuse, portability and interoperability of learning content: Or why an educational modelling language. In R. McGreal, (Ed.), *Online Education Using Learning Objects* (pp. 128–137). London: Routledge/Falmer.

Sparks, R., Dooley, S., Meiskey, L., & Blumenthal, R. (2003). The Leap authoring tool: Supporting complex courseware authoring through reuse, rapid prototyping, and interactive visualizations. In T. Murray, S. Blessing, & S. E. Ainsworth (Eds.), *Tools for Advanced Technology Learning Environments.* (pp. 411–438). Amsterdam: Kluwer Academic Publishers.

Towne, D. (2003). Automated knowledge acquisition for intelligent support of diagnostic reasoning. In T. Murray, S. Blessing, & S. E. Ainsworth (Eds.), *Tools for Advanced Technology Learning Environments.* (pp. 121–148). Amsterdam: Kluwer Academic Publishers.

van Joolingen, W. R., & De Jong, T. (2003). SIMQUEST: Authoring educational simulations. In T. Murray, S. Blessing, & S. E. Ainsworth (Eds.), *Tools for Advanced Technology Learning Environments.* (pp. 1–32). Amsterdam: Kluwer Academic Publishers.

Chieu, V. M. (2007). An Operational Approach for Building Learning Environments Supporting Cognitive Flexibility. *Educational Technology & Society*, 10 (3), 32-46.

An Operational Approach for Building Learning Environments Supporting Cognitive Flexibility

Vu Minh Chieu
University of Michigan, School of Education, Ann Arbor, MI, USA // vmchieu@umich.edu

ABSTRACT

Constructivism is a learning theory that states that people learn by actively constructing their own knowledge, based on prior knowledge. A significant number of ICT-based constructivist learning systems have been proposed in recent years. According to our analysis, those systems exhibit only a few constructivist principles, and a critical problem related to the design and use of this kind of systems has been the lack of a practical means to facilitate the instructional design process. Our research aims to help designing truly constructivist learning environments. Our approach is based on a set of operational criteria for certain aspects of constructivism: We use these criteria as a useful pedagogical framework to provide easy-to-use tools and operational guidelines for teachers to build ICT-based constructivist learning environments. One facet often mentioned as being strongly relevant to constructivism is cognitive flexibility. This paper presents COFALE—a new, domain-independent, and open-source e-learning platform that could be used to devise learning conditions fostering cognitive flexibility—and an example of its use: the design of a course on recursion in computing science.

Keywords

E-learning, Constructivism, Instructional design, Operational criteria, Open-source platform.

Introduction

Piagetian or cognitive constructivism (Piaget, 1975) is an educational approach that "emphasizes that individuals learn best when they actively construct knowledge and understanding" (Santrock, 2001, p. 318). Constructivist learning is a process of active construction and transformation of knowledge (Bourgeois & Nizet, 1999). Bruner (1973) introduces the following example of constructivist learning:

> The concept of prime numbers appears to be more readily grasped when the child, through construction, discovers that certain handfuls of beans cannot be laid out in completed rows and columns. Such quantities have either to be laid out in a single file or in an incomplete row-column design in which there is always one extra or one too few to fill the pattern. These patterns, the child learns, happen to be called prime. It is easy for the child to go from this step to the recognition that a multiple table, so called, is a record sheet of quantities in completed multiple rows and columns. Here is factoring, multiplication and primes in a construction that can be visualized.

A counter-example of constructivist learning would be a case in which the child is given a textual definition to learn the concept of prime numbers. This situation may not foster learning, from a constructivist point of view, because it could lead to "rote" or passive learning (Chieu, 2005).

In recent years, constructivist beliefs and practices have been widely adopted, as evidenced by the appearance of a significant number of ICT-based constructivist learning systems (Kinshuk et al., 2004). Many researchers accept the central assumption of constructivism as stated by Santrock; however, they derive different pedagogical implications from the same basic principles. Driscoll (Driscoll, 2000), for instance, identifies five major facets of constructivism related to instructional design: (1) reasoning, critical thinking, and problem solving; (2) retention, understanding, and use; (3) cognitive flexibility; (4) self-regulation; and (5) mindful reflection and epistemic flexibility.

A major problem related to the design and use of constructivist learning systems has been that, while many pedagogical principles for constructivism exist, there is little *practical* advice on how to exploit advanced learning technology to exhibit constructivist principles.

In earlier work (Chieu et al., 2004; Chieu & Milgrom, 2005), we have defined and justified a set of operational criteria for cognitive flexibility, one of the important facets of constructivism. Also in earlier work (Chieu, 2006), we have presented a new authoring system, named COFALE, in which we provide the course designer with *easy-to-use* tools and *operational* guidelines for building ICT-based learning environments fostering cognitive flexibility. In this paper, as an extended work of (Chieu, 2006), we present and discuss more about the operational approach we have applied to help teachers *effectively* create learning conditions that facilitate and stimulate cognitive flexibility in a variety of domains. To illustrate the usefulness of our approach, we show how the course designer might use COFALE to devise conditions of learning for a problem area presented in the next paragraph: the learning of the recursion concept. We also report on a preliminary evaluation of the operational approach, which shows several encouraging results for fostering cognitive flexibility by means of ICT-based learning conditions.

The concept of recursion is very important in computing science (Bhuiyan et al., 1994). Many teachers and educational researchers consider that both teaching and learning recursion are difficult because of three main reasons (Anderson et al., 1988; Bhuiyan et al. 1994): (1) the concept is unfamiliar (students are induced to proceed by analogy from examples); (2) the concept is complex (it is hard for students to transfer from a pattern of recursion to a new one); and (3) interference may arise from knowledge of other methods of solution (e.g., iterations).

In the following sections, we first introduce necessary background on cognitive flexibility and present operational criteria for cognitive flexibility; then we show how the course designer might use the set of operational criteria as a useful pedagogical framework and COFALE as an effective technological means for creating learning conditions leading to cognitive flexibility, and we report on a preliminary evaluation of the recursion “course” handled by COFALE with actual students; finally, we present our discussion and conclusion.

Cognitive flexibility

Among the five facets of constructivism identified previously, we chose cognitive flexibility because of three main reasons. Firstly, cognitive flexibility is often mentioned by constructivist authors (Bourgeois & Nizet, 1999; Driscoll, 2000; Spiro & Jehng, 1990). Secondly, the pedagogical principles underlying cognitive flexibility reflect the basic characteristics of constructivism (Spiro & Jehng, 1990; Spiro et al., 1991). Thirdly, a significant number of examples have showed that ICT may facilitate the implementation of learning conditions fostering cognitive flexibility (Driscoll, 2000; Spiro & Jehng, 1990; Wilson, 1996).

In this section, we first define and present several examples of cognitive flexibility. Then, we present the main conditions of learning suggested by educational theorists for cognitive flexibility. Finally, we show why and how we have proposed operational criteria for cognitive flexibility.

Definition and examples of cognitive flexibility

According to Spiro and Jehng (Spiro & Jehng, 1990), cognitive flexibility is “the ability to spontaneously restructure one’s knowledge, in many ways, in adaptive response to radically changing situational demands” (p. 165).

In a Piagetian point of view, cognitive flexibility, as learning, is the ability that newborns already have when they come into the world. Indeed, when an infant is born, it possesses a variety of innate reflexes, for instance, sucking, reacting to noises, focusing on objects within their view. Within a short time, it begins to modify these reflexes to adapt to the new environment surrounding the newborn, for example, sucking a finger becomes a different action from sucking a nipple. As the child develops, his or her ability to exhibit cognitive flexibility gradually matures (Driscoll, 2000).

Here are several examples of cognitive flexibility behavior we deduce from indications suggested by educational theorists (Bourgeois & Nizet, 1999; Spiro & Jehng, 1990):

- When students are faced with a new problem, they try to analyze different aspects of the problem in a systematic manner and to use different ways they have successfully used in the past to solve similar or related problems in order to find a solution as complete as possible.
- When students are confronted with a new concept, they try to perform different activities in different contexts to look further into various aspects of the new concept.

- When students discuss with peers, they try to listen and ask, in a systematic manner, questions such as “Why?”, “What is your source of information?” in an effort to understand other points of view.

The individual's cognitive flexibility is there, but in instruction we need to provide *explicitly* and *systematically* learning conditions that facilitate and stimulate students' cognitive flexibility, especially in complex and ill-structured domains, that is, the domains in which cases or examples are diverse, irregular, and complex (Spiro & Jehng, 1990; Feltovich et al., 1996). The next sub-section describes those conditions of learning.

Conditions of learning for cognitive flexibility

Advanced learning in ill-structured and complex domains such as biomedicine and literature gives rise to a difficult problem: What one has to do to attain a *deep understanding* of a complex concept (Spiro & Jehng, 1990). Deep understanding means that students are prepared to be ready to apply conceptual knowledge in a domain where the phenomena occur in irregular patterns, and to use knowledge in a great variety of ways that may be required in a rich domain.

Spiro and colleagues have shown in a number of studies that when students attempt to apply, to ill-structured domains, the strategies they have used effectively for understanding well-structured domains (e.g., in introductory learning), they make errors of oversimplification, overgeneralization, and "overreliance" on context-independent representations (Spiro et al., 1988). In the biomedical domain, for example, students who use only organicist metaphors or only the metaphor of the machine to help them understand how the body functions tend to analyze cases only partially. The point Spiro and associates make is that neither metaphor captures all aspects of body functions, although neither metaphor is wrong.

Therefore, in attempting to solve the problem of instruction in ill-structured domains, Spiro and associates have presented a new Cognitive Flexibility Theory in which they have advocated the use of multiples forms of pedagogical models, multiple metaphors and analogies, and multiple interpretations of the same information (Feltovich et al., 1996). The central metaphor of Cognitive Flexibility Theory is “learning in criss-crossed landscape”: “Revisiting the same material, at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives is essential for attaining the goals of advanced knowledge acquisition” (Spiro et al., 1991, p. 28). The authors have argued that by criss-crossing a conceptual landscape in many directions, knowledge that will have to be used in many ways is acquired in many ways. If taught in this manner, medical students, for instance, would be able to examine a single case from many different vantage points and see firsthand the effect of reinterpreting a particular symptom. Examining multiple cases in different contexts will help students build new cognitive structures in order to account for new cases.

Another point of view proposed by educational theorists (Bourgeois & Nizet, 1999; Frenay & Bédard, 2004) about cognitive flexibility in adult education have stressed that teachers should encourage learners to explore new knowledge in various concrete situations, more or less different from the ones with which learners have been familiar. Those authors claim that this operation is important for knowledge transfer because it provides the chances for learning reinforcement (i.e., prior knowledge helps accounting for new knowledge). On the other hand, Bourgeois and Nizet have added, it is necessary to give means allowing learners to analyze and evaluate the new knowledge "from the outside". According to this approach, teachers are responsible for the following three activities: (1) engage learners in expressing their personal points of view, (2) organize the confrontation of learners' points of view, and (3) provide methodological tools allowing learners to treat different points of view. The point Bourgeois and Nizet make is that learners are confronted not with only one alternative point of view on a given object but with a diversity of points of view, and that learners are systematically encouraged to "come in" and "come out" different points of view with which they are confronted, and to connect those points of views one to another.

Driscoll (Driscoll, 2000) have examined the assumptions proposed by Spiro and colleagues, and identified two principal conditions of learning for cognitive flexibility: (1) *multiple modes of learning* (i.e., multiple representations of contents, multiple ways and methods for exploring contents), and (2) *multiple perspectives on learning* (i.e., expression, confrontation, and treatment of multiple points of view).

We believe that the previous indications are still too general for the course designer to be able to imagine concrete steps when he or she wants to design learning systems leading to cognitive flexibility. For instance, what has to be done with the learning contents in the recursion problem presented earlier? That is why we propose *operational criteria* for cognitive flexibility.

Operational criteria for cognitive flexibility

In earlier work (Chieu et al., 2004; Chieu, 2005), we transformed the pedagogical principles underlying Driscoll's two learning conditions for cognitive flexibility into operational criteria (Table 1) and we showed examples of their use. We followed Driscoll's conditions of learning because they appear to embody different points of view proposed by other educational theorists.

Table 1. Operational criteria for cognitive flexibility (MM = multiple modes, MP = multiple perspectives)

Learning components	Learning conditions	
	Multiple modes of learning	Multiple perspectives on learning
Learning contents	MM1: *The same learning content presenting concepts and their relationships is represented in different forms (e.g., text, images, audio, video, simulations).*	MP1: *The same abstract concept is explained, used, and applied systematically with other concepts in a diversity of examples of use, exercises, and case studies in complex, realistic, and relevant situations.*
Pedagogical devices	MM2: *Learners are encouraged to study the same abstract concept for different purposes, at different times, by different methods including different activities (reading, exploring, knowledge reorganization, etc.).*	MP2: *When facing a new concept, learners are encouraged to explore the relationships between this concept and other ones as far as possible in complex, realistic, and relevant situations.* MP3: *When facing a new concept, learners are encouraged to explore different interpretations of this concept (by other authors and by peers), to express their personal point of view on the new concept, and to give feedback on the points of view of other people.* MP4: *When facing a new concept, learners are encouraged to examine, analyze, and synthesize a diversity of points of view on the new concept.*
Human interactions	MM3: *The number of participants, the type of participant (learner, tutor, expert, etc.), the communication tools (e-mail, mailing lists, face to face, chat room, video conferencing, etc.), and the location (in the classroom, on campus, anywhere in the world, etc.) are varied.*	MP5: *During the discussion, learners are encouraged to diversify – as far as possible – the different points of view about the topic discussed.*
Assessment	MM4: *During the learning process, learners are encouraged to use different assessment methods and tools, at different times, and in different contexts for demonstrating their ability to solve different problems.*	MP6: *During the problem-solving process, learners are encouraged to confront multiple ways to solve the problem and multiple possible solutions to the problem.*

We defined an operational criterion for cognitive flexibility to be a test that allows a straightforward decision about whether or not a learning situation reflects the pedagogical principles underlying cognitive flexibility. To propose operational criteria for cognitive flexibility, we first examined many existing learning systems and identified four main components of learning systems: (1) learning contents (e.g., concept definitions); (2) pedagogical devices (e.g., tools provided for learners for exploring learning contents); (3) human interactions (e.g., means for engaging tutors and learners in exchanges); and (4) assessment (e.g., post-tests for determining whether learners have achieved learning objectives). Then, in each of the four learning components and for each of the two learning conditions for cognitive flexibility, we defined criteria that can be applied for checking the presence of the learning condition in the learning component (Table 1).

In the next section, we show how the course designer might use learning and authoring tools provided by the COFALE system to satisfy criteria for cognitive flexibility.

COFALE as a learning environment and as an authoring system

COFALE is based on ATutor (Adaptive Technology Resource Center, 2004), an open-source Web-based learning content management system. For the purpose of the discussion, we shall assume that a “novice” learner (Bob), familiar with “traditional” programming (say in the Java programming language), wants to learn recursion (i.e., to develop the ability to solve problems recursively). In this section, for each criterion for cognitive flexibility defined in the previous section, we show how a course designer (Tom) uses COFALE to present Bob with learning situations satisfying the corresponding criterion. Note that a number of learning and authoring tools are originally supported by ATutor (thus also by COFALE).

Bob needs to develop his capacity to implement recursive solutions for a variety of problems. Navigating the "Local Menu" seen on the right hand side of Figure 1, Bob reads the definition and examples of the main concepts such as recursion, recursive algorithms, and recursive methods (Figure 1: Area 1). After that, Bob is encouraged to explore a situation about arithmetic expressions (Figure 1: Area 2). We show, in the following presentation for criterion MM2, how Bob is encouraged, in COFALE, to explore situations.

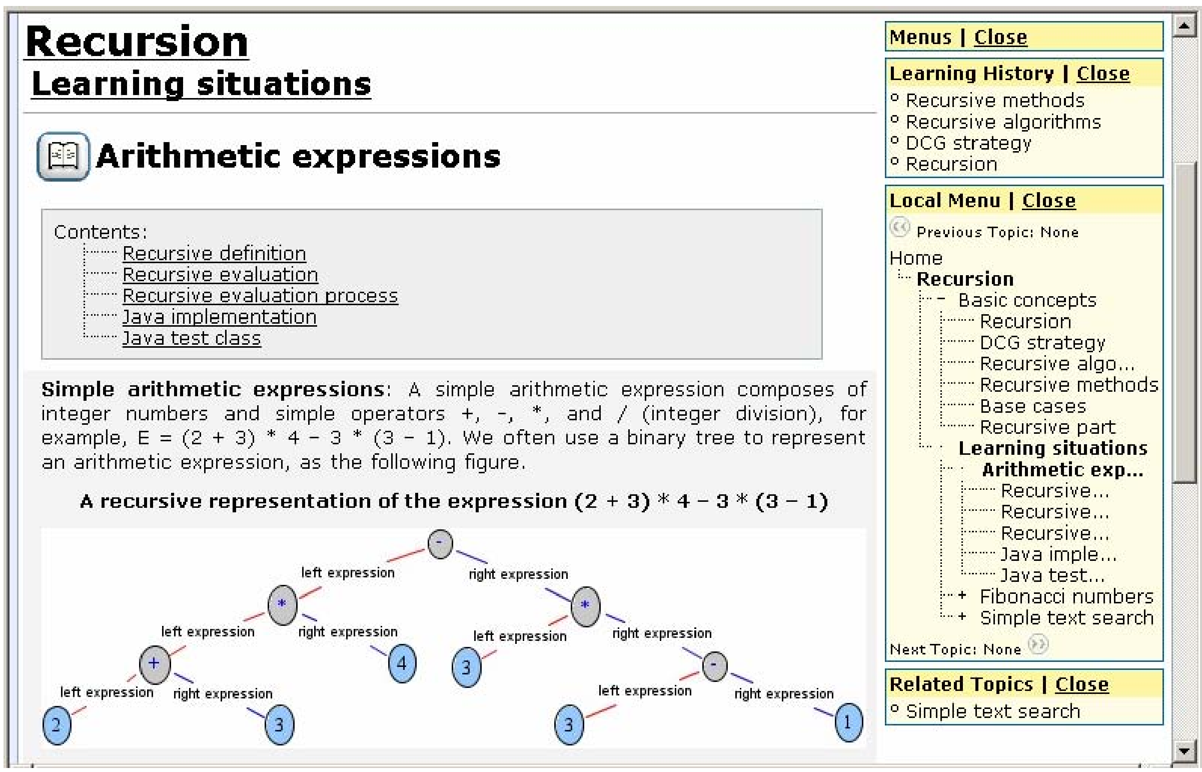

Figure 1. A part of Bob's learning hyperspace in COFALE

Criterion MM1

In the arithmetic expressions situation, Tom induces Bob to examine multiple representations of recursion through the use of hyperlinks presented in Area 3 or in Area 4 of Figure 1: a textual definition, two simulations, and a Java implementation.

To satisfy criterion MM1, Tom has made multiple representations available for recursion: A combination of text, images, and simulations helps Bob grasp diverse aspects of recursion better than does a single text. ATutor provides Tom with a hypermedia authoring tool (Figure 2) to create learning content objects (i.e., content pages) in different forms.

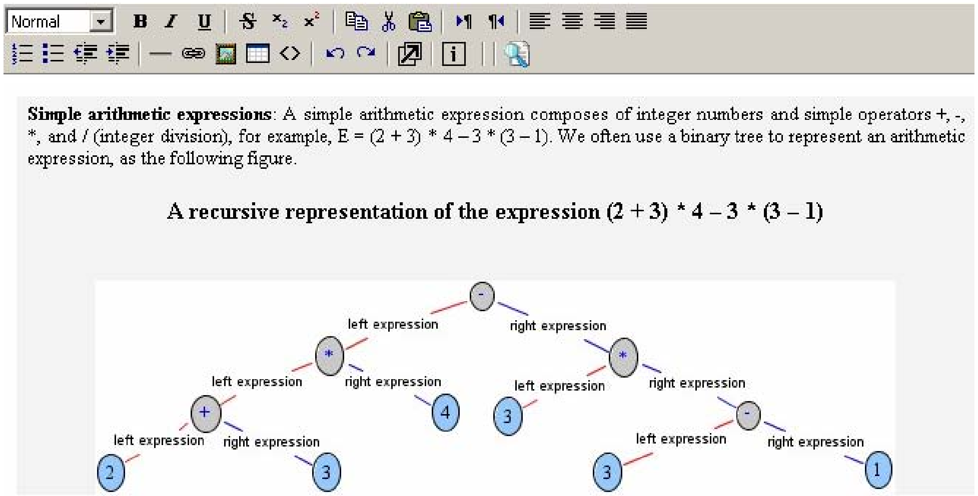

Figure 2. Tool for creating content objects

Criterion MP1

After exploring the first situation, Bob is encouraged to explore the second one: “Simple text search”, seen at the bottom of the menu “Related Topics” offered by ATutor (Figure 1: Area 5). In this situation, Bob sees how to apply recursion to represent a text (i.e., a list of words) as a linked list and how to look up a phrase in a document.

In COFALE, we explicitly encourage Tom to prepare several situations to help Bob understand how to apply the concept of recursion in different contexts. Arithmetic expressions explain the use of recursion in binary trees in a natural way and simple text search explains the use of recursion in linked lists. Note that criterion MP1 is independent to ICT and that Tom must be versed in the subject of recursion to be able to prepare a *diversity* of learning situations for the student.

Criterion MP2

When Bob explores simple text search, Tom presents a hyperlink encouraging Bob to examine “linked lists”, an important concept related to recursion. Similarly, while exploring this concept, Bob could return to the recursion hyperspace by using one of the hyperlinks presented in “Related Topics” and “Learning History”, shown at the top right of Figure 1. The latter contains the hyperlinks of Bob’s recently visited content pages, which are generated by COFALE. The two menus also help Bob navigate intelligently to avoid getting lost in the learning hyperspace.

To satisfy criterion MP2, Tom has defined, for every discrete piece of learning content (page), the other pages related to that one: simple text search related to arithmetic expressions, linked lists related to simple text search, and so on. For instance, the tool (Figure 3) provided by ATutor allows Tom to associate “Simple text search” with “Arithmetic expressions” by selecting the checkbox next to “Simple text search”. On the basis of those associations, ATutor automatically generates the hyperlinks in menu “Related Topics”.

Criterion MM2

To encourage Bob to look further into the concept of recursion, Tom presents Bob with a number of learning activities at the end of each content page, for example, at the end of the final page of the situation about arithmetic expressions, Bob is invited to explore related topics, to add comments, to do tests, to discuss with peers, and so on (Figure 5).

COFALE supports a set of predefined learning activities (Figure 5), most of which are associated with a hyperlink, which allows learners to go directly to the pedagogical device(s) corresponding to the activity. To define, for each activity (e.g., "Examples & Summaries"), the content pages to which the activity is related, Tom selects the checkboxes next to the content pages he wants to associate with the learning activity (Figure 4). On the basis of those associations, at the end of each selected page, COFALE presents Bob with a hyperlink to the activity (i.e., "Examples & Summaries").

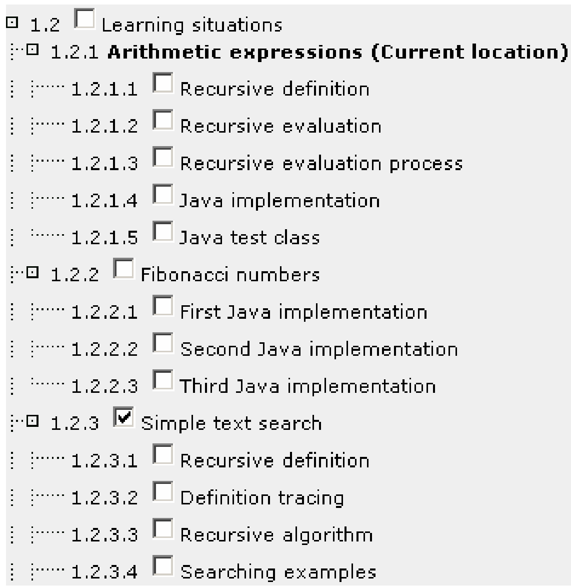

Figure 3. Tool for defining related topics relations

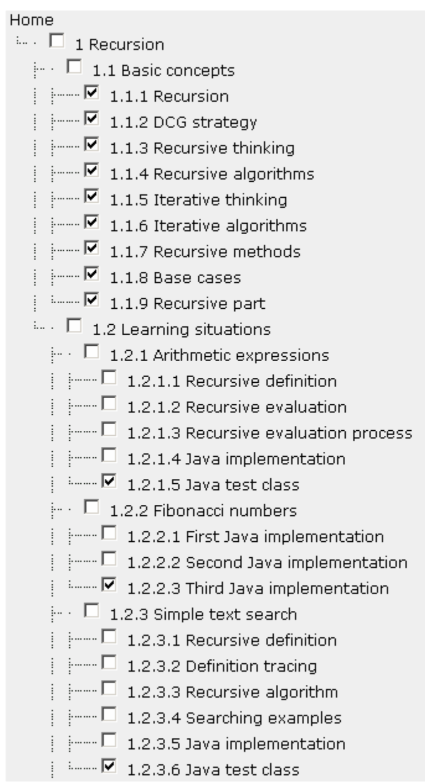

Figure 4. Tool for defining pages related to an activity

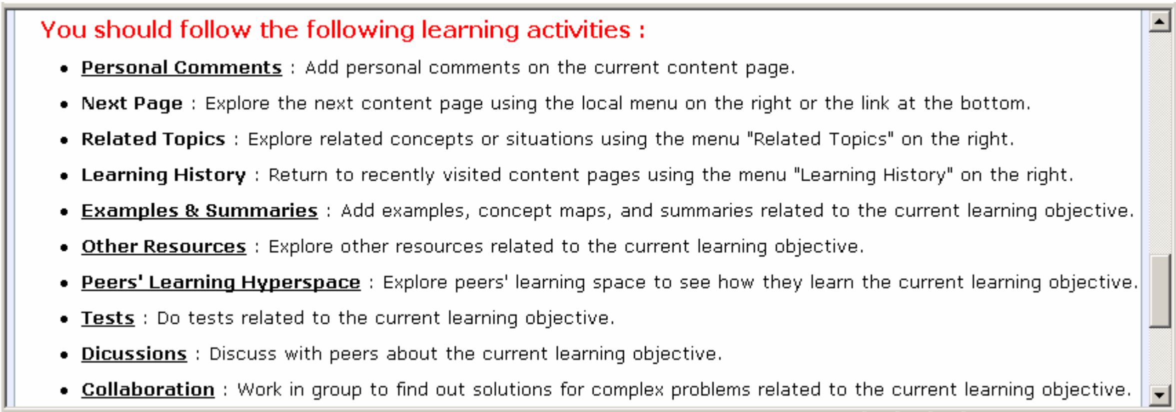

Figure 5. Learning activities proposed to Bob

Criterion MP3

To satisfy this criterion, COFALE engages Bob in four learning activities: (1) add comments on the learning content proposed by the course designer ("Personal Comments" in Figure 5), for example, reformulate the main points of the definition of recursion; (2) add his own examples such as a recursive phenomenon in his life ("Examples & Summaries" in Figure 5); (3) explore external resources ("Other Resources" in Figure 5), for example, the online Java tutorial (Kjell, 2003) in which the author illustrates a great number of recursive examples; and (4) explore peers' learning spaces ("Peers' Learning Hyperspace" in Figure 5), for instance, log into the learning hyperspace of an "expert" learner to see and give feedback on her own recursive examples.

To support the exploration of external resources, Tom has needed to search the Internet and introduce the chosen links (e.g., the Java tutorial). The other three activities are supported by COFALE without Tom' explicit intervention.

Criterion MP4

To satisfy this criterion, Tom engages Bob to produce summaries of the points of view of other sources and peers ("Examples & Summaries" in Figure 5). For instance, COFALE provides Bob with an empty table so that he can state his own definitions of recursion, recursive methods, and recursive problem solving, together with peers'. COFALE supports this activity without intervention of the course designer (Tom).

Criterion MM3

To satisfy this criterion, Tom encourages Bob to work with others ("Discussions" in Figure 5), sometimes with the participation of the tutor, by using multiple communication tools supported by ATutor such as e-mail, forums, chat rooms. Tom also incites Bob to use a Q&A website (Java World, 2004) to ask experts questions about recursion.

The ATutor platform supports multiple communication tools, but to engage learners to use them in COFALE, Tom has created a forum and invited Bob and his peers to confront and discuss their recursive examples that they have encountered in their everyday life.

Criterion MP5

To satisfy this criterion, for every discussion tool provided for students, COFALE attaches two dropdown lists of general and domain-specific questions that Bob could use to elicit peers' point of view. For instance, when Bob sees an example or solution proposed by a peer, Bob can select the question "What was your source of information?" from the list of general questions to ask the peer to justify the solution.

Tom is asked to prepare a list of general questions and a list of domain-specific questions. COFALE supports a list of predefined general questions proposed by researchers in pedagogy (e.g., Wright, 1995).

Criterion MM4

At different points in time, for example, after exploring multiple learning situations or after discussing with peers, Bob is engaged in two assessment activities: (1) individual tests in which Bob is asked to solve problems in the robot situation (e.g., a robot can walk 1 or 2 or 4 meters, computing the number of ways the robot can walk n meters and listing all the ways the robot can walk n meters where n is a positive integer); (2) work in group in which Bob and one or two other peers are asked to solve complex problems in a tree-structured file system (e.g., listing all files and sub-directories in a given directory).

COFALE provides Tom with a test manager (Figure 6) so that he can create individual tests, for example, introduce an assessment situation, a passing score, one or more questions. Presently, Tom can create three types of questions: multiple-choice, true-false, and open-ended. Furthermore, Tom can use ATutor's tools (Figure 7) to create assessment situations in groups. For instance, he can constitute small groups of learners, and present them with problems in the situation about file management and with a brief description of the class File in Java, which is useful for students to solve the given problems (Figure 7: Area 1).

Criterion MP6

In the robot situation, to compute the number of ways the robot can walk n meters, Bob is encouraged to use and compare both the iterative method and the recursive one. In the file management situation, Tom exhorts Bob and his peers to confront and compare different solutions. For example, in the "Drafting Room" (Figure 7: Area 2), Bob and Alice propose two different solutions to the given problems: Bob first lists the files and sub-directories in the given directory, then in its sub-directories, and Alice first lists the files and sub-directories in the sub-directories of the given directory, then in the given directory. Because they confront multiple solutions, they are invited to use a domain-specific tool, JDiff (JEdit, 2005), to analyze the difference between the two Java implementations.

Tom must be an expert in the subject of recursion to be able to satisfy this ICT-independent criterion. For instance, Tom has proposed the file-listing assessment problem because it may evoke different solutions by students to the given problem.

Tests							
Status	**Title**	**Availablity**	**Questions**	**Type**	**Passing score**	**Results**	**Edit & Delete**
Ongoing!	Prerequisite	29/6/04 16:00 to 31/12/05 16:00	· 1 Questions · Preview	normal	60 %	· 2 Unmarked · 4 Results	· Edit · Delete
Ongoing!	Test 1: Background on recursion	1/7/04 16:00 to 31/12/05 16:00	· 5 Questions · Preview	normal	60 %	· 0 Unmarked · 1 Results	· Edit · Delete
Ongoing!	Test 2: Recursive method 1	1/7/04 18:00 to 31/12/05 18:00	· 1 Questions · Preview	normal	60 %	· 0 Unmarked · 0 Results	· Edit · Delete
Ongoing!	Test 3: Recursive method 2	1/7/04 18:00 to 31/12/05 18:00	· 1 Questions · Preview	normal	60 %	· 0 Unmarked · 0 Results	· Edit · Delete
Ongoing!	Test 4: Advanced recursive method 1	1/7/04 18:00 to 31/12/05 18:00	· 1 Questions · Preview	normal	60 %	· 0 Unmarked · 0 Results	· Edit · Delete
Ongoing!	Test 5: Concept of recursion	1/7/04 18:00 to 31/12/05 18:00	· 3 Questions · Preview	normal	60 %	· 0 Unmarked · 0 Results	· Edit · Delete
Ongoing!	Test 6: Advanced recursive method 2	1/7/04 19:00 to 31/12/05 19:00	· 1 Questions · Preview	normal	60 %	· 0 Unmarked · 0 Results	· Edit · Delete

Figure 6. Individual tests manager

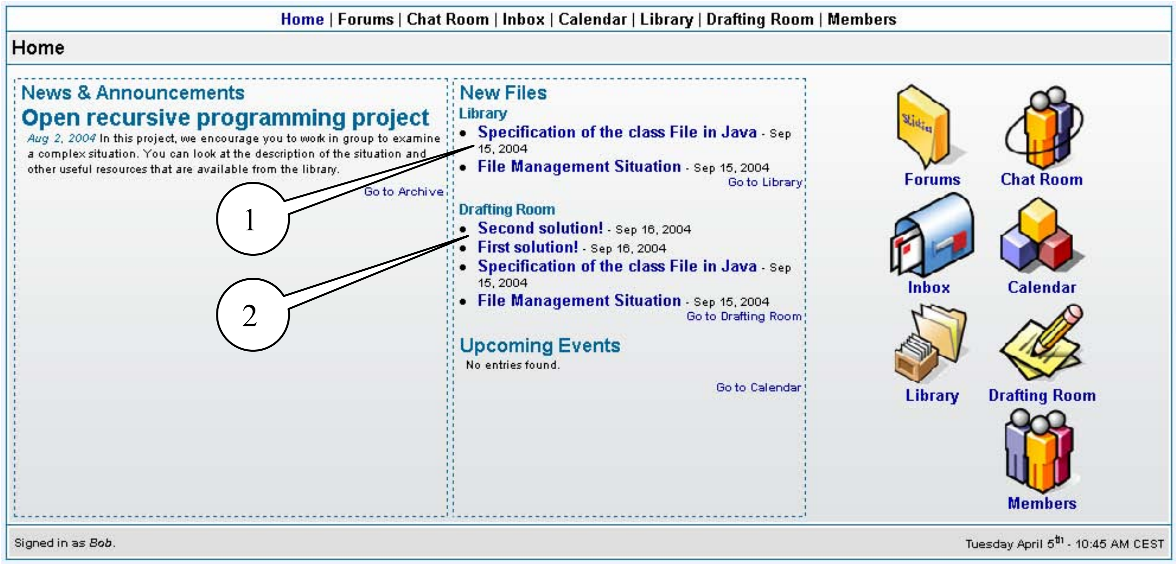

Figure 7. Collaboration hyperspace

All criteria

In addition to the previous learning situations proposed to Bob, at any time he may review his learning behavior or navigation history. For instance, after exploring arithmetic expressions, Bob can look again at the content pages he has viewed, the number of visits for each content page, and the total time he has used for each content page. Bob can also see the tutor's feedback on his learning behavior with respect to cognitive flexibility.

To give Bob feedback on his learning behavior, the tutor first logs into his learning hyperspace. Then, the tutor examines Bob' navigation history to see how Bob has explored the recursion hyperspace and constructed his own learning space. Finally, the tutor uses a simple text editor supported by COFALE to give comments to Bob. For example, if Bob explored only one learning situation (e.g., arithmetic expressions), the tutor may give him the following suggestion: "You should examine multiple learning situations presented in COFALE in order to try and apply recursion in diverse contexts".

Preliminary evaluation

A number of studies have showed positive results that pedagogical models proposed for cognitive flexibility help students in advanced knowledge acquisition (Spiro & Jehng, 1990). The implementation of learning conditions fostering cognitive flexibility in an e-learning platform such as COFALE, however, is relatively new. Thus, it must carry out surveys to evaluate various aspects of COFALE. For example: Do learning conditions provided by COFALE foster students' cognitive flexibility effectively? Do students follow suggestions proposed by COFALE (e.g., to explore related concepts and do learning activities presented at the bottom of each page), more specifically, do their learning processes respect criteria for cognitive flexibility? Nevertheless, the evaluation of learners' cognitive ability must be very hard (de Jong, 2005; Wilson, 1997). For the time being, we could perform only a preliminary study to answer the previous questions partly.

A 2-week-long study was performed to formatively evaluate the recursion course we designed using COFALE (Chieu, 2005). The study method is as follows: Nine first-year engineering students at the *Université catholique de Louvain*, having acquired knowledge of programming and Java in a problem-based learning approach but no knowledge of recursion, were randomly organized into two groups: four in the COFALE group and five in the control group. We organized the study into four phases: pretest, experiment, posttest, and interview. Both groups were given the same pretest, posttest, and interview questions. For the experimental phase, they were given the same

45-minute-long lecture and 2-hour-long homework. The only difference was that: After the lecture, within 1 hour the COFALE group explored the recursion course maintained by COFALE whereas the control group read a chapter about recursion of a reference book (Lewis & Loftus, 2003), both with the participation of the tutor.

Several encouraging results were reported on learning with the help of COFALE. Students in both groups mastered the concept of recursion to a significant degree. The COFALE group's learning behavior, however, seemed to be somewhat more consistent with cognitive flexibility than the control group's. For example: in the posttest, more students of the COFALE group than of the control group tried to activate their prior knowledge, in different ways, to analyze different aspects of a new problem and to propose a solution as complete as possible; in the interview, the COFALE group tried to define the concept of recursion more clearly and accurately than did the control group. The COFALE group had more learning motivation than did the control group. For instance: during the exploration of COFALE, students asked the tutor 20 questions by e-mail in comparison with 3 face-to-face questions of control group students during their reading of the book chapter; students in the COFALE group did all three exercises proposed by the tutor whereas students in the control group did only one or two among many exercises proposed by the authors of the book chapter. One of the reasons for those differences may be that criterion MP1 has not been seriously taken into account in the creation of examples and exercises in the book chapter, meaning that its examples and exercises are more or less similar in terms of instruction–they emphasize only one or two aspects of the underlying concept (we see this problem in many textbooks). Indeed, the following short extract of an interview of a student in the COFALE group could show the effectiveness of criteria MM1 and MP1 in the recursion course we designed in COFALE (the evidence is in italic):

> COFALE is good, personalized… We can work anywhere, submit exercises online … There is not much in one content page... *Many examples, they are clear and well explained, in each example they do not give the solution immediately, there is one page to explain how to think, one page to explain how to build the solution, and one page to show the solution. This helps to construct our own solution by ourselves.*

Discussion

To understand learning tools and authoring tools supported by COFALE completely, one should examine the dissertation of a researcher of ours (Chieu, 2005). To explore the COFALE open-source project (including the online course on recursion), one should visit the following website: http://cofale.info.ucl.ac.be.

COFALE is a domain-independent platform, meaning that it can be used to design "courses" in a variety of domains. Indeed, COFALE is based on ATutor, claimed to be domain-independent (Adaptive Technology Resource Center, 2004). Furthermore, the features COFALE has added on to ATutor are also domain-independent, for example, the tool shown in Figure 4 could be used in the design of any "courses".

The course designer's workload for making a course available in COFALE is not very high (about 8 person-hours for the course on recursion) because of two main reasons. Firstly, COFALE supports many learning activities without direct intervention of the course designer. Secondly, operational criteria provide useful guidelines for the course designer.

For the implementation of COFALE, we have modified several components of ATutor and added a number of learning and authoring tools. We have selected ATutor among many open-source learning content management systems because it makes it easy to add pedagogical devices exhibiting the desired characteristics for cognitive flexibility and to create and manage fine-grained sharable content objects that are compliant with the IMS/SCORM standard (MASIE Center E-learning CONSORTIUM, 2003). This latter characteristic is useful both for the design of goal-based learning and for the personalization of learning contents (MASIE Center E-learning CONSORTIUM, 2003). Our contribution to ATutor is about 20 percent of the source code (or 5,000 lines of PHP code). It is worth to note that the development of the COFALE system has been mainly oriented to the set of criteria for cognitive flexibility: Each learning tool and each authoring tool in COFALE must have at least a *raison d'être*, that is to be present to satisfy one or more criteria for cognitive flexibility. Therefore, the workload for the design and implementation of the COFALE system could be considered as relatively low (about 6 person-months of programming work). That is why we could claim that *the operational approach we proposed is effective*.

In earlier work (Chieu et al., 2006), we analyzed several "courses" handled by existing systems, claimed to support constructivism explicitly, with respect to the criteria for cognitive flexibility: a motion course by SimQuest (de Jong et al., 2004), a Moodle features course by Moodle (Dougiamas, 2004), and a Java course by KBS (Henze & Nejdl, 2001). We also tried to use ATutor's tools to devise a course on recursion with the set of criteria for cognitive flexibility in our "mind" during the instructional design process. The result of the analysis is presented in Table 2. It is not surprising that the examples we analyzed do not satisfy all criteria for cognitive flexibility, because the authors of those learning systems may have designed those examples without any explicit ideas of cognitive flexibility in "mind".

The analysis showed the following main conclusions:

- There would be many different ways to create ICT-based learning conditions fostering cognitive flexibility. For example, we could use computer-based simulations (SimQuest) or hypermedia (Moodle, KBS, ATutor, COFALE) to satisfy criteria MM1 and MM2.
- The course designer should take into account the quality of criteria satisfaction rather than only the number of satisfied criteria, meaning that the course designer's expertise in the subject of instruction is essential. For criterion MP1, for instance, one must be an expert in the subject of recursion to be able to devise a *diversity* of meaningful instructional situations for the concept of recursion (e.g., arithmetic expressions and simple text search). The point here is that preparing a diversity of situations that emphasize different aspects or interpretations of a new concept is more important than preparing many situations that emphasize only one or two aspects of the new concept.
- In practice, it is not necessary to always satisfy all of the criteria for cognitive flexibility: In certain contexts, for example in introductory learning such as SimQuest's motion course, satisfying a half of the criteria might be sufficient enough to help students attain the learning objectives effectively. For the time being, there has been no evidence indicating that satisfying all criteria is always better than satisfying, for instance, two thirds of the set of criteria.

Table 2. Existing learning systems and cognitive flexibility

Learning components	**Criteria**	**SimQuest**	**Moodle**	**KBS**	**ATutor**
Learning contents	MM1	X	X	X	X
	MP1	X		X	X
Pedagogical devices	MM2	X	X	X	X
	MP2	X		X	X
	MP3		X		
	MP4				
Human communication	MM3		X		X
	MP5		X		
Assessment	MM4		X	X	X
	MP6				X

The important point we make here is that the set of criteria, learning tools, and authoring tools we have proposed is not exhaustive. One can surely modify them, propose new ones, or even reject part of them, according to his or her personal interpretation of learning conditions fostering cognitive flexibility.

Conclusion

Cognitive flexibility is one of the important facets of constructivism (Spiro & Jehng, 1990). It is also one of the important requirements for professional and life-long learning (Driscoll, 2000; Bourgeois & Nizet, 1999; Spiro & Jehng, 1990). From the development and validation of COFALE, a new domain-independent e-learning platform, we may conclude that our approach, based on *operational criteria*, makes the design and use of ICT-based learning environments supporting cognitive flexibility *straightforward* and *effective*. Indeed, the course designer can use the set of criteria for cognitive flexibility as a useful pedagogical framework (i.e., a checklist) and the COFALE platform as an easy-to-use technological means to create "courses" exhibiting the desired characteristics of cognitive flexibility.

We believe that our operational approach could also be used to exploit other facets of constructivism (e.g., problem solving) in order to design more completely constructivist learning environments. It should be noted that proposing criteria for the facet of problem solving must be hard because problem solving is domain-dependent (Weber & Brusilovsky, 2001).

Although a preliminary evaluation of COFALE has reported on several encouraging results, we shall conduct more long-term studies to know the full extent of how ICT-based learning conditions fostering cognitive flexibility affect how students learn, especially in life-long learning contexts. Evaluating students' cognitive flexibility, however, is very hard because it is really difficult to know what happens exactly in the "mind" of an individual when he or she is learning (Wilson, 1997). For example, during the evaluation of COFALE, it was hard for us to find pertinent questions in order to help students to express what happens to them cognitively during their learning process. For this kind of exercise, we believe that operational criteria could be very useful, in the same way that operational criteria have been used to evaluate learning conditions. Nevertheless, proposing criteria for evaluating learners' cognitive behavior is much harder than proposing criteria for evaluating conditions of learning, because conditions of learning are observable whereas cognitive behavior is not always observable. We hope that researchers in education and cognition shall contribute to figure out this problem in the future.

Besides studying COFALE's cognitive tools for learners by ourselves, we shall also collect and analyze empirical data about teachers' feedback on the use of the operational criteria and of the COFALE system for the design of their own "courses" in different teaching subjects.

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References

Adaptive Technology Resource Center (2004). *ATutor learning content management system*, Retrieved June 2, 2007, from, http://www.atutor.ca.

Anderson, J. R., Pirolli, P., & Farrell, R. (1988). Learning to program recursive functions. In Chi, M., Glaser R., & Farr, M. (Eds.), *The nature of expertise*, Hillsdale: Erlbaum, 153–184.

Bhuiyan, S., Greer, J., & McCalla, G. (1994). Supporting the learning of recursive problem solving. *Interactive Learning Environments, 4*(2), 115–139.

Bourgeois, E. & Nizet, J. (1999). *Apprentissage et formation des adultes*, Paris: Presses Universitaires de France.

Bruner, J. S. (1973). *Going beyond the information given*, New York: Norton.

Chieu, V. M., Milgrom, E., & Frenay, M. (2004). Constructivist learning: Operational criteria for cognitive flexibility. In Kinshuk, Looi C.-K., Sutinen E., Sampson D., Aedo I., Uden L. & Kähkönen E. (Eds.), *Proceedings of the 4th IEEE International Conference on Advanced learning Technologies 2004*, Los Alamitos, CA: IEEE Computer Society, 221–225.

Chieu, V. M. (2005). *Constructivist learning: An operational approach for designing adaptive learning environments supporting cognitive flexibility*, Louvain-la-Neuve: Université catholique de Louvain, Thèse de doctorat.

Chieu, V. M., & Milgrom, E. (2005). COFALE: An adaptive learning environment supporting cognitive flexibility. In *Proceedings of the Twelfth International Conference on Artificial Intelligence in Education*, 491–498.

Chieu, V. M. (2006). COFALE: An authoring system for supporting cognitive flexibility. In Kinshuk, Koper, R., Kommers, P., Kirschner, P., Sampson, D. G. & Didderen W. (Eds.), *Proceedings of the 6th IEEE International Conference on Advanced learning Technologies 2006*, Los Alamitos, CA: IEEE Computer Society, 335–339.

Chieu, V. M., Anh, D. T. V., & Hung, P. K. (2006). An operational approach for analyzing ICT-based constructivist and adaptive learning systems. In *IEEE Proceedings of the Fourth International Conference on Computer Sciences: Research, Innovation & Vision for the Future*, 177–186.

de Jong, T., van Joolingen, W., & van der Meij, J. (2004). *SimQuest discovery learning*, Retrieved June 8, 2007, from, http://www.simquest.nl.

de Jong, T. (2005). The guided discovery principle in multimedia learning. In Mayer, R. E. (Ed.), *The Cambridge handbook of multimedia learning*, New York: Cambridge University Press, 215–228.

Driscoll, M. P. (2000). *Psychology of learning for instruction*, Massachusetts: Allyn and Bacon.

Dougiamas, M. (2004). *Moodle: Course management system*, Retrieved June 8, 2007, from, http://moodle.org.

Feltovich, P. J., Spiro, R. J., Coulson, R. L., & Feltovich, J. (1996). Collaboration within and among minds: Mastering complexity, individually, and in groups. In Koschmann T. (Eds.), *CSCL: Theory and practice of an emerging paradigm*, Mahweh: Erlbaum, 25–44.

Frenay, M., & Bédard, D. (2004). Des dispositifs de formation s'inscrivant dans la perspective d'un apprentissage et d'un enseignement contextualisés pour favoriser la construction de connaissances et leur transfert. In Presseau A. & Frenay M. (Dir.), *Le transfert des apprentissages : comprendre pour mieux intervenir*, Québec: Les Presses de l'Université Laval, 241–268.

Henze, N., & Nejdl, W. (2001). Adaptation in open corpus hypermedia. *International Journal of Artificial Intelligence in Education*, 12, 325–350.

Java World (2004). *Java Q&A*, Retrieved June 8, 2007, from, http://www.javaworld.com/columns/jw-qna-index.shtml.

JEdit (2005). *Programmer's text editor*, Retrieved June 8, 2007, from, http://www.jedit.org.

Kinshuk, Looi, C. K., Sutinen, E., Sampson, D., Aedo, I., Uden, L., & Kähkönen, E. (2004). *Proceedings of the 4th IEEE International Conference on Advanced Learning Technologies*, Los Alamitos, CA: IEEE Computer Society.

Kjell, B. (2003). *Introduction to computer science using Java*, Retrieved June 8, 2007, from, http://chortle.ccsu.edu/CS151/cs151java.html.

Lewis, J., & Loftus, W. (2003). *Java software solutions*, Boston: Addison Wesley Longman.

MASIE Center E-learning CONSORTIUM (2003). *Making sense of learning standards and specifications*, Retrieved June 8, 2007, from, http://www.masie.com/standards/s3_2nd_edition.pdf.

Piaget, J. (1975). *L'équilibration des structures cognitives*, Paris: Presses Universitaires de France.

Santrock, J. W. (2001). *Educational psychology*, New York: McGraw-Hill.

Spiro, R. J., Coulson, R. L., Feltovich, P. J., & Anderson, D. K. (1988). Cognitive flexibility theory: Advanced knowledge acquisition in ill-structured domains. In *Tenth Annual Conference of the Cognitive Science Society*, Hillsdale: Erlbaum.

Spiro, R. J., & Jehng, J. C. (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and multidimensional traversal of complex subject matter. In Nix, D. & Spiro, R. J. (Eds.), *Cognition, education and multimedia*, Hillsdale: Erlbaum, 163–205.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (1991, May). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. *Educational Technology, 31*, 24–33.

Weber, G., & Brusilovsky, P. (2001). ELM-ART: an adaptive versatile system for Web-based instruction. *International Journal of Artificial Intelligence in Education, 12*, 351–384.

Wilson, B. G. (1996). *Constructivist learning environments: Case studies in instructional design*, Englewood Cliffs: Educational Technology Publications.

Wilson, B.G. (1997). Reflections on constructivism and instructional design. In Dills C. R., & Romiszowski A. A. (Eds.), *Instructional development paradigms*, Englewood Cliffs: Educational Technology Publications.

Wright, W. A. (1995). *Teaching improvement practices. Successful strategies for higher education*, Bolton: Anker Publishing Company.

Jovanović, J., Gašević, D., Knight, C., & Richards, G. (2007). Ontologies for Effective Use of Context in e-Learning Settings. *Educational Technology & Society*, 10 (3), 47-59.

Ontologies for Effective Use of Context in e-Learning Settings

Jelena Jovanović[1], Dragan Gašević[2, 3], Colin Knight[3], and Griff Richards[3]
[1]FON, School of Business Administration, University of Belgrade, Belgrade, Serbia // jeljov@gmail.com
[2]School of Computing and Information System, Athabasca University, Athabasca, Canada // dgasevic@acm.org
[3]School of Interactive arts and Technology, Simon Fraser University, Surrey, BC, Canada // {cjk2, griff}@sfu.ca

ABSTRACT

This paper presents an ontology-based framework aimed at explicit representation of context-specific metadata derived from the actual usage of learning objects and learning designs. The core part of the proposed framework is a learning object context ontology, that leverages a range of other kinds of learning ontologies (e.g., user modeling ontology, domain ontology, and learning design ontology) to capture the information about the real usage of a learning object inside a learning design. We also present some learner-centered and teacher-centered scenarios enabled by the proposed framework in order to illustrate the benefits the framework offers to these key participants of any learning process. Finally, we demonstrate how two present educational tools (i.e. TANGRAM and LOCO-Analyst) correspond to the proposed architecture.

Keywords

Learning objects, Learning context, Learning design, Ontologies, Personalization

Introduction

The recognition of the increased need for reusing learning content led to the adoption of a standard format for describing learning content with metadata, the widely known IEEE Learning Object Metadata Standard - IEEE LOM (WG12: Learning Object Metadata, 2002). The use of its predefined set of metadata fields promotes exchange of learning objects (LOs) among different e-learning systems and content providers, and offers higher potentials for finding existing learning content (i.e. LOs). Even though the IEEE LOM standard was undertaken by the e-learning community to facilitate and foster interoperability and reuse of learning artifacts among different e-learning platforms, decisions about reuse involve a broad set of issues about content, context and pedagogy that cannot be fully expressed in the LOM's metadata fields.

In order to be effective and bring expected learning results, LOs need to be organized in a pedagogically sound manner, according to an instructional plan, or a learning design. A learning design is about identifying necessary learning activities and assigning LOs to those activities in order to achieve the specified learning objective (Koper & Olivier, 2004). The idea of having a uniform method for expressing the design of the learning process began with the Educational Modeling Languages proposed by Koper (2001). This work evolved into the IMS Learning Design (IMS-LD) specification (IMS-LD-IM, 2003) that provides a common set of concepts for representing learning designs, hence enabling the share and reuse of learning designs across learning systems. These two specifications were supposed to enable specification of learning designs (and learning objects) targeted for different learning situations, based on different pedagogical theories, comprising different learning activities where students and teachers can play many roles, and that can be carried out in diverse learning environments.

However, the abovementioned specifications/standards (i.e., IEEE LOM and IMS-LD) do not enable capturing all the information required for advanced learning services, such as personalization or adaptation of content in accordance with the students' objectives, preferences, learning styles, and knowledge levels. The requirements for effective personalization include (but are not limited to) (Cristea, 2005):

1. Direct access to low-granularity content units comprising the structure of a LO;
2. Recognition of the pedagogical role played by each content unit in a specific situation (e.g., in a learning activity);
3. Awareness of the learners' evaluations about usefulness of a specific content unit within a specific learning design;
4. Characteristics of learners that best fit a specific learning design.

Further, if adaptation or personalization is supposed to happen automatically, all of these requirements must be codified in some unambiguous manner. Finally, the learning specifications/standards do not provide space for any kind of teacher-directed feedback about the usefulness and appropriateness of a LO or a learning design for certain learning settings. However, such a feedback is quintessential in online learning environments where the teachers' awareness of the learning process is significantly lower than in traditional classroom settings.

One strategy to address some of these shortcomings is suggested in the Ecological approach (McCalla, 2004). According to this approach, each time a user interacts with a LO, his/her user model is attached to the LO; as the time passes, user models accumulate around each LO stored in a repository. Annotation of a LO (i.e. assignment of metadata) is based on applying various data mining techniques on the data stored in the accumulated user models. However, metadata is generated only when needed and only for the needed purpose. In other words, the purpose determines which metadata will be generated and how – hence McCalla argues for the Pragmatic Web. This approach promises to provide LOs with metadata that are much more valuable for the personalization process than those prescribed by IEEE LOM.

Another strategy has been to encourage the use of concepts from controlled vocabularies, taxonomies, and ontologies as metadata values (Brase & Nejdl, 2004). Ontologies help increase the consistency and interoperability of metadata, however, they face strong barriers to adoption because users prefer using local terminology over familiarizing with ontologies and their structure (which can be rather complex) (Li et al., 2005; Li, 2006).The number of ontologies being developed is growing – domain ontologies covering diverse subject domains, competency ontologies and user model ontologies have already gained a widespread use in technology-enhanced learning. These different kinds of ontologies can be integrated in an ontological framework in order to enable adaptive use of LOs. This paper presents our proposal for such a framework, taking into account the need for contextualized metadata as suggested by McCalla (McCalla, 2004).

The paper first motivates the collection of metadata other than those prescribed by present learning specifications and standards. Next, the paper introduces the notion of the *Learning Object Context* as a kind of LO metadata that captures all the information that characterizes the specific situations (contexts) in which certain LO has been used. This idea is presented both at the conceptual level and at the level of formal representation, i.e., as an ontological framework (called LOCO). Some usage scenarios are also presented in order to illustrate the benefits of the proposed context-based approach. Finally, the paper illustrates two educational tools (TANGRAM (Jovanović et al, 2006a) and LOCO-Analyst (Jovanović et al, 2007)) that we have been developing, and positions them with respect to the proposed ontological framework. The last section concludes the paper and points out directions for future work.

Motivation

In our opinion, the learning specifications, such as IEEE LOM, IMS-LD and SCORM (SCORM, 2006), are of limited use and we are not alone in that belief. For example, Recker and Wiley (2001) have noted that prescriptive metadata in the form of IEEE LOM does not provide enough information to adequately support the learning process (e.g. to enable recommendation of learning content). We share this view and as well as their opinion on the main drawbacks of such metadata:

- Metadata of limited complexity and semantics. Metadata is often stored as simple text, sometimes as terms from a controlled vocabulary and sometimes not. As authors are typically reluctant to provide metadata, the amount of metadata is usually negligent, and either too broad (e.g. determining the target audience using the age range) or too narrow (excessively specific descriptions that are unlikely to anticipate all possible situations of use). Besides, restricting metadata to the values from controlled vocabularies is both a help and a hindrance – help as it enables automatic processing and hindrance since specification of an adequate vocabulary for a metadata element is an extremely complex and never fulfilled task. For example, the IEEE LOM standard defines 'School', 'Higher education', 'Training' and 'Other' as possible values of the Context metadata field. However, this set of values is neither comprehensive enough to cover all possible learning contexts, nor descriptive enough to depict their peculiarities. Or consider the acceptable set of values of the Learning Resource Type metadata element – it is a mix of presentation related (e.g. table, slide) and instruction related (e.g. exam, experiment) terms.
- With prescriptive metadata, it is neither possible to receive feedback from the users to determine the accuracy of the made assumptions about metadata values, nor to suggest new possible contexts of use. Likewise, some metadata values are difficult or even impossible to predict during content authoring, i.e. before the actual use of the learning content. Accordingly, in such situations content users (i.e. learners) are in a far better position to determine the suitability of the learning content for the learning situation at hand.

Even when learning content is substantially annotated (which is often not the case), the user needs to absorb this information, consider the value of the metadata given the context of the publisher of the metadata, and finally make a decision as to which object fits the present circumstances best. In other words, metadata is always influenced by the particularities of the authoring context and the intended use of the learning content – this is something that has to be taken into account when metadata-based query is issued to search for learning content with the ultimate aim of content reuse.

Finally, all of the information in a conventional learning system flows in one direction – towards the learner. We instead argue that the information needs to circulate, i.e. that a communication flow between all tools and actors in a learning environment needs to be established. The key to such a dynamic workflow is being able to represent the context of use of a LO. By associating a LO with a user model, and the observed interactions the user has with the LO, the process of inspecting metadata can be changed from a database lookup into a process of reasoning. This changes both the concept and the target of metadata – instead of being aimed directly at end users, metadata is now aimed at computer programs that can make sense of this data for end users (Jovanović et al, 2006c).

Learning Object Context – Conceptual Model

In the previous section, we have explained why the present learning specifications and standards are not sufficient for providing advanced levels of learning process support (e.g. recommending the content to learn from). If those advanced services are to be provided, then besides prescriptive metadata (e.g., IEEE LOM metadata) one also needs to be aware of the particularities of all the situations in which a LO was used. In other words, one needs to be informed of the *learning object context* – the specific context of use of the LO.

Likewise, context-related data are essential for instructors. When learning content is assembled into larger objects or designs to be presented to learners many assumptions are made about the learners and the learning situation: assumptions about the learners' experiences, skills, and competencies; about their personal preferences, learning styles, goals, and motivations; about the available time, etc. These assumptions are what we refer to as the *context* – the unique situation-related rules that implicitly govern how content should be structured into a flow of interaction for a particular learner.

To overcome the abovementioned shortcomings of learning specifications and enable capturing of context-related data, in our previous work, we developed an ontology-based framework, called LOCO (Learning Object Context Ontologies) (Knight et al, 2006), which consists of:

- *Learning object content structure* ontology – Formally identifies the information objects within a LO with the goal of making each component of the LO directly accessible.
- *Learning design* ontology – We have developed an ontology aimed at formal representation of the basic building blocks of an instructional design. The design of the ontology was inspired by the IMS-LD Information Model (IMS-LD-IM, 2003). However, the ontology is general enough to support any other model of instructional design.
- *Learning object context ontology* – The LOCO-Cite is an ontology originally developed to promote the integration and reuse of LOs and learning designs (Knight et al, 2006). The original conceptual model focused on using a Learning Object Context as a bridge between a LO (or one of its components) and the learning design in which the LO (or its component) was used.

Our subsequent efforts to utilize the elements of context for personalization of the learning process revealed that the LOCO framework needs to be further extended. Hence, we extended it to integrate connections to user modeling and subject domain ontologies as well as user evaluation information and other relevant data. These extensions are described in the next section.

LOCO-Cite Ontology

Aiming to further enhance the proposed formalization of the learning object context, we extended the LOCO framework to make use of a number of other types of ontologies relevant in the e-learning domain (Figure 1a). Specifically, connections with those other relevant ontologies are established via an additional set of properties introduced in the LOCO-Cite ontology. The *LearningObjectContext* class, representing a specific context of use, is maintained as the central item of the ontology. A number of properties were introduced to enable formal description of a LO's context-related (meta)data (Figure 1b).

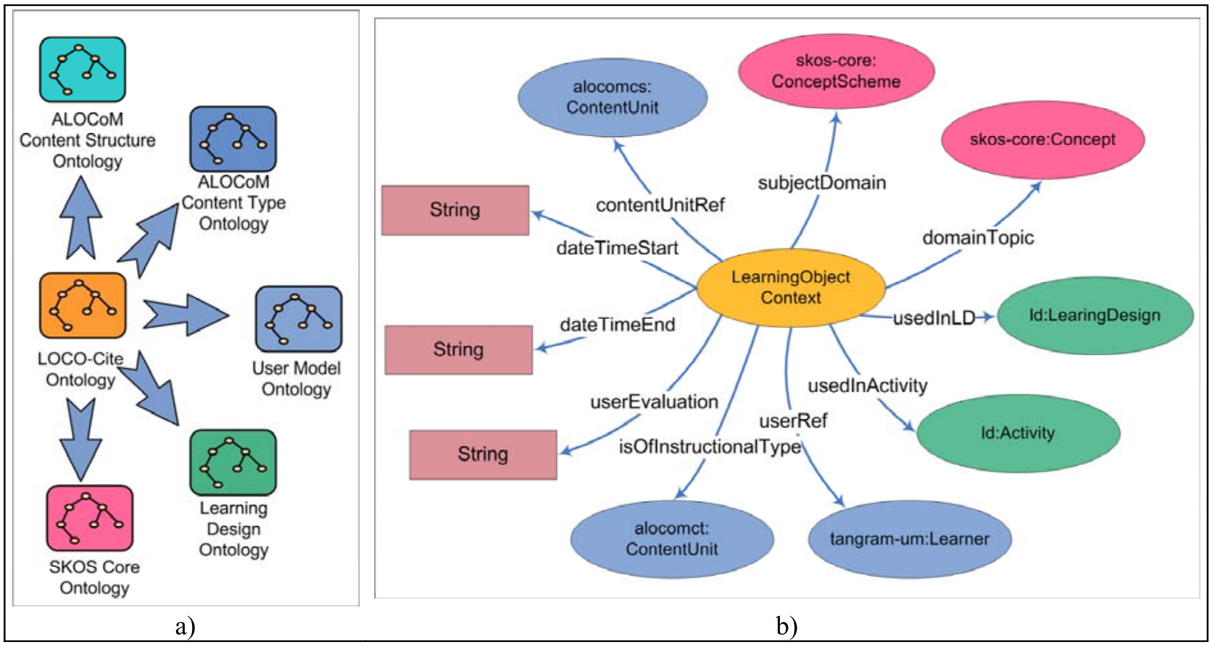

Figure 1. The LOCO-Cite ontology and its relations with other e-Learning ontologies

The *contentUnitRef* property refers to the actual unit of content that the context is about. The range of this property is the *alocomcs:ContentUnit* class, an abstract class defined in the ALOCoM Content Structure Ontology to formally represent a content unit of any granularity level (Jovanović et al, 2006b). Therefore, even though we refer to the context of a LO, the ontology design enables for a more generic approach – it provides a common formalism for representing context-relevant metadata for content units of diverse levels of granularity.

The *subjectDomain* and *domainTopic* properties are aimed at representing the subject domain and the domain topic, respectively, that best describe the context of use of a specific LO. Specifically, the two properties link learning object context with an appropriate domain ontology and its concept(s) represented in accordance with the W3C's SKOS Core Specification (http://www.w3.org/2004/02/skos/core/). The SKOS Core ontology is aimed at formal representation of concept schemes (e.g. taxonomies, thesauri, controlled vocabularies) (Miles & Brickley, 2005) and contains an excellent variety of classes (e.g. *concept scheme, concept*) and properties (e.g. *broader, narrower, prefLabel*) that can be used to describe topics of a LO and their relationships.

The *usedInLD* property points to the instance of the *ld:LearningDesign* class as a formalization of the actual learning design the LO was used in. Here we assume that a repository of learning designs, represented in compliance with the ontology of learning design exists and is accessible. If such a repository does not exist, but an elementary set of data about the design of the unit of learning that the LO was used in is available (e.g. general pedagogical model it is based on, learning objective both general and domain-specific, targeted learners), an instance of the *ld:LearningDesign* class would be created and stored with the learning object context.

The *usedInActivity* property is actually a reference to the learning activity (*ld:Activity*) the LO was used within. The underlying assumption for this property (as for the previous one) is the existence of an ontology-based repository of learning designs that facilitates direct access to any activity of any learning design stored in it. Alternatively, an instance of the *ld:Activity* class needs to be created out of the available activity-related data and stored with the learning object context.

The *isOfInstructionalType* property relates the learning object context with the instructional/pedagogical role the LO assumed in the learning activity it was used in. The range of this property is *alocomct:ContentUnit*, the top level class of the ALOCoM Content Type ontology developed to formally represent different instructional types a content unit might have (Jovanović et al, 2006b).

The *userRef* property refers to the user model of the learner who actually used the learning object in that specific learning context. We suggest the usage of the user model ontology developed in the scope of the TANGRAM project (Jovanović et al, 2006a). Even though the ontology enables formal representation of relevant information about all participants in the learning process (content authors, teachers and learners), it is mostly focused on the representation of the learners' features. The ontology defines formalisms for representing the learners' basic personal data, their preferences regarding language, domain topics and content authors, their performance, as well as different dimensions of their learning styles. A detailed description of the ontology is given in (Jovanović et al, 2006a).

The *dateTimeStart* and *dateTimeEnd* properties store data about the date and the time when the learner started and finished working with the LO. Hence, the time period the learner spent dwelling on the LO can be deduced.

The *userEvaluation* property reports on the usefulness of the LO in the given context as perceived by its users. Even though, this kind of user feedback is often neglected, we consider it highly important to capture the users' opinion about a LO with respect to different evaluation categories, such as clearness, usefulness, and pro collaborative nature. Each category is modeled as a subclass of the *UserEvaluation* class, hence the inclusion of a new (different) evaluation category is made as easy as extending this class with a new subclass. Course players should provide support for this kind of feedback.

The Framework in Use

The proposed ontological framework is beneficial both for teacher-centric and learner-centric tools and systems. In this section we present some usage scenarios in order to illustrate the advantages of the suggested approach, whereas in the next section we give an overview of two applications based on the LOCO framework.

Learner-centric scenarios

Figure 2 illustrates the basic architecture of an adaptive educational system leveraging the capabilities of the presented ontologies for discovery, reuse and adaptation of LOs. The architecture comprises a repository of LOs and its accompanying repository of learning object context (LOC) data. The repository of LOCs stores learning objects' context-related data in accordance with the LOCO-Cite ontology. The idea is that each object from the LO repository has its context data in the repository of LOCs. Being aware of the fact that right after being uploaded to the repository, a LO can not have any context-related data (as it has not been used yet), we introduce the notion of 'artificial' LOCs in order to alleviate the 'cold-start' problem (well known in recommender systems (Recker et al, 2001)). Since LOs are often designed for a specific purpose (i.e., intended use), their (prescriptive) metadata can be collected to seed the "artificial" LOCs. As the time passes and the LO is used in different courses (i.e. learning designs), its context data become available in the repository of LOCs.

During the learning process, the repository of LOCs can be searched for LOC instances that 'match' the requirements of the current learning situation (e.g., prerequisites, learning objectives, and available amount of time). These requirements can be expressed as a query using an ontology query language (e.g. RDQL (Seaborne, 2004)). Such a query should use the concepts/instances from relevant ontologies and/or taxonomies whenever it is possible, since their usage enables an advanced matching process. For example, if no LOC instance can be found that 'has' the required learning activity, an instance with a 'similar' activity can be used instead. The notion of similarity here is rooted in the ontologies used and semantic relations among their concepts. In our example, the similarity can be inferred from a taxonomy (or an ontology) of learning activities (as the one suggested in (Conole et al, 2005)) and the search query can be extended to encompass other kinds of activities that are semantically close to the desired one. Accordingly, a course/lesson delivery system working on top of the aforementioned repositories is able to provide a learner with the best suited LOs for every learning activity specified in the learning design of the course/lesson (i.e. course/lesson plan) (s)he is taking. To put it differently, we suggest providing the learner with a custom 'view' (or a ‘virtual subsection’) of the LOs repository, generated in accordance with the requirements (e.g., prerequisites and learning objectives) of the current learning situation. The introduced notion of the custom ‘view’ is analogous to the well-known concept of view in databases that is used to protect the database users from the complexity of the underlying database schema. The learner is free to search and/or browse through that ‘virtual subsection’ of the LOs repository. This way the learners are given a substantial level of control over their learning process (i.e., we advocate in the active learning approach), whereas, at the same time, the usage of custom ‘views’ over the repository protects them from the cognitive overload. The learner’s searching/browsing behavior is tracked, as that data can be mined to infer the learner’s preferences, as well as some dimensions of his/her learning style. Based on the acquired insights into the learner’s preferences, the virtual subsection of the LOs repository for every subsequent activity the learner performs can be further customized. In other words, the customization would not be based only on the requirements of the learning activity, but also on the information inferred about the learner’s preferences/style. One should also note that each time a learner selects a LO from the repository of LOs, a learning object context instance is created in the repository of LOCs and all relevant context-related data for that usage are stored in it.

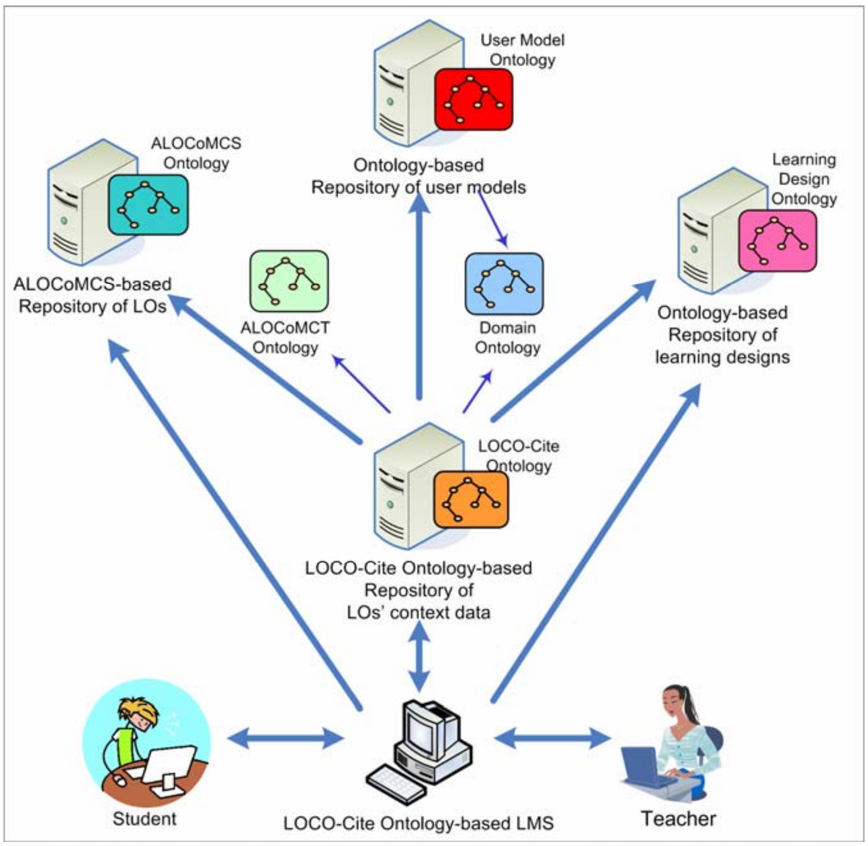

Figure 2. The architecture for the learning process adaptation

Furthermore, the information about the learners’ on-line communication and collaboration activities can also be used to improve the learners’ learning experience. In particular, by analyzing the context and the content of the messages exchanged in on-line discussion forums and chat rooms, a learning system can identify the problems some learners might have experienced and take appropriate actions. For example, having recognized that a learner is experiencing problems with a certain domain topic, the system can:

- recommend additional readings for the sake of clarifications (i.e., provides links to potentially relevant content that treats the unclear topics);
- suggest reading some postings from a specific discussion forum/chat room where the problematic issue was already discussed;
- suggest discussing the topic with some other learner(s) who knows the topic well, that is, with learner(s) who had high score on the quiz which tested the knowledge on that topic and/or related topics (where relatedness is inferred from the domain ontology).

Teacher-centric scenarios

Besides being beneficial for providing learners with personalized learning experience, the proposed framework and the reasoning that can be performed over it are also useful for generating feedback for other key participants in the learning process – content authors and instructors. Content authors are typically subject matter experts who create learning content, that is subsequently used by instructors (i.e., teachers) who wrap that content into a learning design (Jovanović et al, 2006c). The proposed framework can be used to inform learning content authors about the actual usage of their content during the learning process. Likewise, the framework can be used to provide feedback to instructors about the learners' activities, their performance, achieved collaboration level and the like. In both cases, the feedback helps improve the learning process. To support this statement, we give a few illustrative scenarios:

- If the majority of learners have spent a lot of time on some lesson and made frequent revisits to it, it is highly probable that the lesson is overly difficult for learners. This finding can be a signal for the content author to improve the expressivity of the content. It might also be a signal for the instructor to alter the applied instructional model (e.g., include more exercises or alter the lessons' sequence).
- If the majority of learners who performed poorly on an assessment followed the same or similar learning trajectory (i.e., sequence of lessons), it might signal to the instructor that either more tutoring (i.e., explicit directing of learners activities) is needed or the learning trajectory should be restricted (e.g., by means of link hiding techniques). Semantic annotation of lessons can further improve this feedback by helping identify semantically similar learning trajectories.
- If majority of learners answered incorrectly to the assessment question(s) about a particular domain topic and there were a lot of on-line exchanged messages discussing the topic in question as well as frequent revisits to the lesson(s) explaining the 'problematic' topic, then it is a clear signal that some alternations of the lessons' content or way of teaching the respective topic are needed.
- The feedback may be generated out of analyzes of the learners online communication and collaboration. Being informed about how active students were in social interactions, the instructor can more easily decide how to alter his/her teaching approach to activate them more, or make them more focused on the relevant parts of lessons.
- Finally, the ontological framework facilitates visualization of the learning process, hence providing instructors with visual clues of the learning progress. For example, from the visual representation of the learning object's context data, an instructor can easily perceive the suitability of that LO for different learning activities.

Applications

This section describes two educational systems based on the suggested ontological framework. The first one is TANGRAM, an ontology-based environment for generating personalized assemblies of learning object components. The second one is LOCO-Analyst, a tool for generating feedback for online instructors.

TANGRAM

TANGRAM is an adaptive learning environment for the domain of Intelligent Information Systems (Jovanović et al, 2006a). It is implemented as a Web application built on top of a repository of LOs and intended to be useful to both content authors and learners interested in the domain of Intelligent information systems (see http://iis.fon.bg.ac.yu/TANGRAM/home.html for more information).

Being fully ontology-based, TANGRAM actually illustrates how Semantic Web technologies, particularly ontologies and ontology-based reasoning, enable on-the-fly assembly of personalized learning content out of existing content units (note that a content unit is an abstract concept aimed at representing content of any level of granularity). Its principle functionality is to enable reuse of existing content units to dynamically generate new learning content adapted to a learner's knowledge, preferences, and learning styles. Additionally, the use of ontologies for structuring and annotation of the learning content (i.e., LOs) enables advanced search of the LOs repository, empowered by the Semantic Web reasoners. This means that the system is able to search for a content unit of a certain type (as defined in the ontology of pedagogical roles, e.g. "definition"), dealing with a certain topic (from the domain ontology, e.g. "Semantic Web") and being at a certain level of granularity (as defined in the structure ontology, e.g. "slide").

Accordingly, TANGRAM provides students with quick access to a particular type of content about a topic of interest, e.g. access to *example*s of RDF documents or *definition*s of the Semantic Web (both topics belong to the domain of Intelligent Information Systems).

To enable formal representation of learning content TANGRAM makes use of the aforementioned ALOCoM CS ontology and ALOCoM CT ontology (see Section 3.1). Additionally, TANGRAM uses the domain ontology to semantically annotate content units with appropriate domain concepts. We used an OWL binding of the SKOS Core specification (Miles & Brickley, 2005) to formally represent a sub-domain of intelligent information systems. However, note that TANGRAM is actually domain independent – to support any other subject domain it suffices to provide TANGRAM with a SKOS-Core-compliant ontology of that domain. To perform its personalization task TANGRAM heavily relies on its user model ontology. The system contains a repository of user models represented in accordance with this ontology.

TANGRAM also makes use of a Learning Paths ontology that defines learning trajectories through the domain's topics. This ontology relates instances of the domain ontology through an additional set of relationships reflecting a specific instructional approach to teaching/learning intelligent information systems. Hence, it can be regarded as a simplistic form of a learning design ontology. Whenever a student requests a certain topic (i.e. domain concept) to learn about, TANGRAM performs a sort of comparative analysis of data stored in the student's model and in the learning paths ontology in order to determine the student's knowledge about the domain concepts required for successful comprehension of the chosen topic. Information resulting from this analysis is used to provide adaptive guidance and direct the student towards the most appropriate learning content for him/her at that moment (Figure 3).

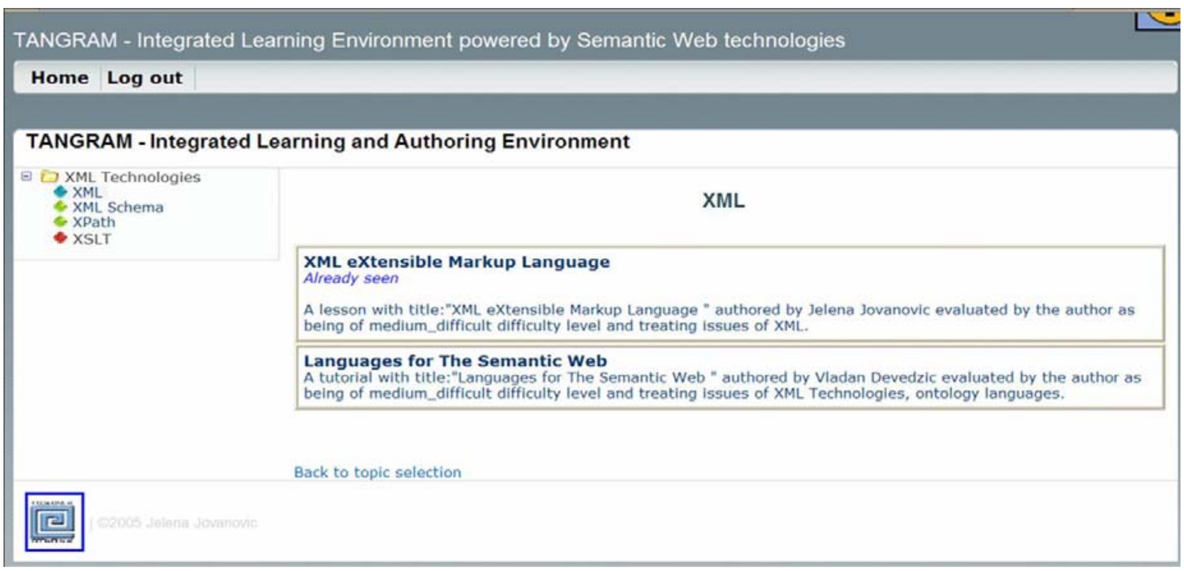

Figure 3. A screenshot of TANGRAM

TANGRAM also enables a content author to upload a new LO into the repository of LOs with the idea of later being able to reuse its components. The uploaded LO is decomposed into its components and its structure is explicitely represented according to the ALOCoM CS ontology. Additionally, the author can easily attach semantic markup to the uploaded LO, whereas TANGRAM automatically annotates the learning object's components using its own IEEE LOM profile (in RDF format).

As the previous discussion suggests, TANGRAM generally fits into the proposed framework: it decomposes LOs in accordance with a content structure ontology (ALOCOM CS) and enables direct access to (and hence reuse of) content units of diverse granularity levels; it annotates content units with concepts of an ontology of instructional roles (ALOCOM CT); it annotates content units with concepts of the domain ontology structured in accordance with the SKOS Core ontology; it keeps track of its users through the concepts and properties of its user model ontology. Besides, the architecture of TANGRAM (Jovanović et al, 2006b) closely resembles the one presented on Figure 2. The only part of the framework that TANGRAM currently does not support is the learning design. In particular, it does have an instructional model (formalized in the Learning Paths ontology), but it is really a rudimentary form of learning design. Essentially, TANGRAM's main deficiency is its lack of support for active learning, i.e. learning that is not restricted to reading, but also includes (even fosters) learning through communication and collaboration with others. Extending the system to include more advanced instructional planning is one of the main directions of our future work regarding TANGRAM.

LOCO-Analyst

LOCO-Analyst aims at helping instructors rethink the quality of the learning content and learning design of the courses they teach (Jovanović et al, 2007). To this end, it provides instructors with feedback about the relevant aspects of the learning process taking place in the online learning environment they use. The provided feedback is based on the analyses of the context data collected in the learning environment. In particular, LOCO-Analyst informs instructors about:

- the activities the learners performed and/or participated in during the learning process;
- the usage of the learning content they had prepared and deployed in the online learning environment;
- the peculiarities of the interactions among members of the online learning community.

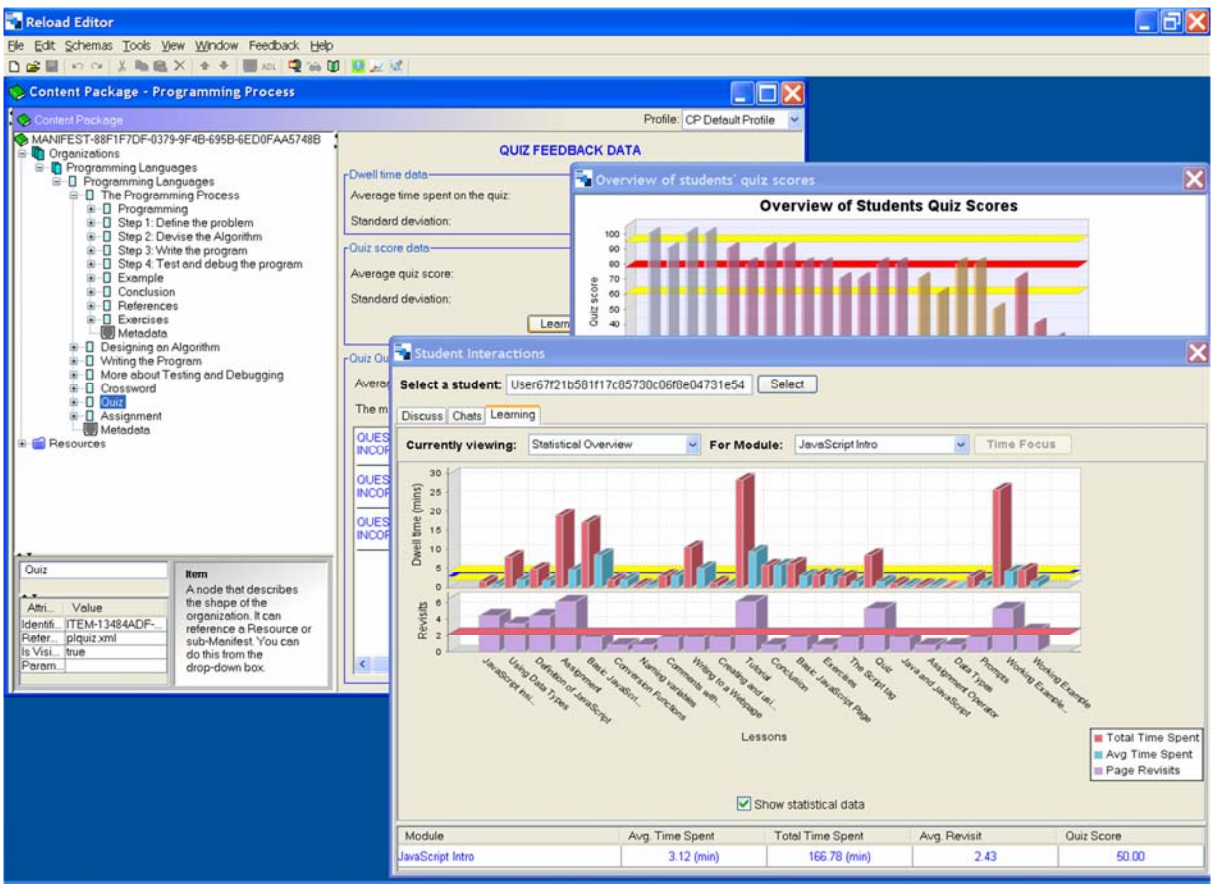

Figure 4. A screenshot of LOCO-Analyst

The current implementation of LOCO-Analyst uses tracking data from the iHelp Courses (Brooks et al, 2005) Learning Content Management System (LCMS). Nonetheless, LOCO-Analyst can be considered as a generic feedback generation tool since it is not tied to any specific distance learning environment. This independence is accomplished by developing the LOCO-Analyst's feedback provision functionalities on top of the LOCO ontological framework. Therefore, the only thing that needs to be done in order to apply LOCO-Analyst to any other online learning environment is to define the mapping between the tracking data format of that learning environment and the LOCO-Cite ontology.

LOCO-Analyst (Figure 4) is implemented as an extension of the well-known open-source Reload Content Packaging Editor (http://www.reload.ac.uk/editor.html). This way we have ensured that instructors effectively use the same tool for creating LOs, receiving and viewing automatically generated feedback about their use, and modifying the LOs accordingly. This further ensures easier and wider acceptance of LOCO-Analyst.

Like TANGRAM, LOCO-Analyst does not make use of the learning design ontology since the present state-of-the-art LCMSs do not support explicit definition and specification of learning design. We wanted to have a feedback generation tool that will meet the requirements of the presently available e-learning tools, so the ontology for learning design was redundant as in the present e-learning tools learning design is only implicitly present (typically as a sequence of lessons represented as a tree structure). However, as a part of our future work, we will investigate how implicit learning patterns can be extracted from the usage data and used to help course authors and instructors make better informed decisions when structuring the course. Successful patterns can be formalized as ontology-based learning designs according to the ontology of learning designs (build on top of IMS LD (Knight et al., 2006)), and thus made easily sharable and reusable.

Related Work

Context has been the subject of research in different research areas, but it seams that it has been mostly explored in the fields of pervasive (ubiquitous) computing and ambient intelligence. In these fields, context is considered as any information that can be used to characterize the situation of an actor - a person, a computing device, or a software agent. A ubiquitous computing environment integrates different sensors that sense various contexts, reasoners that infer new context information from the sensed data, and applications that make use of context to adapt the way they behave (Ranganathan et al., 2003). In such an environment, ontologies are used to uniquely describe context, and hence ensure that different entities that use context have a common semantic understanding of the contextual information. In other words, ontologies define standard descriptions for locations, services, activities, user preferences, beliefs, intentions, and other information that may be used by context-aware applications. For example, in the GAIA ubiquitous computing environment, contexts are represented in the form of predicates - the name of the predicate is the type of context that is being described (e.g., location, temperature or time) (Ranganathan et al., 2003). Ontologies essentially define the vocabulary and types of arguments that may be used in the predicates. On the other hand, Preuveneers and his associates proposed a generic context ontology that can be considered as a metamodel for context modeling and not as a vocabulary. The ontology consists of four basic context entities: (i) user, as the central concept in context-aware computing, (ii) environment, as a description of relevant aspects of the user’s surroundings, (iii) platform, the hardware and software of the device(s) in the user’s disposal, (iv) service, the functionality offered in the user’s environment (Preuveneers et al, 2004). Context is also the central concept of the CoBRa brokerage architecture aimed at supporting context-aware computing in intelligent spaces (Chen et al, 2004). The broker maintains and manages a shared context model on the behalf of a community of devices and agents and provides necessary common services. This shared model is actually a context ontology (dubbed CoBRa ontology), which defines some of the common relationships and attributes associated with people, places and activities in an intelligent space. The broker’s reasoning engine uses the ontological knowledge together with the acquired situational information to reason about the context in an intelligent space. Our approach is closest to the one suggested by Preuveneers et al (Preuveneers et al, 2004), since our ontological framework can be considered as a metamodel for modeling context in e-learning settings.

Context has also been explored in relation to Web services. For example, Maamar et al. argue for and provide the rational for associating context with Web services (Maamar et al, 2006). They consider context as any information that characterizes the interactions between humans, applications, and the environment, and suggest using context in conjunction with Web services in three intertwined steps: 1) deploying context-aware Web services (i.e., Web services that assess their environment before accepting to participate in compositions), 2) using context to reduce the semantic heterogeneity of Web services that participate in a composition, 3) conciliating contexts of Web services using ontologies. Their idea of using context for tracing the execution of Web services and using the past context to predict and adapt the behavior of Web services is analogous to our idea of using LOCs to track the usage of LOs and enable personalization of the learning process. Another work on context that is oriented towards service frameworks in general, and Web services in particular is the work of Strang et al. (2003) on Context Ontology Language (CoOL). CoOL is an ontology-based context modeling approach, which uses the Aspect-Scale-Context (ASC) model where each aspect (e.g. spatial distance) can have several scales (e.g., kilometer scale or mile scale) to express some context information (e.g. 20). Whereas CoOL is very useful for requirements relying on concepts with an inherent metric ordering, it is less practical for requirements such as adaptation of the learning content to the user needs.

The notion of context has already been explored in the e-learning community as well, but primarily as a mean for improving the performance of content search and retrieval. For example, Dichev & Dicheva (2006) explore the idea of using contexts to enable more efficient information search in Topic Map-based digital library applications. They perceive context as an abstraction of grouping of domain concepts and resources based on the existing semantic relationships between them. Technically, in Topic Map (http://www.topicmaps.org) terms a context is a nested topic map drawn around the topic chosen to name the context. The proposed context model is integrated into TM4L, a Topic Maps-based environment for creation, maintenance, and use of ontology-aware courseware. Thus, TM4L enables personalized, context-based search by allowing users to define their own contextualized queries. The advantage of this context-based search is twofold: first, the retrieved resources better satisfy the user requirements; and second, they provide a starting point for further exploration of relevant resources.

Huang et al. (2006) propose a generic context model as a basis of an intelligent semantic e-learning framework. The proposed model is based on the notion of semantic context as a collection of semantic rich situational information about the entity's internal features and external relations in a specific situation. Their proposal can be considered as a metamodel for context-aware semantic description (annotation) of learning content, learning processes, and learners. Actually, it is a generalization of existing learning specifications/standards extended with some additional features aimed at better context modeling (e.g., assigning weights to define the impact of a statement in a specific context). The authors also propose a concept schema as a vocabulary to be used in conjunction with the proposed (meta)model. However, in the suggested e-learning framework the context (meta)model is used for representing explicit metadata, that is, descriptions of learning processes and their constituents (i.e., LOs, activities, actors) explicitly provided by content authors, course authors, instructional designers and/or learners. Contrary to that, our LOCO framework is aimed at capturing and representing implicit metadata (i.e. context data originating from the learning process itself) that is subsequently used for analyzing (i.e., reasoning about) the learning process, its participants, and LOs.

Conclusions

Aiming to enable advanced services for all key participants of the learning process (learners, content authors and instructors), we came up with the idea of learning object context (LOC) as a unique set of interrelated data that characterize a specific learning situation. We have also developed an ontology framework (dubbed LOCO) as a formalization of the concept of LOC. The framework integrates several kinds of learning-related ontologies (e.g., user modeling ontology and content structuring ontology) in order to capture the information about specific context of use of a LO inside a learning design. Information of this kind can be rather useful for personalization of learning process. For example, during a learning session a query specifying the main features of the current learning situation can be sent to the repository of LOCs in order to identify LOC instances representing similar learning situations and from them infer the most suitable LOs for the present circumstances (e.g., learning objectives, learner's preferences, and available time). Furthermore, the idea of personalized views over repository of LOs is presented as a benefit resulting from the proposed ontology-based framework. Some of these advantages we have already implemented in TANGRAM, a Web-based application for personalized learning in the area of Intelligent information systems. In addition, our work on the LOCO-Analyst tool proved that the LOCO framework is useful for generating feedback aimed at informing content authors and instructors about the relevant aspects of the learning process. In both of these systems, we have demonstrated that not all features of the LOCO framework ought to be used in a specific application. On the contrary, application developers should choose those features that are needed for their current needs. Yet, thanks to the generality of the LOCO framework and its ontological formalization, developers can easily interoperate with systems that support other features of LOCO.

In our future research we intend to relate TANGRAM and LOCO-Analyst. The idea is to make learners interactions with TANGRAM traceable by LOCO-Analyst and hence unify learner-centric and teacher-centric tools in order to accomplish the circular flow of information in the learning process.

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References

ADL. (2005). *Advanced Distributed Learning SCORM Specification*, Retrieved June 6, 2007, from, http://www.adlnet.gov/scorm/.

Brase, J., & Nejdl, W. (2004). Ontologies and Metadata for eLearning, In Staab, S. & Studer R. (Eds.), *Handbook on Ontologies*, Berlin: Springer-Verlag, 555-574.

Brooks, C., Kettel, L., Hansen, C., & Greer, J. (2005). Building a Learning Object Content Management System. In Richards, G. (Ed.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2005*, Chesapeake, VA: AACE, 2836-2843.

Chen, H., Finin, T., & Joshi, A. (2004). An Ontology for Context-Aware Pervasive Computing Environments. *Knowledge Engineering Review, 18*(3), 197-207.

Conole, G., Littlejohn, A., Falconer, I., & Jeffrey, A. (2005). *Pedagogical review of learning activities and use cases, LADIE project report*, Retrieved June 6, 2007, from, http://www.jisc.ac.uk/uploaded_documents/PedVocab_VocabsReport_v0p11.doc.

Cristea, A. (2005). Authoring of Adaptive Hypermedia. *Educational Technology & Society, 8*(3), 6-8.

Dichev C., & Dicheva D. (2006). *Context-based Search in Topic-centered Digital Repositories*, Retrieved June 6, 2007, from, http://swui.semanticweb.org/swui06/papers/DichevDicheva/DichevDicheva.pdf.

Huang, W., Webster, D., Wood, D., & Ishaya, T. (2006). An intelligent semantic e-learning framework using context-aware Semantic Web technologies. *British Journal of Educational Technology, 37*(3), 351–373.

WG12: Learning Object Metadata (2002). *1484.12.1 IEEE Standard for learning Object Metadata*, IEEE Learning Technology Standards Committee, Retrieved June 6, 2007, from, http://ltsc.ieee.org/wg12/.

IMS Global Learning Consortium (2003). *IMS Learning Design Information Model, Version 1.0 Final Specification, revision 20*, Retrieved June 6, 2007, from, http://www.imsglobal.org/learningdesign/ldv1p0/imsld_infov1p0.html.

Jovanović, J., Gašević, D., & Devedžić, V. (2006). Dynamic Assembly of Personalized Learning Content on the Semantic Web. *Lecture Notes in Computer Science, 4011*, 545-559.

Jovanović, J., Gašević, D. & Devedžić, V. (2006). Ontology-Based Automatic Annotation of Learning Content. *International Journal on Semantic Web and Information Systems, 2*(2), 91-119.

Jovanović, J., Gašević, D., Brooks, C. A., Knight, C., Richards, G., & McCalla, G. I. (2006). Ontologies to Support Learning Design Context. *Lecture Notes in Computer Science, 4227*, 615-620.

Jovanović, J., Gašević, D., Brooks, C., Eap, T., Devedžić, V., Marek, H., & Richards, G. (2007). Leveraging the Semantic Web for Providing Educational Feedback. In Spector J. M., Sampson D. G., Okamoto T., Kinshuk, Cerri S.

A., Ueno M. & Kashihara A. (Eds.), *Proceedings of the 7th IEEE International Conference on Advanced learning Technologies*, Los Alamitos, CA: IEEE Computer Society, 551-555.

Knight, C., Gašević, D., & Richards, G. (2006). An Ontology-Based Framework for Bridging Learning Design and Learning Content. *Educational Technology & Society, 9*(1), 23-37.

Koper, R., & Olivier, B. (2004). Representing the Learning Design of Units of Learning. *Educational Technology & Society, 7*(3), 97-111.

Koper, R. (2001). *Modeling units of study from a pedagogical perspective - The pedagogical metamodel behind EML*, Retrieved June 7, 2007, from, http://dspace.ou.nl/bitstream/1820/36/1/Pedagogical+metamodel+behind+EMLv2.pdf.

Li, J. Z., Gašević, D., Nesbit, J. C., & Richards, G. (2005). *Ontology Mappings Enable Interoperation of Knowledge Domain Taxonomies*, Retrieved June 7, 2007, from, http://www.lornet.org/Portals/7/presentation_i2lor_05/papers/i2lor05-07.pdf.

Li, J. Z. (2006). Mapping Local Ontologies: Authentic Semantics for Learning Object Evaluation, *M.Sc. Thesis*, School of Interactive Arts and Technology, Simon Fraser University, Canada.

Maamar, Z., Benslimane, D., & Narendra, N. C. (2006). What can context do for web services? *Communications of the ACM, 49*(12), 98–103.

McCalla, G. (2004). The Ecological Approach to the Design of E-Learning Environments: Purpose-based Capture and Use of Information about Learners. *Journal of Interactive Media in Education, 2004*(7), Retrieved June 7, 2007, from, http://www-jime.open.ac.uk/2004/7.

Miles, A., & Brickley D. (2005). *SKOS Core Guide*, Retrieved June 7, 2007, from, http://www.w3.org/2004/02/skos/core/guide/2005-02-15.html.

Preuveneers, D., den Bergh, J. V., Wagelaar, D., Georges, A., Rigole, P., Clerckx, T., Berbers, Y., Coninx, K., Jonckers, V., & Bosschere, K. D. (2004). Towards an extensible context ontology for Ambient Intelligence. *Lecture Notes in Computer Science, 3295*, 148-159.

Ranganathan, A., McGrath, R. E., Campbell, R. H., & Mickunas, D. M. (2003). Ontologies in a Pervasive Computing Environment. In Giunchiglia, F., Gomez-Perez, A., Stuckenschmidt, H., Pease, A., Sure, Y. & Willmott, S. (Eds.), *Proceeding of the 1st International Workshop on Ontologies and Distributed Systems*, Retrieved June 7, 2007, from, http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS//Vol-71/.

Seaborne, A. (2004). *RDQL - A Query Language for RDF, W3C Member Submission*, Retrieved June 7, 2007, from, http://www.w3.org/Submission/RDQL.

Recker, M. M., & Wiley, D. (2001). A Non-authoritative Educational Metadata Ontology for Filtering and Recommending Learning Objects. *Interactive Learning Environments, 9*(3), 255-271.

Recker, M., Walker, A., & Willey, D. (2001). Collaboratively filtering learning objects. In D. A. Wiley (Ed.), The Instructional Use of Learning Objects, Retrieved June 7, 2007, from, http://reusability.org/read/chapters/recker.doc.

Strang, T., Linnhoff-Popien, C., & Frank, K. (2003). CoOL: A Context Ontology Language to enable Contextual Interoperability. *Lecture Notes in Computer Science, 2893*, 236–247.

Designing the Undesignable: Social Software and Control

Jon Dron
University of Brighton, UK // Jon.dron@brighton.ac.uk

ABSTRACT

Social software, such as blogs, wikis, tagging systems and collaborative filters, treats the group as a first-class object within the system. Drawing from theories of transactional distance and control, this paper proposes a model of e-learning that extends traditional concepts of learner-teacher-content interactions to include these emergent properties of the group. It suggests that this feature of social software can facilitate an approach to e-learning that is qualitatively different from and capable of significantly augmenting traditional methods, with especial benefits for lifelong learners and those outside institutional boundaries. The paper goes on to explore some of the dangers and issues that need to be addressed in order for this new model to fulfill its promise, and to suggest a framework of principles to be used by designers of educationally-oriented social software.

Keywords

Social software, Transactional distance, Control, Web 2.0, Self-organization

Introduction

This is a paper about the potential of social software in education. Social software treats the group as a first class object within the system (Allen, 2004). It is becoming embedded in all aspects of our online lives, from the recommendations of Amazon to the photo sharing of Flickr to the ordering of search results in Google. Social software such as blogs, wikis, link sharing systems, collaborative filters and other tools employing tagging, social recommendation and social navigation are increasingly a part of the fabric of an e-learning environment. In this paper I argue that they have characteristics that strongly distinguish them from earlier software for e-learning, providing particularly notable benefits to informal and lifelong learners. I describe a theoretical foundation which explains the potential benefits of social software in the context of transactional distance and control, extending earlier frameworks for e-learning to account for the emergent control of the group. Drawing on this foundation, I offer a set of ten principles to be employed by designers of social software environments for e-learning.

Transactional control

Michael Moore's theory of transactional distance suggests that the relative amount of dialogue and structure is what determines 'distance' in learning, rather than physical separation between learner and teacher (Moore, 1986). It is implied by the theory and independently confirmed by Saba and Shearer, that the two are inversely interdependent (Saba & Shearer, 1994). The greater the structure, the lesser the dialogue, and vice versa. To this mix, Moore adds a third dimension of autonomy. Fully autonomous learners need neither dialogue nor structure to learn. Like dialogue and structure, autonomy is seldom absolute. Others have refined this concept, noting that there is a big difference between autonomy as a psychological trait, and the varying degrees of autonomy of the learner to choose a path within a given learning context (Brockett & Hiemstra, 1991; Candy, 1991).

Moore's theory has been widely used and verified in a number of contexts (Chen, 2000; Dron, Seidel, & Litten, 2004; Lowe, 2000; Saba & Shearer, 1994; Stein, Wanstreet, Calvin, Overtoom, & Wheaton, 2005), but suffers from a fuzziness and inconsistency that troubles some (Garrison, 2000; Gorsky & Caspi, 2005).

I have proposed a different but intimately connected model, a subset of transactional distance that I have called *transactional control* (Dron, 2006). Transactional control is concerned with choices. In traditional education, whether online or offline, some choices are made by teachers and some by learners. The extent to which those choices are dictated by particular individuals determines their level of transactional control at any moment. Transactional control theory does not aim to replace transactional distance theory as it says nothing significant of the psychological gap between learner and teacher, but it helps to explain some of its dynamics. Structure equates to teacher control, dialogue to negotiated control, and autonomy to learner control. At any point in a learning trajectory, transactional control will vary. It is concerned with the choices that determine a change in trajectory, not those that follow from the intrinsic logic of the transaction nor from the extrinsic constraints which mould it. However, we shall see that there are other ways that control can arise and other entities that can wield it.

Figure 1 illustrates how transactional control captures the dynamics of transactional distance, but not the trait of autonomy nor the closeness felt by the learner to the teacher.

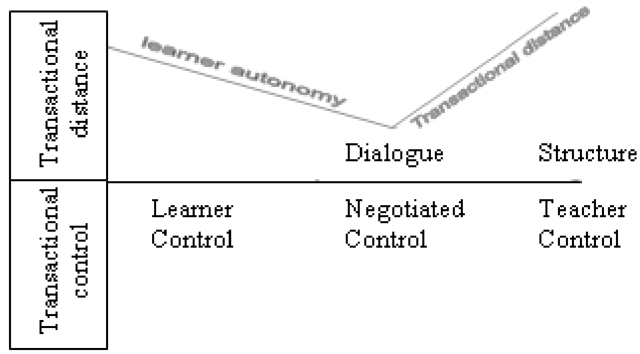


Figure 1. transactional control mapped to transactional distance

Transactional control is always on a continuum between two extremes, changing with each choice we or someone/something else makes. No matter how much a teacher may control the transaction, the learner can always choose not to pay attention, to disagree (if only internally) or perhaps to interrupt. Similarly, the learner must almost always delegate control at some level. Sometimes this may be a result of extrinsic or intrinsic constraints. More often than not, the simple fact of being a learner implies a lack of knowledge and consequently requires control to be delegated to one who possesses that knowledge and is willing to communicate it, whether directly or mediated through a book, web page or computer program.

Control occurs at a range of scales. As in nature and the development of cities, the large influence the small more than vice versa (Brand, 1997). The smaller the scale, the more constrained the choices become: each level of constraint applies further control that adds to the previous. When we reach the point of making decisions about which word to use next, or whether to read the next word in the sentence, it is barely a choice at all. Choices *are* made at this level, but the constraints overwhelm the choices most of the time. The fact that a choice is small does not necessarily reflect its consequences. If I make the small choice to continue walking when that leads me into the path of a speeding juggernaut, the effects may be significant.

A change in learning trajectory occurs when it represents a departure from the path dictated by intrinsic and extrinsic constraints. The smaller the choices become, the more there is an element of subjectivity in deciding what constitutes a change in trajectory. What may be a natural continuation for some may seem like a change of tack to another.

Most learning transactions tend towards control by either the learner or, more often, the teacher. From a learner perspective, being given control without the power to utilize it effectively is bad: learners are by definition not sufficiently knowledgeable to be able to make effective decisions about at least some aspects of their learning trajectory. On the other hand, too much teacher control will lead to poorly tailored learning experiences and the learner may experience boredom, demotivation or confusion. Dialogue is usually the best solution to the problem, enabling a constant negotiation of control so that a learner's needs are satisfied (Garrison & Baynton, 1987). Unfortunately, dialogue is expensive and becomes more so the fewer participants are involved. The ideal would be to allow the learner to choose whether and when to delegate control at any point in a learning transaction.

Social software

Social software is a relatively new and poorly defined concept. Systems such as del.icio.us, Flickr, YouTube, MySpace and Ning are unequivocally accepted as instances of the genre, and most writers are happy to accept that wikis and blogs (or at least, collections of blogs) are likewise forms of social software. So too are technological approaches such as collaborative filtering/ recommender systems, shared tagging and social navigation. Some extend the definition to include virtually any software that supports social interaction, including newsgroups, instant messaging and email (Mejias, 2005), but this stretches it beyond the point of usefulness. One useful way to distinguish social software from earlier forms of mediated communication is that, compared with, say, chat rooms, discussion forums and mailing lists, it scales very well, gaining strength from large numbers: while earlier forms of computer mediated communication tend to become overwhelmed once a certain optimum number of participants has been exceeded, social software (with some provisos) just gets better and better.

Social software is organic and self-organizing, underpinned by dynamics that parallel natural processes. It is evolutionary, replicating the successful and diminishing or killing the unsuccessful (Shirky, 1996). It is stigmergic: signs left in the environment communicate with others who leave further signs in the environment (Bonabeau, Dorigo, & Theraulaz, 1999). It has an emergent structure, formed from bottom-up control rather than top-down design.

Social software has recently become popular in online learning, but its roots in this context can be traced back to the early nineties (e.g. (Ackerman, 1994; Boder, 1992; Davis & Huttenlocher, 1995)). Collaborative filters have long been used for learning (e.g. (Dron, Mitchell, Siviter, & Boyne, 1999; Recker, Walker, & Wiley, 2000; Terveen, Hill, Amento, McDonald, & Creter, 1997)) and social navigation techniques have been applied in various educational contexts (e.g. (Brusilovsky, Chavan, & Farzan, 2004; Dron, Mitchell, Boyne, & Siviter, 2000; Kurhila, Miettinen, Nokelainen, & Tirri, 2002; Miettinen, Kurhila, Nokelainen, & Tirri, 2005; Vassileva, 2004)). Blogs and wikis, as well as other forms of social software, are becoming commonplace (e.g. (Barker, 2005; Downes, 2004; Dron, 2003; Mejias, 2005)). The tools seem, intuitively, to offer value to learners, allowing the social construction of meaning and relatively effortless collaboration in new and interesting ways. Social software presents the learner with options, implicitly or explicitly recommending links and paths as a result of the behavior of an indefinite number of others. This can range in scale from the tight, linear control of the text of a wiki to the social navigation signposts of different font sizes for tags in del.icio.us, to the vague and amorphous choices implicit in links and trackbacks between blogs or Google’s PageRank algorithm (Brin & Page, 2000). It therefore may be seen as fulfilling a teacher role of providing control over the learning trajectory. This control is not the result of a single individual’s determination of a trajectory, but is an emergent property of the interactions of the group as a whole.

Modes of interaction in e-learning

Anderson describes six modes of interaction in online learning – teacher-student, teacher-content, teacher-teacher, student-student, student-content and content-content (Anderson, 2003). In social software, the group is a first class object that has an existence in its own right, mediated through the environment just as interactions between individuals are mediated. A further four interactions are therefore significant: student-group, teacher-group, content-group and group-group.

Student-group: In a social software environment, the learner is a part of the group mind, influencing yet influenced by it. This dual role makes the notion of control very fluid.

Teacher-group: The role of the teacher in social software systems is potentially less significant than in conventional e-learning environments, despite the fact that use of such software may be initiated at a larger scale by the teacher and he or she may determine goals and outcomes, shaping the ecology in which it resides. For example, when I presented links to my own lecture notes along with other resources through a social link-sharing system they were less popular than some of the others (Dron, Mitchell, Boyne, & Siviter, 2000). Lately I have taken to providing my notes in the form of a wiki, to which students contribute and correct, sometimes because I ask them explicitly, sometimes because they spot mistakes, wish to add more depth or seek clarification. I have used blogs for several years, gaining many benefits, notably including the fact that students teach each other more than I teach them (Dron, 2003).

While the teacher may have a relatively small role in the detailed form that a social software system may take, social software can tell the teacher a great deal about the group: their preferences, their interests, their needs, their weaknesses, their strengths.

Content-group: Social software typically leads to an emergent structure that is not planned by an individual, but which emerges from the individual actions of members of the group. In turn, this affects the individual actions of its members. Thus, the content is a reification of the group's behavior, and the group's behavior is at least partially a consequence of the content.

Group-group: Open standards such as RSS and web services make the exchange of information between social software systems a simple and ubiquitous feature. It is common to link together such diverse services as Google Maps, Flickr images, blogs, del.icio.us tags and so on to create new 'mashups.' Group to group interactions make blogs into social software: an individual blog is little more than a web page with annotations/discussions attached. However, when combined through blogrolls, trackbacks, common tags and embedded feeds, the space becomes the blogosphere, rich and interconnected, with clusters, social groupings and two-way links combining to create an emergent and intricately structured community.

Social software and transactional control

Because of its emphasis on the group, social software occupies an interesting space in terms of transactional control and, consequently, transactional distance, providing both user-control and the delegation of control simultaneously. Recursively, structure arises as a result of dialogue (perhaps implicit) which in turn influences dialogue. Negotiation of control leads to a reified structure, to which control may be delegated. A dependent learner can choose to be controlled, while a more autonomous learner can take more control. Both may influence and be influenced by the structure that ensues, to whatever extent that they find comfortable.

Benefits to lifelong learners

Social software can allow learners to choose whether to control their learning or to delegate that control to the group. In principle, then, it appears to offer the best of both worlds, assisting dependent learners through the provision of structure, yet enabling autonomy at any point. It is significant that this structure does not necessarily arise through the intercession of teachers or instructional designers. In a world where continual learning is the usual state of being and a necessary condition of successful existence, yet where the cost of traditional institutional learning is high, both in money and time, this is a strong benefit. Importantly, the structure that emerges through group interaction constantly evolves and changes, adapting to the changing needs and interests of the group it serves. This brings further advantages over traditional institutional forms of learning and teaching. For a range of reasons, some related to personalities and interests, some to the inevitably viscous institutional processes, it is the norm for the subject matter of institutional learning to slip a little behind the needs of industry, especially at undergraduate level and in fast-changing practical subjects such as computing, engineering and medicine. This is not to deny the importance of research-led teaching which moves ahead of industry on many occasions, but even then, the practical benefits of such subjects are typically less immediate for most learners. Driven by the needs of the group, it is easier for content to adapt quickly to more relevant subjects.

Like many others, if I wish to know what is the latest and most important research going on in my area, I am more inclined to turn to blogs and wikis than to journals and conferences. Traditional fora lag months or even years behind the current state of the art, whereas social software may tell me what happened yesterday or even today, and to participate in its development. Scientific breakthroughs are no longer the preserve of journals and conferences. Some social journals, such as PLoS One, or the older but still innovative JIME have exploited this process, blending the benefits of rigorous peer review with the strengths of a multitude of eyes and a plenitude of brains. Breaking news is no longer the domain of the established press as the likes of Digg become more relevant and responsive than traditional media could ever be. Google is often the first port of call for those seeking understanding of an unfamiliar topic and Wikipedia is often the second. Social software dominates our online landscape, so it is very important that we should explore ways to better exploit its benefits and avoid its pitfalls. Even small improvements in the effectiveness of such environments in meeting learning needs could bring immense value to lifelong learners for whom they are an increasingly significant source of information.

The darker side of social software

There are still some significant issues to be addressed if social technologies are to fully fulfill their exciting educational promise. Notably, the structure generated through social software may not be useful or pedagogically sound. Few systems employed with educational intent take this into consideration, allowing whatever structure that emerges to guide users. The CoFIND system is an exception, explicitly using two forms of tagging, encouraging not only the tagging of resources according to topic, but also with pedagogical metadata described as 'qualities,' which are then used to supply implicit and explicit ratings that feed back through stigmergic social navigation cues.

Many of the larger social software sites have millions of users, all of whom are contributing to the overall shape of the system. While the formation of small-world clusters makes these variegated spaces, they are often too large for significant parcellation to occur – it is one large evolutionary landscape, without the small peninsulas, continents and islands that deform the natural evolutionary landscape to allow diverse species to develop. It is significant that many (perhaps most) educational uses of such software make use of smaller systems which can adapt more easily to the needs of the group. Others (CoFIND again) intentionally parcellate the landscape so that smaller niches can develop.

Crowds are only wise when the individuals of which they are comprised are unaware of the choices others make (Surowiecki, 2004). With awareness of the behavior of others, the influence of a few (usually those who make the first contributions) is disproportionately large, shaping the behaviors of those who follow. Systems such as collaborative filters that amalgamate independently collected rankings are less susceptible to these effects than those employing social navigation or simple aggregation, but even very large collaborative filters such as Google are inherently stigmergic (Gregorio, 2003). They are susceptible to the Matthew Principle, whereby the rich get richer while the poor get poorer. The most common solution to this problem in institutional learning is to use such software as part of a learning ecology, often within specific taught courses, thereby situating them in a framework that is somewhat controlled by a tutor (e.g. (Brusilovsky, Chavan, & Farzan, 2004; Miettinen, Kurhila, Nokelainen, & Tirri, 2005)). However, if such structure is being used and generated by autonomous lifelong learners and a tutor is not in control, the positive feedback loop can run out of control.

Most social software is susceptible to intentional attack, whereby a malevolent or mischievous individual or group can bend the system to its purposes. For example, until recently, a search on Google for 'miserable failure' would point to George W. Bush's biography, as a direct result of the manipulation of backlinks by many people. Google have adjusted their algorithms to inhibit such attacks, but it is likely that, unless top-down control is exercised, flaws will again be discovered and exploited. Similar issues have been observed with social software used in education (Dron, Mitchell, Boyne, & Siviter, 2000; Vassileva, 2004). Intentional behavior can affect a virtual environment much as it can in nature and, much as in nature, the virtual environment can be polluted and corrupted. This remains an issue that is poorly resolved, with most existing solutions requiring some top-down editorial control.

Ten design principles for educational social software

There are many ways that social software can fail to address the needs of learners. If it is to be successful, there are ten principles that I have identified which make success more likely (Dron, 2007). The list is no doubt incomplete, but without adherence to each of these principles it is unlikely that social software will be successful in self-organizing for the benefit of learners. These principles are highly interconnected, each feeding from or informing one or more others and two in particular (connectivity and scale) are more meta-principles than guidelines.

The principle of adaptability

The principle of adaptability requires that we must try to build small services that interoperate, that we must build to connect using open standards and, where possible, we should build as open source, so that others may adapt and evolve systems to suit local needs.

Single-purpose software is like what Stuart Brand describes as 'magazine architecture' – beautiful perhaps, fit for purpose, but ultimately disposable as needs change and technology marches on (Brand, 1997, p. 52). Systems must be built based on the assumption that they are here today and gone tomorrow, especially those that deal with the constant flux of needs that emerge in lifelong learning. This implies an architecture of small, service-based, interoperable systems, employing mashup technologies like RSS, web services, FOAF (friend of a friend), SSO (single sign-on), as well as stalwarts of the old-guard of designed learning technologies such as SCORM, IMS-LD and IEEE-LOM. A particularly promising technology is ELF (the E-Learning Framework) which specifies web services targeted at e-learning (JISC, 2004).

Open source approaches are ideally suited to adaptability as they allow changes to be made at a local level, which can fit the needs of particular groups.

Big, comprehensive commercial social software systems such as MySpace and FaceBook adhere to standards, at least to the extent that they can use and, in limited ways, share information with other sites. However, the kind of monolithic approach they embody is not to be recommended if we are to build truly adaptable systems. Such systems are the vacuum cleaners of the social world, sucking in other technologies but giving relatively little back.

The principle of evolvability

The principle of evolvability is that we must build deferred systems (Patel, 2003), systems whose structure is not fixed, systems that can change after the software designer has left the building.

Not only should the systems themselves be fluid and capable of change, the structures within the systems should be capable of change and evolution. Indeed, in a perfectly evolvable system, the rules of change themselves should be capable of evolving. This means creating systems that are not only adaptive but also adaptable. Evolution, by which I mean replication with variation combined with survival of the fittest, can be seen on most social sites. Tags in tag clouds may be seen as battling for prominence on an evolutionary landscape, with fitness decided (usually) by popularity. Wikis offer a rich evolutionary landscape where content is continually revised, deleted, refined and mutated to adapt to the needs and knowledge of the community (whose knowledge is itself revised and mutated as a result). Ideas in blogs are replicated and adapted as memes spread through trackbacks, annotated links, comments and blogrolls.

Systems that employ mashups may select between competing components, which consequently evolve at a higher level. A particularly successful and pure application of this principle is employed by Ning, where whole social applications are replicated and modified to suit changing needs and adapt to different ecological niches. Through a multi-dimensional matrix of tag clouds, these applications are red in tooth and claw as they fight for prominence in these constantly evolving ecological niches. Ning is a single site, but if it were more distributed and open, it would offer a superb model for social software design.

The principle of parcellation

The principle of parcellation requires that we must build systems in which there are distinct, ideally hierarchical ecological niches that are only weakly or occasionally connected with each other. Where possible, such niches should emerge rather than be imposed by a designer.

Ning's innovative use of tag clouds enables groups of applications to compete to some extent separately from other groups, which is very much in keeping with one of the prime drivers for evolution. Evolution works fastest on relatively small, isolated populations (it was, for example, the different species on the Galapagos Islands that inspired Darwin's theory), with changes propagated through the occasional rare event such as the formation of isthmuses through falling water levels, changing ice-cover or the chance mingling of ecosystems (Calvin, 1997; Jones, 1999). If systems become too large then innovations and changes tend to be swamped by the prevalent majority, and diversity is stifled (Gould, 1978).

The benefits of diversity and rapid adaptation brought about by parcellation are of special significance when social software is used for e-learning, improving its capacity to adapt quickly and to cater for diverse learning needs. Tags and topics/categories can help to provide some element of parcellation, but too often they simply chop up a large space into a number of equal small ones. In natural systems, there are richly connected hierarchies of parcellation: islands act as delimiters for mountains, that constrain the trees, that constrain the shrubs, that provide the boundaries for the beetles, whose guts act as defining spaces for countless bacteria and other bugs. Intermingling occurs at several different scales, but the hierarchical boundaries offer great scope for local adaptation.

In a large social site such as Digg, the parcellation provided by tags is perhaps insufficient to allow the novel or minority interests to influence the majority, so a further top-down taxonomy has been introduced to help make sense of the mass of communication and information. To some extent this is a kludge. If we are to encourage evolution, we need to build systems that are far more variegated and diverse, where small ecological niches can form within the wider learning environment and where the landscape can be shaped, not just by system designers, but by the crowd. Without this, we introduce what Dennett (Dennett, 1995) describes as a 'skyhook' – an invented intervention from outside the system which, in a social software environment, seems a superfluous piece of top-down design.

Various approaches can assist the process of bottom-up emergence of parcellated structure. Elgg, for instance, allows creators of social spaces to emphasise specific key tags to create a kind of tag aristocracy, in which some tags are more important than others. All the various kinds of metadata in CoFIND are created by end users and their combinations form intentionally clustered micro-environments, albeit with a hierarchy that is currently limited to only two or three levels.

Whether imposed from the top down, as a kind of landscape gardening, or from the bottom up, as in a jungle, parcellation can be used to good effect if we wish to encourage the development of pedagogically useful structures. Top-down creation of structural parcellating features offers opportunities to teachers to regain some of the control that is inevitably lost when using social software, while bottom-up methods allow groups of learners to achieve more control themselves.

The principle of trust

The principle of trust makes it necessary for us to build the means to reliably identify reliability in people and resources, to protect ourselves from harm and to do this without resorting to top-down constraints.

Trust in an e-learning system is central to its success. There are many aspects of trust that are significant here, including: trust that it will work, trust that it is secure, trust that the information provided is reliable, trust that one will be supported, or at least not abused. As we move away from a central model of control, where policing comes from the top down, alternatives need to be sought so as to provide the learner with the necessary security to learn. Some, such as Piczo, take a simple if draconian approach by not giving a search facility, making it difficult or impossible to discover information about others except by explicit invitation. Although the site has many other innovative features to compensate, this is clumsy and counters some of the benefits of social software. Elgg takes a far better approach: its greatest strength as a tool for education lies in its elegant and hugely flexible authorization mechanisms. Access to every object in the system, be it a file, a blog posting or even a comment may be controlled in the minutest detail by its owner. This goes a long way towards dealing with issues of intentional attack and allows trust to be given at any level that a learner feels comfortable with. Authorisation arises from the bottom up and users can exclude those that they do not trust. The social networking features built in allow inhabitants to explore each other's profiles and social networks, to discover people with similar interests, to help to identify who is and is not trustworthy. Again, every bit of information can be revealed to as small or as large a population as the learner feels comfortable with. A less sophisticated but similarly intentioned mechanism is employed in my own Dwellings system. Once again, parcellation is important as trust is often more easily maintained in relatively small communities, where individuals are known.

Because we rely on the machine to mediate on behalf of the group, it is important that we trust its mechanisms and algorithms. If the results are helpful, then this will happen naturally, but even so it would sometimes be helpful to expose the machinery to the users, to give them control over the ways that information is aggregated and displayed, to create what Kay calls 'scrutable' systems (Kay, 2006).

The principle of stigmergy

The principle of stigmergy is that we should use signs to guide, but not to constrain, and to enable mechanisms to destroy those signs when they are no longer needed or are harmful.

People are influenced by signs left in the environment, whether direct (e.g. the presence of other people) or indirect (e.g. the size of specific tags in tag clouds). In nature, this kind of effect is known as stigmergy, a word originally coined to describe the nest building behaviour of termites, where pheromones in the saliva of termites collecting and dropping balls of mud act as signals to others to drop their balls of mud, collectively leading to complex cathedral-like structures through simple local communication processes. Much of the structure that is formed through dialogue-like processes in social software makes use of such social navigation cues, including things like the ordering of results in Google, the ubiquitous tag cloud in most social software and the density of messages in forums. Stigmergy is the primary means by which the group-mind is both revealed and formed. But stigmergy is a two-edged sword which, out of control, can fall prey to the Matthew Principle, whereby the rich get richer while the poor get poorer. This leads to runaway positive feedback loops like bank runs and devastating swarming behaviour. It is therefore vital to ensure that evolutionary or other feedback mechanisms (such as link fading, or other variations on pheromone evaporation) are in place that will prevent such out-of-control behaviour. Parcellation is again helpful here as it can limit the scope for damage caused by the Matthew Principle.

The principle of context

The principle of context is that, when building social software systems, we must consider the entire virtual ecosystem in which they reside and remember that they are only a part of a much greater whole.

If a system is not used with the intent to learn or assist learning, then the odds are that it will evolve into something different. It also exists in an environment which contains many other tools, social structures and hierarchies, and conflicting demands. If social software is not fit for its purpose, alternatives will be found – the continuing overwhelming popularity of email in the face of competing technologies is a testament to this (Anderson, 2006).

Context can also constrain. If the surrounding structures dictate an ethos of top-down control (notably in institutional learning) then the conflicting demands of teacher-imposed instruction and group-led direction may lead to a distorted, two-headed monster that gets consumed in its struggle to find a direction. A tutor who wishes to maintain control will be lost and confused in an environment which is controlled by the crowd.

The principle of constraint

The principle of constraint requires us to be aware of the constraints that we build into our systems and to use them to enhance learning, much as an architect influences use of a building through the placement of walls, windows and doors.

The degree to which system designers and administrators exert control over the system largely dictates whether its form will be determined by the group or by the designer. Sometimes this will be determined by context: blogs used in the service of traditional instruction will be very different from those that record a learning journey undertaken by an individual with personal motivations, for instance.

Decisions taken by system designers, on the other hand, profoundly affect the potential forms that may arise. At a coarse but far from trivial level of affordance, for example, if a system provides a facility for uploading images easily, the system will have more pictures one that does not. Affordances can also affect form and socialization. For instance, a system that allows personalization will lead to very different sense of ownership than one that does not. Interaction design plays a major role here: for instance, an always-on instant messenger will encourage different patterns of use compared with one that can only be reached through several intentional clicks through submenus. The inevitability of constraint should be capitalized upon, to encourage structures to evolve that are pedagogically useful. For example, CoFIND's use of qualities (pedagogic metadata) helps to bring focus on educational goals, while Elgg's fine-grained bottom-up user-controlled authorisation mechanism helps to build the trust needed in a learning community. Even when using a system that does not offer such features, it is possible for a designer to provide constraint by pre-seeding the system with content, tags and other metadata – this technique has been used by WikiProfessional, for example, which attempts to overcome concerns about reliability by starting with a large, reliable database culled from peer-reviewed sources. This uses the natural structural scaling where precedence, whether by design or as an accident of history, acts as a controlling influence on what follows.

The principle of sociability

The principle of sociability is that attention must be paid to the total system's capacity to enable social presence and communication and that, where possible, this should be embedded throughout.

Features of the software that enable communication and which encourage a sense of social presence are essential glue to hold together the structures that form, to negotiate subtleties of meaning, so socially construct knowledge. The group is an unintelligent beast despite being created out of intelligent agents, and the system must support direct interaction between people if they are to learn effectively. Comments on blogs and other shared resources, discussion forums, wiki discussion areas and so on can provide the fine-grained communication that individuals need to learn, diminishing the psychological gulf that transactional distance implies. Having said that, it is also important to remember that the environment is not simply a piece of software: for most of us, email is a click or even a mouse gesture away, and there are many alternative communication technologies available. This takes us back to the principle of adaptability: it is better to build small systems that slot together and interoperate than monoliths that attempt to be everything to every person.

The principle of connectivity

The principle of connectivity is that nothing should exist in isolation, everything should influence everything else, much as the beat of a butterfly's wing might affect the weather in another part of the world.

An over-riding principle that relates to most of the other principles is that of making connections: social software is entirely built upon connections between people, systems and subsystems. In particular, this means that an effective design for social software implies that a change anywhere in the system may have an impact, whether microscopically small, large, or anywhere in between, on anything and everything else in the system. Because structure is determined by behaviour, therefore all behaviour should have an effect. This is the primary reason that social software systems may only be influenced, not controlled. If there are parts of the system that do not have such connections, it may be a sign of top-down design intruding. This is not necessarily a problem as such (control may be what is sought), but should be viewed with suspicion by the designer if it arises unintentionally.

The principle of scale

The principle of scale is that we must be aware of the large and the small in our social systems, and ensure that, where possible, the large should arise out of the small in an endless iterative cycle of renewal.

The other central principle the underpins all the rest is the importance of scale. Whether thinking of hierarchical parcellation, degrees of constraint, the context in which the system resides or the overall design, the influence of the big and slow over the small and fast provides one of the key structural features that makes social software work, or fail. Scale effects often rely on an even higher-level structural feature of *priority*: one of the main reasons that the large influences the small is that it provides the context in which the small exists. By definition, therefore, the large exists prior to the small. On the other hand, while the small and fast seldom have much influence as individual system elements, the combined effects of many small elements can be vast: locust swarms and mob behaviour are obvious examples, but equally the spread of memes in a population or even simple stigmergic effects such as termite mounds or ant trails can bring about significant structural change to the environment. Social software capitalizes on this effect to bring about changes to large scale structures as a result of small-scale interactions, which in turn affect the small-scale interactions in a constant iterative cycle of growth and dynamic change.

Conclusions

Social software in e-learning offers great potential pedagogic and practical benefits, both through the amplification and creation of social ties, and through allowing learners to choose to choose whether they to control or be controlled in a learning transaction. This accounts to some extent for the enormous popularity of social systems like Google and Wikipedia which may fast be becoming the dominant learning tools of this first decade of the twenty-first century.

Perhaps this should be re-christened *g-learning* (for group-learning or Google-learning). It is, however, important that we understand the dynamics of social software and are aware of its potential weaknesses. A self-organizing environment is not necessarily an effective *learning* environment. Out of control, the wisdom of crowds can too easily become the stupidity of mobs, or be hijacked by those with other agendas. The ongoing challenge for developers and users of social software in e-learning is therefore to build systems and processes in which the structures that develop are capable of being pedagogically sound and supportive of learning communities. The ten principles described in this paper offer a starting point for discussion and experimentation, but they are undoubtedly a stepping stone towards a more refined, richer understanding of ways that environments may be built that encourage learning to occur, not through the intentional acts of individuals, but through the combined intelligence of the group.

A far fuller discussion of the issues and ideas discussed in this paper may be found in (Dron, 2007).

Websites and systems discussed in this paper

CoFIND: http://www.cofind.net
Del.icio.us: http://del.icio.us
Digg: http://www.digg.com
Dwellings: http://dwellings.cofind.net
Elgg: http://elgg.net
Facebook: http://www.facebook.com
Flickr: http://www.flickr.com
Google: http://www.google.com
JIME: http://www-jime.open.ac.uk/
MySpace: http://www.myspace.com
Ning: http://www.ning.com
Piczo: http://piczo.com
PLoS One: http://www.plosone.org/home.action
Slashdot: http://Slashdot.org
Wikipedia: http://www.wikipedia.org
WikiProfessional: http://www.wikiprofessional.info
YouTube: http://www.youtube.com

References

Ackerman, M. S. (1994). *Answer Garden: A Tool for Growing Organizational Memory.* Unpublished PhD, Massachussetts Institute of Technology.

Allen, C. (2004). Tracing the evolution of social software, Retrieved June 7, 2007, from, http://www.lifewithalacrity.com/2004/10/tracing_the_evo.html.

Anderson, T. (2003). Modes of interaction in distance education: Recent developments and research questions. In M. G. Moore & W. G. Anderson (Eds.), *Handbook of Distance Education* (pp. 129-146). New Jersey: Lawrence Erlbaum Associates.

Anderson, T. (2006). Social Software Applications in Formal Online Education. *Paper presented at the The 6th IEEE International Conference on Advanced Learning Technologies*, July 5-7, 2006, Kerkrade, The Netherlands.

Barker, P. (2005). *Potential Uses for Weblogs in Electronic Course Delivery.* Paper presented at the E-Learn 2005, October 24-28, 2005, Vancouver, Canada.

Boder, A. (1992). The process of knowledge reification in human-human interaction. *Journal of Computer Assisted Learning, 8*, 177-185.

Bonabeau, E., Dorigo, M., & Theraulaz, G. (1999). *Swarm Intelligence: From Natural to Artificial Systems*, New York: Oxford University Press.

Brand, S. (1997). *How buildings learn*, London: Phoenix Illustrated.

Brin, S., & Page, L. (2000). The Anatomy of a Large-Scale Hypertextual Web Search Engine. Retrieved June 7, 2007, from, http://www-db.stanford.edu/pub/papers/google.pdf.

Brockett, R. G., & Hiemstra, R. (1991). A conceptual framework for understanding self-direction in adult learning. In R. G. Brockett & R. Hiemstra (Eds.), *Self-Direction in Adult Learning: Perspectives on Theory, Research, and Practice,* New York & London: Routledge, Retrieved June 7, 2007, from, http://home.twcny.rr.com/hiemstra/sdilch2.html.

Brusilovsky, P., Chavan, G., & Farzan, R. (2004). Social Adaptive Navigation Support for Open Corpus Electronic Textbooks. *Paper presented at the AH 2004*, August 23-26, Eindhoven, The Netherlands.

Calvin, W. H. (1997). The Six Essentials? Minimal Requirements for the Darwinian Bootstrapping of Quality. *Journal of Memetics, 1*, Retrieved June 7, 2007, from, http://williamcalvin.com/1990s/1997JMemetics.htm.

Candy, P. C. (1991). *Self-direction for Lifelong Learning: A comprehensive Guide to Theory and Practice*, San Francisco: Jossey Bass.

Chen, Y.-J. (2000). Transactional Distance in World Wide Web Learning Environments. *Innovations in Education and Teaching International, 38*(2), 327-338.

Davis, J. R., & Huttenlocher, D. P. (1995). Shared Annotation for Cooperative Learning. *Paper presented at the International Conference on Computer Support for Collaborative Learning*, October 17-20, 1995, Bloomington, IN, USA.

Dennett, D. (1995). *Darwin's Dangerous Idea*, Harmondsworth: Penguin.

Downes, S. (2004). Educational Blogging. *Educause Review, 39*(5), 14-26.

Dron, J. (2003). The Blog and the Borg: a Collective Approach to E-Learning. *Paper presented at the E-Learn 2003*, November 7-11, 2003, Phoenix, Arizona.

Dron, J. (2006). The Teacher, the Learner and the Collective Mind. *AI & Society, 21* (1-2), 200-216.

Dron, J. (2007). *Control and Constraint in E-Learning: Choosing When to Choose*, Hershey, PA: Idea Group.

Dron, J., Mitchell, R., Boyne, C., & Siviter, P. (2000). CoFIND: steps towards a self-organising learning environment. *Paper presented at the WebNet 2000*, October 30-November 4, 2000, San Antonio, Texas, USA.

Dron, J., Mitchell, R., Siviter, P., & Boyne, C. (1999). CoFIND- an experiment in n-dimensional collaborative filtering. *Paper presented at the WebNet 99*, October 24-30, 1999, Honolulu, Hawaii.

Dron, J., Seidel, C., & Litten, G. (2004). Transactional distance in a blended learning environment. *ALT-J, 12*(2), 163-174.

Garrison, D. R. (2000). Theoretical Challenges for Distance Education in the 21st Century: A Shift from Structural to Transactional Issues. *International Review of Research in Open and Distance Learning, 1*(1), Retrieved June 7, 2007, from, http://www.irrodl.org/index.php/irrodl/article/viewFile/2/22.

Garrison, D. R., & Baynton, M. (1987). Beyond Independence in Distance Education: The Concept of Control. *American Journal of Distance Education, 1*(3), 3-15.

Gorsky, P., & Caspi, A. (2005). A Critical Analysis of Transactional Distance Theory. *The Quarterly Review of Distance Education, 6*(1), 1-11.

Gould, S. J. (1978). *Ever Since Darwin- Reflections in Natural History*. Burnett.

Gregorio, J. (2003). Stigmergy and the World-Wide Web. Retrieved June 7, 2007, from, http://bitworking.org/news/Stigmergy/.

JISC. (2004). *The e-Learning Framework (ELF)– Summary*, Retrieved June 7, 2007, from, http://www.jisc.ac.uk/uploaded_documents/elf-summary7-04.doc.

Jones, S. (1999). *Almost Like a Whale*, London: Doubleday.

Kay, J. (2006). Scrutable Adaptation: Because We Can and Must. *Paper presented at the AH 2006*, June 21-23, 2006, Dublin, Ireland.

Kurhila, J., Miettinen, M., Nokelainen, P., & Tirri, H. (2002). Use of Social Navigation Features in Collaborative E-Learning. *Paper presented at the E-Learn 2002*, October 15-18, 2002, Montreal, Canada.

Lowe, W. (2000). Transactional distance theory as a foundation for developing innovative and reactive instruction. *Educational Technology & Society, 3*(1), 1-3.

Mejias, U. A. (2005). A Nomad's Guide to Learning and Social Software. *The Knowledge Tree*, Retrieved June 7, 2007, from, http://knowledgetree.flexiblelearning.net.au/edition07/html/la_mejias.html.

Miettinen, M., Kurhila, J., Nokelainen, P., & Tirri, H. (2005). OurWeb - Transparent groupware for online communities. *Paper presented at the Web Based Communities 2005*, February 23-25, 2005, Algarve, Portugal.

Moore, M. G. (1986). Self-Directed Learning and Distance Education. *Journal of Distance Education, 1*, Retrieved June 7, 2007, from http://cade.athabascau.ca/vol1.1/moore.html.

Patel, N. (2003). Deferred System's Design: Countering the Primacy of Reflective IS Development With Action-Based Information Systems. In N. Patel (Ed.), *Adaptive Evolutionary Information Systems* (pp. 1-29). London: Idea Group Publishing.

Recker, M. M., Walker, A., & Wiley, D. A. (2000). An interface for collaborative filtering of educational resources. *Paper presented at the 2000 International Conference on Artificial Intelligence*, June 26-29, 2000, Las Vegas, USA.

Saba, F., & Shearer, R. L. (1994). Verifying key theoretical concepts in a dynamic model of distance education. *The American Journal of Distance Education, 8*(1), 36-59.

Shirky, C. (1996). In Praise of Evolvable Systems. *ACM Net_Worker*, Retrieved June 7, 2007, from, http://www.shirky.com/writings/evolve.html.

Stein, D. S., Wanstreet, C. E., Calvin, J., Overtoom, C., & Wheaton, J. E. (2005). Bridging the Transactional Distance Gap in Online Learning Environments. *American Journal of Distance Education, 19*(2), 105-119.

Surowiecki, J. (2004). *The Wisdom of Crowds*, London: Little, Brown.

Terveen, L., Hill, W., Amento, B., McDonald, D., & Creter, J. (1997). PHOAKS: A System for Sharing Recommendations. *Communications of the ACM, 40*(3), 59-62.

Vassileva, J. (2004). Harnessing P2P Power in the Classroom. *Paper presented at the ITS 2004*, August 30-September 3, 2004, Maceio, Brazil.

Klamma, R., Chatti, M. A., Duval, E., Hummel, H., Hvannberg, E. H., Kravcik, M., Law, E., Naeve, A., & Scott, P. (2007). Social Software for Life-long Learning. *Educational Technology & Society*, 10 (3), 72-83.

Social Software for Life-long Learning

Ralf Klamma[*], Mohamed Amine Chatti, Erik Duval, Hans Hummel, Ebba Thora Hvannberg, Milos Kravcik, Effie Law, Ambjörn Naeve and Peter Scott
[*]Informatik V, RWTH Aachen, Aachen, Germany // klamma@informatik.rwth-aachen.de
PROLEARN Network of Excellence

ABSTRACT

Life-long learning is a key issue for our knowledge society. With social software systems new heterogeneous kinds of technology enhanced informal learning are now available to the life-long learner. Learners outside of learning institutions now have access to powerful social communities of experts and peers who are together forging a new web 2.0. This paper reviews current work in pan-European initiatives that impact upon life-long learning via views of professional learning, learner competence and social networking. It seeks to provide an overview of some of the critical research questions for the interdisciplinary field of social software research.

Keywords

Social Software, Life-long Learning, Learning Networks, Blogs

Introduction

Life-long learning (Aspin & Chapman, 2000) refers to a society in which learning possibilities exist for those who want to learn (Fischer, 2001). Learning is not restricted to the classroom and to formal learning inside learning institutions, it an activity which happens throughout life, at work, play and home. In the modern knowledge-intensive era, life-long competence development has become a major challenge to our educational systems that have not changed their educational policies and pedagogical models to support life-long learning. There is an increasing demand for new approaches towards fostering life-long learning perspectives. Emergent Web 2.0 concepts and technologies are opening new doors for more effective learning and have the potential to support life-long competence development. For life-long learners the first generation Internet allowed easy access to a vast range of published materials. The second generation Internet allows them to contribute to it. This ability for new life-long learning communities to participate and create the new web has lead to a whole generation of new 'socially based' tools and systems that are generically referred to as social software. Social software can be broadly defined as tools and environments that support activities in digital social networks (Klamma et al., 2006; Chatti et al., 2006a). Digital social networks are social networks mainly realised by means of computer-mediated communication (Licklider et al., 1968). Most social software research (Wellman et al., 2002; Shirky, 2003) concentrates on the relations between social entities in digital social networks and their interaction, while community information systems contain and group social entities.

For the life-long learner who is learning at work or at home, outside the context of a formal institutional learning programme, the initial problem of access to powerful learning materials has been significantly improved by the world-wide-web. This first generation Internet has allowed institutions to publish materials with ease and made them accessible to all learners. However, until relatively recently the critical difference between those inside learning institutions and those outside was in the access to a ready-made learning community of experts and peers. Recent - so called second generation Internet - developments have started to change that dynamic. Within Web 2.0, whole new communities of self-directed, self-managed and self-maintained communities have started to arise that offer compelling new forms of community. These new communities are typically open to all learners, at any point in their life of learning.

Table 1 illustrates five of the key differences between traditional Web 1.0 and new Web 2.0 (O'Reilly, 2005) knowledge management concepts for life-long learners.

In a Web 2.0 vision, the web is created by those who participate in it. The most obvious contrast is between sites which are published by institutions, such as Britannica online, and those which are maintained by an open community, such as Wikipedia. Projects like Wikipedia let life-long learners become knowledge prosumers (both consumer and producer) and participation becomes essential for wikis replacing old-fashioned content management systems in organizations. Interoperability between content and services is realized by syndications tools (RSS). More and more web sites support RSS instead of placing a button labeled with "Set this page to your home page". It has become natural and a kind of fashion to integrate or 'mesh' third-party *web services* like google, yahoo and del.icio.us etc. Web services and syndication will be even more important in ubiquitous contexts when users need support based on their location, their connectivity, their device capabilities and their usage context.

Table 1: Differences between Web 1.0 and Web 2.0 (adapted from (O'Reilly, 2005)).

Web 1.0	Web 2.0
publishing (Britannica Online)	participation (Wikipedia)
personal websites	blogging
content management	wikis
directories (taxonomy)	tagging (folksonomy)
stickiness	syndication

An important theme in life-long learning, discussed in the projects below, is the nature of "informal and non-formal learning". Once you step beyond traditional institutional boundaries you can find learning which is driven by and for, "you, the learner". If the simplest social networking technology is blogging (Bausch et al., 2002; Blood, 2004), then the concept of 'blogging for business' has migrated out into Web 2.0 to allow significant access to new pools of experts whose views and ideas are now widely and openly available. We discuss blogs here as an example of a class of software often used in organizations nowadays, e.g. corporate wikis, social bookmarks, and RSS web feeds (Kumar et al., 2004). The term 'Blog' is a contraction of 'Weblog' and the act of 'Blogging' is the making of such logs (see for example: (www.blogger.com). Some businesses are coming to understand that 'real' news isn't just a ticker-tape-like news feed from Reuters or the BBC. In business, the most significant news is what you and those you have reason to care about, did yesterday, are doing today, and plan to do tomorrow.

Essentially, blogging tools and portals have become a significant focus for a trendy vision of community publishing outside institutional boundaries. They allow users to quickly generate simple web pages and link to others, directly from within a public web page. In their simplest form they are used as stream-of-consciousness public web diaries or activity logs, hence 'weblogs'. They don't require expertise to use, they capture and share text easily and can even be extended to include images, sounds and movies. Members of your community can "subscribe" to blogs and upload comments to them – and even vote on the significance of the entries. In this way, this simple and yet pervasive set of tools has formed a large number of significant public "communities of practice" (Wenger 1998) around the bottom-up drive of community members.

Empirical Studies on Blog Uses in Online Learning Networks

In this section we delineate two empirical studies about blog uses in online learning networks of two different contexts, namely corporate and in higher education. The former addresses the incentive mechanism underlying blog usage of corporate learners and is part of the project **Learning Network for Learning Design** (LN4LD), whereas the latter analyzes how blogs have been deployed by university students and is part of the project **iCamp** (http://www.icamp-project.org).

One of the major features of blog is the "reputation management" of participants. Indeed, we have recently seen the emergence of so called "Ghost Blogging" services for companies who want more professional marketing and support of their blogging output. Blogs can show participants' daily engagement with key issues. Participants can gain significant reputation in their community by "being seen" publicly creating valuable artefacts that is of use to new members of their group. The individual satisfaction and perception of effectiveness in that sense is closely related to the commitment of the individual to contribute and actively participate.

We perceive adaptivity and personalization as key issues for implementing mechanisms to foster and increase activities in lifelong learning networks. Currently an integrated approach that allows rewarding and incentive mechanisms on different levels of sharing and exchanges is researched in the **TENCompetence** project. A main critical point in building social software that is actually used and in developing communities that become active learning networks (Koper et al., 2005) is the engagement in the sense of active participation and contribution of the individuals.

Today's life-long learners are in constant need to update knowledge and competences, given certain personal or employment-related motives (Aspin & Chapman, 2000; Field, 2001). Online, distributed life-long facilities can be designed that cater for these needs at various levels of competence development. However, merely introducing such facilities will not suffice. Potential learners should also be motivated to actually use and actively contribute (Fisher & Ostwald, 2002). So called 'free-riding' or lurking' is considered to be one of the main problems in online learning. To some, the encouragement of employees to contribute knowledge is even more important than the more technical (interoperability) issues related to its capture, storage and dissemination (Boisot & Griffiths, 1999). What might then motivate an individual to participate actively in a learning network, to respond to others' questions, to contribute content, complete activities, carry out assessments?

Experimentation with incentive mechanisms was heavily inspired by Social Exchange Theory, which informs us that participants will contribute more when there is some kind of intrinsic or extrinsic motive (or reward) involved. This theory (Thibaut & Kelly, 1959; Constant, Kiesler & Sproull, 1994) comes from the rational choice theory of economics, suggesting a relation between a person's satisfaction with a relation (i.e., with the learning network) and a person's commitment to that relation (i.e., his willingness to actively participate). It furthermore suggests four main mechanisms to motivate and encourage participation: (i) *personal access*, or anticipated reciprocity: learner has a pre-existing expectation that he will receive actionable and useful (extra) information in return; (ii) *personal reputation*: learner feels he can improve his visibility and influence to others in the network, e.g. leading to more work or status in the future; (iii) *social altruism*: learner perceives the efficacy of the LN in sharing knowledge as a 'public good', especially when contributions are seen as important, relevant, and related to outcomes; (iv) *tangible rewards*: learners negotiate to get some kind of more tangible asset (financial reward, bond, book, etc) in return. In each of the above cases, incentive mechanisms for knowledge sharing should match the spirit of what has to be achieved (Sawyer, Eschenfelder, & Hexkman, 2000). If this is finding and exchanging information about LD, research suggests that incentives to gain extra personal access to more information about LD can be expected to render best results.

When examining critical facilities for (active) participation, some exemplary studies have been carried out within a learning network about IMS-Learning Design (IMS-LD, 2003), called LN4LD. From initial implementations of this learning network, it could be concluded (Hummel et al., 2005a) that usability, simple structure, and clear policies are necessary requirements to enable participation. More specifically, we found that users should not be overburdened by complex structures and too many facilities. We also concluded that additional policies would be needed for effective exchange and active contributions. From later implementations it could be concluded (Burgos, 2006) that interlacing virtual activities with additional face-to-face meetings on the same topics yielded substantial increases in both activity level and amount of users registering. However, in this paper we would like to focus on the significant increase of active participation when introducing *incentive mechanisms* (Hummel *et al*., 2005b).

The incentive mechanism we introduced to LN4LD allowed the participants, who were interested professionals who wanted to learn more about IMS-LD for modelling / designing courses to earn points for contributions, with the reward scheme including both quantitative and qualitative components. On the quantitative side, points could be earned for: (i) forum postings (20 points for each, labelled 'pointsforpost'); (ii) replying to posts (10 points for each, labelled 'pointsforreply'); and (iii) rating of posts (3 points for each, labelled 'pointsforrate') (see Table 2). With respect to the quality of postings, contributors received additional points for: (iv) each time their contribution prompted a reply (5 points for each reply to a post, labelled 'pointsforreplyrec'); and (v) each time the originator's posting was rated (3 points * rating value, labelled 'pointsforraterec'), whereby the ratings ranged from 1 (very poor) to 5 (very good). A simple interrupted time series with removal design (Robson, 2003) was applied with (active and passive) participation as the independent variable.

Table 2 shows that most active participation points were earned by making postings to forums (320 points in total, with 220 of these being in period B). Over time, the total amount of active participation points was divided as follows: 117 points in period A; 566 points in period B; and 141 points in period C. The average total points for active participation earned by active participants (n = 17) is 48.47 and by all participants (n = 125) it is 6.6. The repeated measures ANOVA, using time of measurement as a within-subjects factor, reveals that 'period' indeed is a very significant factor in explaining the average total amount of points ($F(2, 122) = 14.17$, $MSE = 24{,}966.08$, $p < .001$, $\eta p2 = .104$), even with the majority of participants not actively contributing. When we include 'scoring' (either 'those who did not score' or 'those who did score') as a between-subjects factor, (period * scoring) appears to be an even more significant factor ($F(2, 122) = 31.21$, $MSE = 24{,}966.08$, $p < .001$, $\eta p2 = .204$) in the linear model. It was observed that there was significant increase of both active and passive participation after introducing the incentive mechanism. Besides, choice for extra personal access as incentive mechanism was observed to be in line with the general purpose of the LN (i.e. getting more information), according to Social Exchange Theory.

Table 2: Total active participation points for each period (A-C) and parameter, for all participants (n=125).

Period	Total points	Points forpost	Points forreply	Points forrate	Points forreplyrec	Points forraterec
A.	117	60	20	3	10	24
B.	566	220	120	42	100	84
C.	141	40	30	12	35	24
A-C.	824	320	170	57	145	132

A, B and C were arranged chronologically as three equal periods of 4 weeks each
(A = baseline, B = introducing the incentive mechanism, C = removing the incentive mechanism)

Educational researchers and practitioners have invested efforts in integrating social software such as weblog into higher education. One of such initiatives is the iCamp project. Pedagogically iCamp is grounded in social-constructivist theories. Technologically it is built upon a selected set of prevailing non-proprietary technology-enhanced learning tools by rendering them interoperable. Validation of pedagogical models and technological solutions is realized through user trials. In the first trial (Oct – Dec 2006), four academic institutions from Turkey, Poland, Estonia and Lithuania were involved. There were 3 types of core actors: (i) Facilitators: four university teachers; (ii) Site Coordinators: three researchers providing support to facilitators; (iii) Students: 36 under- and post-graduates majoring in social sciences or software engineering divided into groups of four or five to develop a questionnaire. This first trial was primarily exploratory to understand how the facilitators and students interact and communicate in the online learning environment with the support of social software.

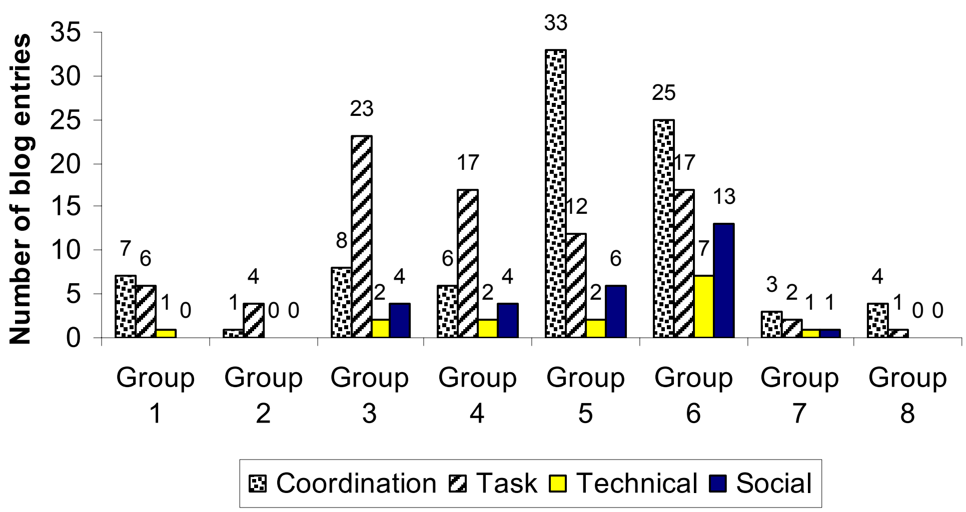


Figure 1: Distribution of content types in student group blogs

Mixed-method evaluation approach triangulating quantitative and qualitative data has been adopted. However, in such a distributed context with heterogeneous users who were basically allowed to use any of the above mentioned tools at any time in any way, it was challenging to capture real-time usage data for assessing usability and user experience. As no automatic data logging facility was installed for this trial, we relied on retrospective self-reporting techniques, i.e., structured surveys and semi-structured interviews, which have some apparent drawbacks – subjective, prone to memory reconstruction and to dilution by other extraneous data, social desirability, and missing critical incidents. Specifically, the contents of the eight student group blogs have been analyzed based on the adapted scheme of Henri (1992). Figure 1 displays the results. The average number of entries per student group-blog was 26.5 (SD = 22.5, range = 5 to 62). Note, however, the number of entries could not truly reflect the activeness of a group, which might prefer other means of communication (e.g. emails). Furthermore, four major types of entries are identified: Coordination (e.g. finding a right date for videoconference), Technical (e.g. selection of an appropriate tool), Task (e.g. ideas how to design the questionnaire), and Social (e.g. sharing cultural-specific information). It is observed that blogs have primarily been used for Coordination in most of the group.

Nevertheless, the overall collaborative experiences of the trial participants were positive, and they could also advance their competencies. There were some negative experiences related to the tools whose learnability nevertheless seemed high as the users could overcome the initial difficulty with some help and practice. Besides, most users intended to deploy this set of social software in a similar learning setting in the future. One implication for the evaluation approach is to automate data capturing; insights can be drawn from the techniques of remote usability evaluation (Paternó & Santoro, in press). The challenge of assessing the usability of social software remains high; especially we evaluate not only user interface but users interface.

Facets of Research in Online Learning Networks

Automated Metadata Generation

Social software techniques enable richer capturing of context in which content has been produced. This offers substantial potential for automating the generation of metadata (“descriptions”), e.g. by reusing metadata from artefacts produced by “close neighbours” in the social network). This sort of mining of social information can enhance the **Automated Metadata Generation** framework (Cardinaels et al., 2005). Similarly, social software based context capturing offers great potential to create advanced tools and services for dealing with the need for content. A rather simple example is to augment user queries with metadata that constrain results to those that are relevant to the context at hand (e.g. in a language that the user has demonstrated to master). A more advanced example is to alert users to relevant content, even before they are aware that it may help them in the task at hand (e.g. because the actions of their peers and colleagues have indicated that this content is relevant in this situation).

The **MACE** project (http://www.mace-project.eu) aims at making several existing learning repositories on architecture interoperable to reach a critical mass of learning resources. The plan is to qualitatively and quantitatively enrich available contents with various types of metadata – domain, usage, competence, contextual, and social. More users will generate extended usage or attention metadata that will significantly enrich the metadata created by authors and annotators. This new metadata will provide the basis for deployment of social recommendation techniques that rely on information about learner success. Attention metadata provide valuable feedback for the authors and tutors, enabling them to further improve their learning materials and experiences (Najjar et al., 2005).

Personalization and Adaptation

A **PROLEARN** (http://www.prolearn-project.org) survey has shown that a high majority of respondents considers personalization and adaptation of learning as important and crucial factors. The main reasons for positive responses are that learning should be individualized to become more effective and efficient, personalization is the key element of the learning process, and specific problems need specific solutions, as students differ greatly in their background and capabilities especially in the field of computers. Learning materials are typically too general to cover a very wide range of purposes, so personalization can be the most important added value that e-learning can offer compared to classical learning – to optimise education, to adjust to various working conditions and needs, because students (academic and corporate) have different goals, interests, motivation levels, learning skills and endurance.

So it is generally recognized that effective and efficient learning need to be individualized – personalized and adapted to the learner's preferences, acquired competences, and evolving knowledge, as well as to the current context. Adaptive learning systems keep the information about the user in the learner model and based on it they provide certain adaptation effects. Based on the information about the learner and the current context an appropriate educational method should be chosen, which uses suitable learning activities that reference proper learning materials. This process is usually accompanied by selection of adequate tutors and co-learners. The outlined reasoning is typically based on a rich set of metadata assigned to the mentioned entities on one hand and on sound pedagogical strategies on the other. To generate the metadata and to support collaborative learning social software can play a crucial role.

In the **WINDS** project (Kravcik et al., 2004a) the consortium partners have implemented the **ALE** system, which integrates the functionality of a complex e-learning system with adaptive educational hypermedia on the Web. Several social software factors can be recognized there, especially support for conversational interaction between individuals, social feedback, as well as shifting the role of the individual from information consumer to producer. Based on the learner model, adaptive annotation and recommendation was provided. Users could assign to each learning object private or public annotations and discussions. These features enable communication between learners and tutors, and they give valuable feedback to the authors as well. The WINDS experience (Kravcik & Specht 2005) shows that teachers, even without programming skills, can create web-based adaptive courses and students can benefit from the usage of these courses. Students and teachers appreciate in the web environment what they cannot find in traditional classroom settings.

Later on the ALE platform was enhanced with services supporting mobile learning in the **RAFT** project (Kravcik et al., 2004b). The idea was to make field trips available for remote participants. Communication and data channels were established between the field and the classroom to let people on both sides not only communicate with each other but also collect, annotate, and exchange data between them. The experiment has shown that school pupils can easily understand the principles of the RAFT mobile applications and that they are able to create rich and well organized reports of field trips.

To simultaneously consider a multitude of different factors when delivering personalized learning experience is still a challenge, as an orchestration of different kinds of knowledge (concerning domain, user, context, learning activity, and adaptation) needs to be taken into account. The technological and conceptual differences between heterogeneous resources and services can be bridged either by means of standards or via approaches based on the Semantic Web. Existing standards are not enough to realize general interoperability in this area, and therefore a Semantic Web-based approach is needed to achieve reasonable results and to contribute to harmonization of available standards (Aroyo et al., 2006).

Conceptual Blogging and Distributed Opinion Publication

A major impact of the Internet has been to promote asynchronous access to online information, with traditional (client/server-based) forms of broadcasting gradually giving way to different (p2p-based) forms of "narrowcasting", such as web-casting or video blogging (vlogging). More recently, a major impact of the Semantic Web stems from the fact that its metadata has acquired the potential to become as distributed as the data it describes – with everyone being able to connect any (online) thing to any other (online) thing. This makes it possible to progress from today's opinion *registration* (opinion polls) systems to opinion *publication systems*, where the "opinionators" themselves, are in control of the exposure of their own opinions.

A **Knowledge Manifold** (KM) consists of a number of linked information landscapes (contexts), where one can navigate, search for, annotate and present all kinds of electronically stored information (Naeve, 2001a). It is constructed by conceptual modelling of a specific knowledge domain in order to capture its underlying thought patterns (mental models) in the form of *context maps*. The KMR group (kmr.nada.kth.se) makes use of this architecture in order to construct a kind of Conceptual ("human-semantic") Web (Naeve 2005), which functions as a conceptual interface to the underlying (machine)-semantic Web. This Conceptual Web can be seen as a collaborative

Garden of Knowledge - with a community of *Knowledge Gardeners*, collectively gardening their interlinked *Knowledge Patches* (Naeve, 2001a).

A **Concept Browser** (Naeve 2001b) is a constructor, an editor and a navigator of a KM. It is a knowledge management tool for collaborative overview-creation, which supports the construction, navigation, annotation and presentation of electronically stored information. A Concept Browser presents "content in contexts through concepts" and makes it possible to investigate the content of different concepts without losing overview of their context. Semantically, a concept is considered as the border between its *inside* (which contains its *content*) and its *outsides*, which represent the different *contexts* where this concept appears.

Conzilla (www.conzilla.org) (Palmér & Naeve 2005) is a Concept Browser, which aims to provide an effective collaboration environment for knowledge management on the Semantic Web. Through the Collaborilla collaboration service, Conzilla can be used for "distributed conceptual blogging", where context-maps are constructed collaboratively in different containers, with each participant in control of which containers to view and publish. This approach makes it possible to reuse and extend concepts and concept-relations published by others, and to add content and comments (metadata) to concepts, concept-relations and context-maps published by others. Hence it becomes possible to perform *bottom-up agreement- and disagreement management* in the form of *conceptual calibration* (Naeve 2005).

Confolio (www.confolio.org) is a semantic web based electronic portfolio system (Naeve et al., 2005). It is based on the infrastructure Edutella (Nejdl et al., 2002) and the frameworks SCAM and SHAME (Palmér et al., 2004), and treats metadata in a way that is consistent with the multi-purpose, subjective view on metadata introduced in (Nilsson et al., 2002). The Confolio system contains a distributed *opinion publication network*, where each portfolio owner can publish opinions on anything that has a publicly retrievable URI (Universal Resource Identifier). Such opinions are directly visible on their "annotation target", while at the same time being controlled by the "opionionator" (annotator) and stored in her own Confolio. This has powerful implications on human interaction in general, since it makes it "semantically machine-computable" – and hence more easily visible - how people actually value their socially or commercially available resources. Such consumer opinion publication can build a qualitative "selection pressure" on producers, working to enhance the ultimate quality of their product offerings (Naeve 2005).

Collaborative Adaptive Learning Platforms

These approaches lead to new collaborative and adaptive learning platforms (CALP) which neatly integrate elements from social software use with the need for business oriented learning management systems for professional learning. CALP aims at supporting life-long competence development and represents a fundamental shift toward a more social, personalized, open, dynamic, and distributed model for learning. The main goals of CALP are on the one hand to achieve the highly challenging task of personalized adaptive learning. That is, to place the learner at the center, give her the control over the learning process and if possible deliver quality learning resources that are tailored to the learner's needs, preferences, interests, skills, learning goals, cultural background etc. On the other hand, CALP needs to support collaborative knowledge creation and foster community building. In CALP a strong emphasis has to be placed on personalization and collaborative work as the cornerstones of the learning process and means to improvement, performance and effectiveness. The primary challenge of CALP is to support life-long competence development by providing means to connect people to people as well as people to the right knowledge. Evolving Web 2.0 concepts and social software technologies have the potential to achieve this challenge and overcome many of the limitations of traditional learning models. CALP has to be based on these concepts and technologies and need to encompass the following elements:

(a) Support for personal knowledge management (PKM). Blogs are great tools for personal knowledge management. They help people organizing and exchanging their personal knowledge and the knowledge they have acquired. In the corporate context, personal business blogs helps the dissemination of knowledge through the organization and offer a platform where knowledge can be shared among employees by reading each other blogs, giving feedback and linking to other entries found in a colleague's blog or elsewhere in other learning communities.

(b) Support for collaborative knowledge capturing, sharing, networking, and community building. Group blogs and wikis for example are effective collaborative knowledge capture systems that support learning communities in designing, creating, reviewing, commenting, modifying, and posting learning objects as support for real time collaboration and authentic learning experiences. In the corporate context, group business blogs offer an opportunity to communicate with employees, suppliers, vendors and partners and provide an efficient way to reach out to customers. Corporate wikis are also a means to connect to other people, share knowledge and form learning communities. Furthermore, webfeeds and pod/vodcasts can be used as a communication medium between employees, partners and customers.

(c) Support for both top-down and bottom-up annotation schemes. The top-down scheme is basically based on system-driven standard-compliant automatic metadata generation to enable indexing, storage, search, and retrieval of appropriate learning assets and learning paths relevant for a specific learner or a group of similar learners. The bottom-up scheme enables personal and collaborative annotation/tagging of learning resources and fosters community building as users share, organize, discover, look for what others have tagged and find people with same interests. Social tagging/bookmarking and folksonomies are good examples of bottom-up annotation systems. Personal mark-up annotation also falls under this category. It allows the learner to annotate the content much the way she would annotate on a paper. The annotations can be circles, lines, underlines, highlighting of text, as well as writing freehand in the margins.

(d) Support for distributed opinion publication networks - and other types of networks – based on Semantic Web technologies. Such networks will be crucial in the community-specific bottom-up organization of tags that will result in community-specific tag-ontologies - built on top of huge folksonomies of tags - for community-specific purposes.

(e) Support for access and search across content and metadata. A learner should be able to query remote distributed learning asset repositories to quickly locate appropriate learning resources. This remote querying facility should be as transparent as possible for the users: queries sent to the own machine are automatically sent to remote repositories and the results are ranked globally and presented back to the user.

(f) Support for personalized learning resource delivery through an intelligent adaptive engine, being able to connect people to the right knowledge and deliver quality learning resources that are tailored to the learner's preferences and learning goals. The adaptation engine handles learner models, gives recommendations, and places the learner at the center by giving her the chance to negotiate the learning experience and to evaluate this experience afterwards.

(g) Support for personal social networks (i.e. individual's self-defined networks) to facilitate bottom-up socialization, that is, help people build new relationships and enable them to join learning communities based on their preferences.

(h) Support for personalized expert/community retrieval. The idea is to connect people to people through content. For example, by searching blog-based distributed communities via metadata and webfeeds and assessing the blogger's digital reputation (i.e. analyzing the feedback, comments and track backs to the blogger's posts), it is possible to identify experts inside or outside the organization with the required know-how that can help achieving better results or persons who share the same interests.

(i) Support for evaluation by quantifying and qualifying user experiences by joining HCI, social capital theory (Granovetter 1973), social exchange theory and Actor-Network Theory (Latour 1998).

(j) Social-topic networks: support for newcomers to integrate in a company. New employees are able to visualize the social networks existing inside the company, immediately find the most representative person for a certain topic and access the most important resources with respect to a certain subject.

(k) Support for a distributed architecture. Service or Web Oriented Architecture (SOA & WOA) and Web Services over protocols and specifications like WSDL, XML-RPC and SOAP (Gottschalk & Graham 2002) or lightweight approaches like RSS, XML/HTTP, and REST enable new forms of social software applications. The accessed microcontent can be remixed and multiple modular Web applications dynamically assembled to create mashups (Chatti et al. 2006b).

Conclusions and Outlook

The PROLEARN network of excellence (Wolpers & Grohmann 2005) as well as the other EU financed projects which have created the Professional Learning Cluster PRO-LC (http://www.professional-learning-cluster.org) have recognised the importance of social software for professional learning. We have tried to illustrate our motivation and give some theoretical background. From our experiences in previous and ongoing projects, we are motivated to identify some systematic solutions for professional learning at the workplace. We have sketched some key requirements for collaborative adaptive learning platforms. Evaluating such platforms by providing companies and people tools for self-monitoring their behaviour in social networks is a great challenge. In the PROLEARN network, we are committed to tackling this issue. We are organising a series of events around the topic of social software for professional learners, aiming to bring together social software researchers and practitioners in an open space for in-depth conversations about their work, possible trends, and visions. The topics covered include business perspectives such as the potential of software tools for knowledge sharing and professional learning.

Two major critical success factors for life-long learning social software are high usability and good sociability, with each of them comprising a set of criteria and measures (Preece 2001).There are inherent social-technical gaps that seem unbridgeable (Ackerman 2000; Olson & Olson 2000), especially the issue of trust that is intricately related to privacy and security. Some standardization efforts and initiatives have been undertaken (Law & Hvannberg 2007) to address this tricky problem, but their actual impacts are yet to identify. There exist no standard ways to measure the above attributes, making benchmarking studies especially difficult, if not impossible. Evaluation of social software is very demanding, given the high variability in users, tasks and contexts. The extended period of interaction among multiple and dynamic user groups may render the conventional, general evaluation methods inadequate. We deploy cross-media dynamic social network tools (Klamma et al., 2006) within the framework of Actor-Network Theory (Latour 1999) for monitoring and self-monitoring purposes of the affected communities. Digital social networks change the agency of people by the visibility of 'things', how they are created and managed and framed in discourses. The 'cow paths' in social software are results of unintended collective action. Put together the underlying research question here is: How to quantify and qualify learner experiences in deploying social software?

References

Aroyo, L., Dolog, P., Houben, G.-J., Kravcik, M., Naeve, A., Nilsson, M., & Wild, F. (2006). Interoperability in Personalized Adaptive Learning. *Educational Technology & Society, 9*(2), 4-18.

Ackerman, M. S. (2000). The intellectual challenge of CSCW: The gap between social requirements and technical feasibility. *Human-Computer Interaction, 15*, 179-203.

Aspin, D. N., & Chapman, J. D. (2000). Lifelong learning: concepts and conceptions. *International Journal of lifelong education, 19*(1), 2-19.

Bausch, P., Haughey, M. & Hourihan, M. (2002). *We Blog: Publishing Online with Weblogs*, Chichester:Wiley.

Blood, R. (2004). How Blogging Software Reshapes the Online Community. *Communications of the ACM, 47*(12), 53-55.

Boisot, M., & Griffiths, D. (1999). Possession is nine tenths of the law: managing a firm's knowledge base in a regime of weak appropriability. *International Journal of Technology Management, 17*(6), 662-676.

Burgos, D. (2006). Estudio de la estructura y del comportamiento de las comunidades virtuales de aprendizaje no formal sobre estandarización del e-learning. *Unpublished doctoral thesis in Communication and Journalism*, European University of Madrid: Villaviciosa de Odón, Spain.

Cardinaels, K., Meire, M., & Duval, E. (2005). Automating metadata generation: the simple indexing interface. In *Proceedings of WWW 2005: 14th international conference on World Wide Web,* ACM Press, 548-556.

Chatti, M. A., Klamma, R., Jarke, M., Kamtsiou, V., Pappa, D., Kravcik, M., & Naeve, A. (2006a). Technology Enhanced Professional Learning – Process, Challenges and Requirements. *Paper presented at the WEBIST 2006*, April 19-122, 2006, San Setúbal, Portugal.

Chatti, M. A., Srirama, S., Kensche, D., & Cao, Y. (2006b). Mobile Web Services for Collaborative Learning. *Paper presented at the 4th International Workshop on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE 2006)*, November 16-17, 2006, Athens, Greece.

Constant, D., Kiesler, S., & Sproull, L. (1994). What is mine is ours, or is it? *Information Systems Research, 5*(4), 400-422.

Davenport T., & Prusak, L. (1998). *Working Knowledge: How Organizations Manage What they Know*, Cambridge:Harvard Business School Press.

Field, J. (2001). Lifelong education. *International Journal of Lifelong Education, 20*(1/2), 3-15.

Fischer, G. (2001). Lifelong Learning and its support with new media. *International Encyclopedia of Social and Behavioral Sciences, Discipline "Cognitive Psychology and Cognitive Science"*, Section Editor: W. Kintsch, Contribution No 41, Retrieved June 7, 2007, from, http://l3d.cs.colorado.edu/~gerhard/papers/iesbs2001.pdf.

Fischer, G., & Ostwald, J. (2002). Transcending the information given: designing learning environments for informed participation. *Paper presented at the International Conference on Computers in Education*, December 3-6, 2002, Auckland, New Zealand.

Granovetter, M. S. (1973). The Strength of Weak Ties, *American Journal of Sociology, 78*(6), 1973, 1360-1380.

Gottschalk, K., & Graham, S. (2002). Introduction to Web Services Architecture. *IBM Systems Journal, 41*(2), 178-198.

Henri, F. (1992). Computer conferencing and content analysis. In A. R. Kaye (Ed.), *Collaborative learning through computer conferencing* (pp. 117-136), Berlin: Springer.

Hummel, H., Burgos, D., Tattersall, C., Brouns, F., Kurvers, H., & Koper, R. (2005a). Encouraging constributions in learning networks using incentive mechanisms. *Journal of Computer Assisted Learning, 21*, 355-365.

Hummel, H., Tattersall, C., Burgos, D., Brouns, F., Kurvers, H., & Koper, R. (2005b). Facilitating participation: From the EML website to the Learning Network for Learning Design. *Interactive Learning Environments, 13*(1-2), 55-69.

IMS-LD (2003). *IMS Learning Design Specification*, Retrieved June 27, 2007, from, http://www.imsglobal.org/learningdesign/index.cfm.

Klamma, R., Spaniol, M., Cao, Y., & Jarke, M. (2006). Pattern-Based Cross Media Social Network Analysis for Technology Enhanced Learning in Europe. *Lecture Notes in Computer Science*, 4227, 242-256.

Koper, R., Giesbers, B., Van Rosmalen, P., Sloep, P., Van Bruggen, J., Tattersall, C., Vogten, H., & Brouns, F. (2005). A Design Model for Lifelong Learning Networks. *Interactive Learning Environments, 13*(1-2), 71-92.

Kravcik, M., Specht, M., & Oppermann, R. (2004a): Evaluation of WINDS Authoring Environment. In De Bra, P. & Nejdl, W. (Eds.), *Proc. of Adaptive Hypermedia and Adaptive Web-Based Systems* (pp. 166-175), Berlin: Springer.

Kravcik, M., Kaibel, A., Specht, M., & Terrenghi, L. (2004b). Mobile Collector for Field Trips. *Educational Technology & Society, 7*(2), 25-33.

Kravcik, M., & Specht, M. (2005). Experience with WINDS Virtual University. In P. Kommers & G. Richards (Eds.), *Proc. of the ED-MEDIA 2005 Conference*, Montreal, 642-649.

Kumar, R., Novak, J., Raghavan, P., & Tomkins, A. (2004). Structure and Evolution of Blogspace, *Communications of the ACM, 47*(12), 35-39.

Latour, B. (1999). On Recalling ANT. In Law, J. & Hassard, J. (Eds.), *Actor-Network Theory and After* (pp. 15–25). Oxford: Oxford University Press.

Law, E. L.-C., & Hvannberg, E. T. (2007). Quality Models of Online Learning Community Systems: Exploration, Evaluation and Exploitation. In Lambropoulous, N. & Zaphiris, P. (Eds.), *User-Centred Design of On-line Learning Communities* (pp. 71-101), Hershey: Idea Publishing.

Licklider, J. C. R., Taylor, R., & Herbert, E. (1968). The Computer as a Communication Device. *Science and Technology, 4*, Retrieved June 27, 2007, from, http://gatekeeper.dec.com/pub/DEC/SRC/publications/taylor/licklider-taylor.pdf.

Naeve, A. (2001a). The Knowledge Manifold - an Educational Architecture that Supports Inquiry-Based Customizable Forms of E-learning. *Proceedings of the 2nd European Web-based Learning Environments Conference (WBLE 2001),* October 24-26, Lund, Sweden, 200-212.

Naeve, A. (2001b). The Concept Browser - a New Form of Knowledge Management Tool. *Proceedings of the 2nd European Web-Based Learning Environment Conference (WBLE 2001),* October 24-26, Lund, Sweden, 151-161.

Naeve, A. (2005). The Human Semantic Web – Shifting from Knowledge Push to Knowledge Pull. *International Journal of Semantic Web and Information Systems, 1*(3), 1-30.

Najjar, J., Meire, M., & Duval, E. (2005). Attention Metadata Management: Tracking the use of Learning Objects through AttentionXML. In Kommers, P. and Richards, G. (Eds.), *Proceedings of EDMEDIA05*, Chesapeake, VA: AACE, 1157-1161.

Nilsson, M., Palmér, M., & Naeve, A. (2002). Semantic Web Meta-data for e-Learning - Some Architectural Guidelines. *Paper presented at the 11th World Wide Web Conference (WWW2002)*, May 7-11, Hawaii.

Nejdl. W., Wolf, B., Qu, C., Decker, S., Sintek, M., Naeve, A., Nilsson, M., Palmér, M., & Risch, T. (2002). Edutella: A P2P Networking Infrastructure Based on RDF. *Paper presented at the 11th World Wide Web Conference (WWW2002)*, May 7-11, Hawaii.

Naeve, A., Nilsson, M., Palmér M., & Paulsson, F. (2005). Contributions to a Public e-Learning Platform – Infrastructure, Architecture, Frameworks and Tools. *International Journal of Learning Technology, 1*(3), 352-381.

Olson, G. M., & Olson, J. S. (2000). Distance matters. *Human-Computer Interaction, 15*, 139-178.

O'Reilly, T. (2005). *What Is Web 2.0 - Design Patterns and Business Models for the Next Generation of Software*, Retrieved June 3, 2007, from, http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html.

Palmér, M., Naeve, A., & Paulsson, F. (2004). The SCAM-framework – helping applications to store and access metadata on the semantic web. *Paper presented at the First European Semantic Web Symposium (ESWC 2004)*, May 10-12, 2004, Heraklion, Greece.

Palmér, M., & Naeve, A. (2005). Conzilla – a Conceptual Interface to the Semantic Web. In Dau, F., Mugnier, M.-L., Stumme, G. (Eds.), *Conceptual Structures: Common Semantics for Sharing Knowledge* (pp. 136-151), Berlin: Springer.

Paternó, F., & Santoro, C. (in press). Remote usability evaluation: Discussion of a general framework and experiences from research with a specific tool. In Law, E., Hvannberg, E. & Cockton, G. (Eds.), *Maturing usability: Quality in software, interaction and value*, London: Springer.

Preece, J. (2001). Sociability and usability in online communities: determining and measuring success. *Behaviour and Information Technology, 29*(5), 347-356.

Robson, C. (2003). *Real world research: A resource for social scientists and practitioner-researchers*, London: Blackwell Publishers

Sawyer, S., Eschenfelder, K., & Hexkman, R. (2000). Knowledge markets: cooperation among distributed technical specialists. In T. Srikantaiah & M. Koenig (Eds.), *Knowledge management for the information professional* (pp. 181-204), Medford, NJ: Information Today.

Shirky, C. (2003) Social Software: A New Generation of Tools. *Esther Dyson's Monthly Report, 10*.
Thibaut, J., & Kelly, H. (1959). *The social psychology of groups*, New York: Wiley.

Wellman, B., Boase, J., & Chen, W. (2002). The networked nature of community on and off the Internet. *IT and Society, 1*(1), 151-165.

Wolpers, M., & Grohmann, G. (2005). PROLEARN: technology-enhanced learning and knowledge distribution for the corporate world. *International Journal on Knowledge and Learning, 1*(1/2), 44-61.

Wang, T. I., Tsai, K. H., Lee, M. C., & Chiu, T. K. (2007). Personalized Learning Objects Recommendation based on the Semantic-Aware Discovery and the Learner Preference Pattern. *Educational Technology & Society*, 10 (3), 84-105.

Personalized Learning Objects Recommendation based on the Semantic-Aware Discovery and the Learner Preference Pattern

Tzone I Wang, Kun Hua Tsai, Ming Che Lee and Ti Kai Chiu
Laboratory of Intelligent Network Applications, Department of Engineering Science, National Chung Kung University, Tainan, Taiwan // wti535@mail.ncku.edu.tw // tsaikunhua@msn.com // apple@system.es.ncku.edu.tw

ABSTRACT

With vigorous development of the Internet, especially the web page interaction technology, distant E-learning has become more and more realistic and popular. Digital courses may consist of many learning units or learning objects and, currently, many learning objects are created according to SCORM standard. It can be seen that, in the near future, a vast amount of SCORM-compliant learning objects will be published and distributed cross the Internet. Facing huge volumes of learning objects, learners may be lost in selecting suitable and favorite learning objects. In this paper, an adaptive personalized recommendation model is proposed in order to help recommend SCORM-compliant learning objects from repositories in the Internet. This model adopts an ontological approach to perform semantic discovery as well as both preference-based and correlation-based approaches to rank the degree of relevance of learning objects to a learner's intension and preference. By implementing this model, a tutoring system is able to provide easily and efficiently suitable learning objects for active learners.

Keywords

Learning object, Personalized recommendation, Learner pattern, Semantic discovery, SCORM, LOM

1. Introduction

With energetic development of the Internet, especially on the web page interaction technology, distant e-learning systems have become more and more realistic and popular in the past ten years. Most of the currently running e-learning platforms are closed systems that have their own digital materials. These materials are hardly shared and re-used by different systems because they are made in proprietary formats. To solve the problems of sharing and reusing teaching materials in different e-learning systems, many international organizations, including IEEE Learning Technologies Standardization Committee (LTSC), Instruction Management System Global Learning Consortium (IMS), Aviation Industry CBT committee (AICC), Advanced Distributed Learning initiative (ADL) (ADL-1, 2001; ADL-2, 2001; ADL, 2003), and Alliance of Remote Instructional Authoring and Distribution Networks for Europe project (ARIADNE, 1998), have devoted to establishing e-learning standards. Among many proposed standards, the Sharable Content Object Reference Model (SCORM) (SCORM, 2003) is recognized as the most popular one and its Learning Object Metadata (LOM) (LOM, 2002) has been approved by the IEEE-Standards Association. The LOM aims to provide structured descriptions of digital contents, sometimes called "Learning Objects", a standard for encoding general learning object information including title, author, right, date, relations, and educational objectives. With the standard protocol, teaching materials made for different learning management systems can be shared, reused, and integrated; more and more learning objects will be authored and shared across the Internet in the near future. Before cooperative e-learning platforms with reusable and shareable learning objects are operational, issues below must be solved.

- **How to collect reusable learning objects on the Internet**. Generally, search engines, such as Google or Yahoo!, can help users search for learning objects. Keywords must be entered into these engines first but users are usually beset with what keywords to enter because they have not studied a specific domain yet. An ontology based query expansion and recommendation system can be used to help people use right keywords in finding suitable learning objects.
- **How to filter out unsuitable results as many as possible**. In general, the result of a query to a search engine is ranked by the degree of similarity to the keywords and uses a general basis for all the users. Search engines give no adaptive and personalized recommendations for each user. For a tutoring system, the ranking strategy should put the learning objects that are most conformed to a user's preference and intention at front places.
- **How to identify related learning objects for a specific course**. Because a learning object may be specifically made for a course, when reusing the object, it's necessary to know what the learning object is made of and what course it is suitable for. LOM is due to easy this problem. A course author has to define what learning objects

are needed for the course and, once this is established, these objects should be found from some repositories or the Internet.

This paper proposes a Personalized Learning Object Recommendation Model (LORM) that adopts ontological approach to guide a tutoring system in providing learning objects for a user according to the user's needs. Through the ontological approach, semantics of user entered query keywords can be conjectured and the expansion system may, according to the ontology inference, add additional keywords to the user's original ones to construct a more complete semantics. In this way, more suitable learning objects (i.e. learning objects a course may need according to a learner's intention) can be discovered and retrieved. A personalized recommendation mechanism is also proposed, which uses two algorithms, the *Preference-based algorithm* and the *Correlation-based algorithm*, to rank the recommended results to advise a learner with the most suitable learning objects. A system realizing this model can:

1. Use the specific ontology to infer what learning objects are needed for a course established for a specific learner requiring a specific subject.
2. Build each learner's personal preference pattern according to past studying histories.
3. Recommend suitable learning objects according to a learner's preference and intention.
4. Refer to the experiences of similar learners when looking for learning objects that should be helpful for each learner.
5. Provide adaptive, personalized learning objects and materials for each learner.

2. Background and Problems

A learning object is a basic component or unit of a course in a tutoring system. Some definitions for learning objects are summarized as follows:

- "Modular digital resources uniquely identified and meta-tagged, that can be used to support learning." -- *National Learning Infrastructure Initiative*
- "The main idea of learning objects is to break educational content down into small chunks that can be reused in various learning environments, in the spirit of object-oriented programming." -- *David A. Wiley*
- "Any entity, digital or non-digital, that may be used for learning, education or training." -- *IEEE 1484.12.1-2002, 15 July 2002, Draft Standard for Learning Object Metadata, IEEE Learning Technology Standards Committee (LTSC)*

2.1 SCORM

When a learning object is a self-contained component, it is natural to reuse the object in many courses. However that needs a common standard for tutoring systems to follow. **SCORM** is implemented by the Advanced Distributed Learning (ADL) Initiative created by the US department of defense. Its purpose is to foster creation of reusable learning content used as "instructional objects" within a common technical framework for both computer and web-based learning. SCORM describes this technical framework by providing a harmonized set of guidelines, specifications, and standards developed by several organizations. All of them are adapted and integrated with one another to form a more complete and easier-to-implement mode by ADL (ADL-1, 2001). Key contributors to SCORM include organizations AICC, ARIADNE, IEEE LTSC, and IMS.

2.2 Learning Object Metadata – LOM

LOM (LOM, 2002) is the set of attributes needed to allow Learning Objects to be managed, located, and evaluated. This standard uses a pre-defined and common vocabulary to describe the content of learning objects learning object content. There are nine categories in the vocabulary, including General, Lifecycle, Meta-metadata, Technical, Educational, Rights, Relation, Annotation, and Classification. They are shown as in Table 1 with short descriptions. The LOM fulfills the same role as "Dewey Decimal Classification" in library books catalog. If learning objects in a repository on the Internet are catalogued according to LOM, it would be easy to identify a particular learning object. In the libraries catalogs rapidly guide a user to locate books of interest, while on the Internet LOM should guide a learner to locate suitable learning objects. When to understand the preference of a learner, we can extract the field values of the learning object from these nine categories and regards them as the major features of the learning object.

2.3 Recommendation Model Survey

In traditional teaching scenarios, a teacher may usually decide what materials and in what order a class of students should learn. In this way, personalized learning for each learner can't be achieved easily. In the E-learning, using a recommendation mechanism to recommend materials (learning objects) to learners according to their actual needs might be a better strategy because the class hedge has been broken. But how to figure out a learner's actual needs without a comprehensive online interrogation becomes a new challenge.

Table 1. LOM categories

Top Level	Description
General	The *General* category groups the general information that describes the resource as a whole.
Lifecycle	The *Lifecycle* category groups the features related to the history and current state of this resource and those who have affected this resource during its evolution.
Meta-Metadata	The *Meta-metadata* category groups information about the meta-data record itself (rather than the resource that the record describes).
Technical	The *Technical* category groups the technical requirements and characteristics of the resource.
Educational	The *Educational* category groups the educational and pedagogic characteristics of the resource.
Rights	The *Rights* category groups the intellectual property rights and conditions of use for the resource.
Relation	The *Relation* category groups features that define the relationship between this resource and other targeted resources.
Annotation	The *Annotation* category provides comments on the educational use of the resource and information on when and by whom the comments were created.
Classification	The *Classification* category describes where this resource falls within a particular classification system.

Currently, recommendation strategies can be divided roughly into three types, i.e. the content-based (Belkin. N. et al., 1992; Mooney, R. J. et al., 1999), the collaborative-based (Konstan, J. A. et al., 1997; Jin, R. et al, 2003(UAI); Jin, R. et al, 2003 *(*CIKM*)*; Hofmann, T., 2003; Hofmann, T., 2004) and the hybrid (Soboroff, I. Et al., 1999; Tran, T. et al., 2000; Popescul, A., 2001; Melville, P. et al., 2002) methods. The idea behind the content-based method is that if a user liked an object in the past, he/she would probably like other similar objects in the future. This method obtains learning objects' features and compares them with a users' profiles to predict their preferences (Jin, R. et al, 2003(UAI); Jin, R. et al, 2003 (CIKM)). Typically a collaborative-based method recommends learning objects to a user based on the preferences of his/her neighbors by using a nearest-neighbor algorithm. On the other hand, a hybrid method, attempting to combine the former two techniques to eliminate drawbacks of each, usually applies a user's profile and descriptions of learning objects to find users who have similar interests, and then uses collaborative filtering to make better predictions. For the time being, to combine the content-based and the collaborative-based method is usually considered to be a better methodology for the recommendation mechanisms. The mechanism in this paper is a hybrid method that recommends the learning objects. First, the preference-based algorithm will calculate a learner's preference score and the second correlation-based algorithm will provide similar learners' experience to calculate the helpfulness score. Finally, the two scores will be aggregated to one recommendation score. The detailed procedures will be introduced in a later section.

2.4 Problems on Recommendation Models

In traditional teaching strategies, learning objects of a course are assigned unique orders. Each learner can only follow this pre-defined sequence to explorer all the learning objects. E-learning systems have potentials of providing an adaptive and personalized learning style easily. Each learner may be allowed to select his/her desired learning objects to study. To do this, a system has to try inferring the semantics of a query a learner types in and recommends learning objects according to the learner's desire. While a beginner generally lacks basic knowledge of a specific domain, the query keywords input to a tutoring system for a specific subject may merely a surmise of the learner and the learning objects retrieved consequently may be incorrect or even misleading. In our observation, most information retrieval (IR) systems that can perform well in keyword matching are deficient in semantic-aware searches or semantic discoveries, as well as inferring queries. Tutoring systems in the E-learning paradigm are subject to the same problem. In IR systems, users know what they meant to is a basic assumption. However in the E-learning paradigm, novice learners may have no idea about what they need and what the metadata of learning objects is. On the other hand, it is unreasonable to require learners to be familiar with the LOM standard, novices and professionals alike. Providing a group of fields for users to fill in is one possible solution. However this practice not only produces inflexible systems and but also requires learners to know various types of metadata. Even though learners are familiar with LOM, a system may be still not semantic aware. That is to say, the field descriptions and titles may be well defined, but the relationships of learning objects, especially those retrieved from other repositories and reused, in the system may not be well organized, and such a system may be incapable of organizing a suitable course for a specific learner if the semantics of input keywords is not properly recognized to reflex the real intention and preference of the user. And users' intentions and preferences awareness is what's called the *Personalization*.

Another challenge related to preferences is when a retrieve returns a result with numerous similar learning objects it is very difficult to decide the recommendation priority of these learning objects. Traditional content-based methods usually assume that a user should prefer something that has contents in accordance with her/his experiences. For the learning object case, this assumption is inadequate because a learner should expect to study something new and desirable. Thus traditional content-based methods should be more adequately changed to preference-based methods in E-learning systems. In this paper, both a learner's preference and other similar learners' experiences are used in ranking and recommending learning objects within top N learning objects to the learner.

3. An Java Tutoring System

A tutoring testbed has been setup to verify and evaluate the perspectives of proposed model. A primary element, the Java Learning Object Ontology (JLOO), of the system will be briefed here. Steps to organize learning objects into an ontology- based repository are also described briefly.

3.1 Java Learning Object Ontology

In 2001, The Joint IEEE Computer Society/ACM Task Force on the Model Curricula for Computing published the Computing Curricula 2001 (CC2001) (CC2001, 2001) that contained curriculum recommendations for undergraduate programming courses in computer science. The report also called for additional discipline-specific volumes for each of computer engineering, information systems, and software engineering. In the curriculum, six top-level concepts are suggested for the programming fundamentals; they are *Data model*, *Control structures*, *Order of execution*, *Encapsulation*, *Relationships among encapsulated components*, and *Testing and debugging* respectively. CC2001 also defined the "Description" and "Associated activities" of these concepts. "Description" describes the inner meaning of these concepts while "Associated activities" describes related activities in programming briefly. For example, the most obvious inner meaning of "Encapsulation" is information-hiding, and the related activities of "Control structures" are reading and explaining the effects of all the operations, implementing and describing these operations, and etc.

In one of our previous researches, an experimental Java programming course ontology -- the "Java Learning Object Ontology – JLOO" was built and introduced in (Lee, M., 2005). JLOO serves as a guideline in developing learning objects of introductory Java course and in organizing these learning objects in an adaptive learning environment. The work is based on CC2001 and is designed as an infrastructure of a Java learning object knowledge base. This ontology is focused on the atomic knowledge units of introductory Java programming, therefore the concept hierarchy has "learning concepts" only, without any Java APIs included. For the same reason, other advanced programming entities (such as swing, networking, multi-thread) are also not included. JLOO covers the six subjects defined in the fields of the introductory curriculum in CC2001. In the case of JLOO, the ontology terminology "concept" represents a learning unit in Java, "instance" represents a learning object that belongs to a concept, and "slot" represents properties and relations between two concepts.

The top level of JLOO is the six programming fundamental categories suggested by CC2001. In Figure 1 is a portion of the concept hierarchy of the category "*Control structure*".

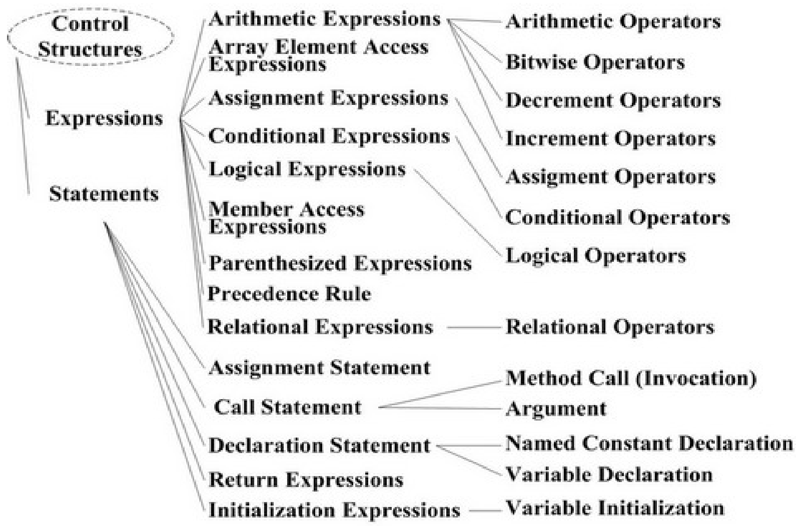


Figure 1. The portion of the concept hierarchy of the category "*Control structure*"

In JLOO, slots provide following information for concepts: 1) recording basic attributes of concepts, i.e., the metadata of learning objects. For example, the author, data, size, format, location, keywords, etc. 2) defining the relationships between concepts. A major slot in JLOO is PREREQUISITES. The PREREQUISITES indicates the concepts that must be learned to gain the prerequisite knowledge before studying a specific concept. A learning object is not to be provided unless the prerequisite condition is satisfied.

3.2 Building a Repository

All the learning objects in the repository are collected from the Internet according to some criteria. Before putting them into the repository, they are examined and formalized, and then classified according to the concept hierarchy in the JLOO. Figure 2 describes these steps and the detailed descriptions are as follows:

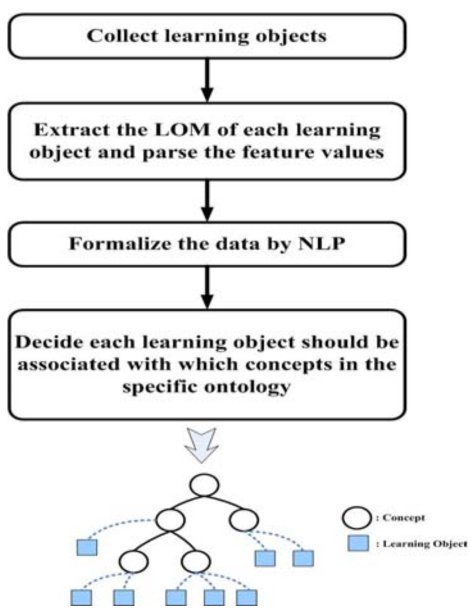


Figure 2. Building the Repository

STEP 1: Collect learning objects

To build the repository, a great number of learning objects has been collected from the Internet. All the learning objects collected are classified, fortified, and are associated to the JLOO. The collection is focused on JAVA programming related objects; most of them are web pages and others are specific learning objects.

STEP2: Extract the feature values from learning objects

The fields of the LOM constitute a standard, following which the detail information of a learning object is to be described. They are the important attributes and features of a learning object if the object is intended for sharing and reusing. As pointed above, for adaptive personalized recommendation, figuring out a learner's preferences is a necessity. But to choose proper learning objects for a learner, it's also necessary to perceive every learning object by extracting their features. If a learning object is obtained with LOM ready, its feature values are automatically extracted from the fields of the LOM (each field is considered as a feature) and are recorded in the ontology database with the learning object. Otherwise, the object is manually given a LOM with proper feature values before it is recorded into the ontology database. The ontology database is a database that uses ontology as an index for learners to look up for something. Some related definitions of the features are described as below.

Definition 1: Features of learning objects. The features are the characteristics of learning objects and the set of feature values represent a specific learning object. Nine categories (as in Table. 1) are specified in the LOM standard for describing the content of a learning object, each containing several fields. The LORM defines each field as one feature. In the features expression of learning objects, f_i represents a feature and LO^F means the set of all features.

$$LO^F = \{f_i \mid \forall f_i \in \text{the fields of LOM, and } f_i \neq f_j \text{ if } i \neq j\}$$

Definition 2: Feature values of a learning object. Each feature (or field) in the LOM may have several feature values and they may be different from the feature values of other learning objects of a similar kind. They are defined as below where $\mathbf{fv_k}$ is a feature value of feature $\mathbf{f_i}$ of a learning object **lo**. Each learning object **lo** can be described by the set of all (f_i, fv_k) pairs.

$$lo = \left\{ \begin{array}{l} (f_i, fv_k) \mid \forall f_i \in \text{the fields of LOM and } f_i \neq f_j \text{ if } i \neq j \\ \qquad\qquad , fv_k \text{ is the feature value of } f_i \end{array} \right\}$$

STEP3: Formalize the attribute values by NLP

The purpose to adopt natural language processing is two folds. One is to ensure the format of all the feature values in a same feature uniform for all the learning objects. Different learning objects may use different styles of feature values in a same feature when they are collected. Inconsistent format may result in wrong mappings to a learner's preferences when recommending learning objects. The other is to ensure precise classification of learning objects. In each learning object, there is a field that describes the content of the learning object using some statements. Generally, learners can understand what for the learning object is according to this field. For example, a JAVA learning object may have a description that reads "*This learning object introduces the concepts of variable declarations and data types such as long, int, short and byte*". A learner can then have an idea of what the learning object will teach. But such a description is difficult for a program to deal with automatically. Hence, a description is pre-processed by a NLP procedure to extract formalized keywords to form a set that are machine-readable. For example, the above description will be reduced to the keyword set as {variable, declaration, long, int, short, byte}.

STEP4: Associated with concepts in the specific ontology

All the learning objects collected are classified, and are associated to one or several concepts in the specific ontology - the JLOO. A special ontological approach (Lee, M. C. et al., 2006(LNCS); Lee, M. C. et al., 2006) is used to classify the learning objects, which makes the JLOO equivalent to an index of all the learning objects. For the time being the classification is partly manual because a lot of learning objects collected are without or with very simple LOM. If the result that comes from step 3 is able to decide automatically which concept(s) a learning object should be associated to, the object is put into the repository with the keyword set. When there is no LOM or the LOM is too simple, manual task is required to create a LOM or enhance the LOM for a learning object before it is sent into step 3 and 4. From the JLOO perspective, each of its concepts owns numerous learning objects. When a learner issues a query, the LORM will infer its semantics by matching the original keywords with the concepts in the ontology and expand the keywords with concepts from a specific part of the ontology hierarchy. The learning objects in the concepts, matched and expanded, are regarded as the candidates for the recommendation to the learner. More detail on recommendation processes is to be described in the next section.

4. Recommendation Model

The Learning Object Recommendation Model is divided into several phases as in Figure 3. The first three phases try to infer the real intention of a learner and try to find for the learner some suitable learning objects. Keywords entered in a query are expanded by exploiting the specific ontology hierarchy. The query expansion algorithm described in section 4.2 will find matched concepts and relationships among them. Matched concepts are then used to extend some more concepts by using specific rules. All the concepts, matched and extended, and relationships among them constitute a new keyword set that is used to collect learning objects within a range of suitability. In the following two phases for recommendation of learning objects, two evaluation algorithms that consider a learner's personal preference and his/her neighbours' suggestions are used to calculate the recommendation scores for ranking all the learning objects collected in the first three phases. The final phase deals with the feedbacks of learners and updates their profiles.

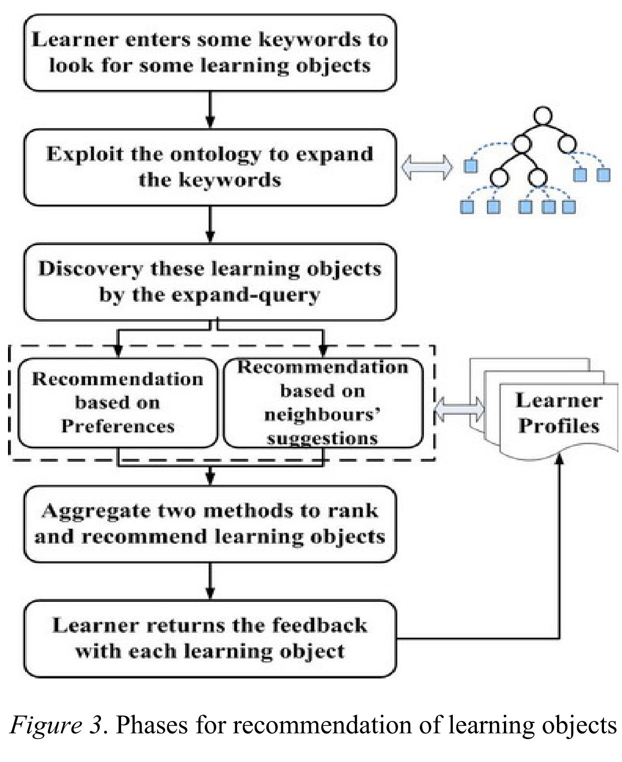


Figure 3. Phases for recommendation of learning objects

4.1 Query Expansion

Traditional search technologies, such as vector space model in informational retrieval system usually are keyword-based. The documents retrieved are those containing one or more user-specified keywords. However, documents may convey heavily desired semantic information implicitly without containing any explicit keywords, and thus may not be retrieved. This problem is usually solved by adopting query expansion algorithms, in which additional search terms are added to the original query based on statistical co-occurrence of terms (Smeaton, A. F. et al., 1993). Consequently, recall rate is increased, while precision is decreased (Peat, H. J. et al., 1991). One way to ease the precision problem is to index documents on both their context and meaning instead of keywords only. This requires a method of mapping the context and their possible meanings and the creation of a meanings- indexed database. Domain ontology, the semantic schema used to build metadata layer upon semantic web, contains the concept hierarchy and the detail features of all concept types of a domain, will provides such a conceptual and semantic indexing for documents. The LORM uses a semantic inference engine to find out the relationships between a user's query and the learning object metadata in the repository in order to semantically expand the learner's query for retrieving more candidate learning objects. Two phases are used, which are 1) *Construct the User Intention Tree (UIT) from ontology,* and *2) Expand query terms from UIT.*

STEP1: Construct the User Intention Tree (UIT)

A UIT is a sub-tree of an ontology hierarchy. It represents a user's intention by aggregating the nodes that are a minimum conjunction of matched concepts. In other words, an UIT is a semantic tree of a user's query constructed from the specific ontology.

Definition 3: Query Keywords and Concept Keywords. The set of keywords in a query ***i*** is called the query keywords set QK^i. In the specific ontology of the repository, each concept ***j*** is described by a set of CK_j.

$$QK^i = \{QK^i_1, QK^i_2, ..., QK^i_m\},\ \text{where } m \text{ represents the number of terms in a query } i$$

$$CK^j = \{CK^j_1, CK^j_2, ..., CK^j_n\},\ \text{where } n \text{ represents the number of terms in a concept } j$$

Definition 4: Basic Concepts and Basic Concept Scores. For a concept ***j*** and a query ***i***, ***j*** is called a Basic Concept (BC) for the ***i***, if $CK^j \cap QK^i \notin \varnothing$. In other words, a BC is a concept in the ontology which has at least one concept keyword that matches one of the query keywords. For each query, the query expansion algorithm first evaluates its Basic Concept Score (BCS) for each BC. These BCSs represents the similarity degree between a portion of concept hierarchy in the ontology and query keywords.

$$W_{QK^i_k, CK^j} = TF_{QK^i_k, CK^j} \times IDF_{QK^i_k, CK^j} \quad (1)$$

$$TF_{QK^i_k, CK^j} = \begin{cases} \dfrac{1}{|CK^j|} & , QK^i_k \in CK^j \\ 0 & , \text{otherwise} \end{cases} \quad (\mathbf{2})$$

$$IDF_{QK^i_k, CK^j} = \log \frac{\#\text{ of concepts in ontology}}{\#\text{ of concepts that match } QK^i_k} \quad (3)$$

$$NW_{QK^i_k, CK^j} = \frac{TF_{QK^i_k, CK^j} \times IDF_{QK^i_k, CK^j}}{\sqrt{\sum_{x=1}^{|CK^j|} (TF_{CK^j_x, CK^j} \times IDF_{CK^j_x, CK^j})^2}} \quad (4)$$

A modified TF-IDF approach is used to evaluate the BCS. The keyword-weighting is given by formula (1), where TF and IDF are evaluated by the formula (2) and (3), respectively. A normalized keyword-weighting NW is then calculated by formula (4).

The BCS of a basic concept ***j*** of a query ***i***, the BCS_{ji}, is the summation of all the normalized keyword-weighting of all the keywords in the query, which is also normalized to have a value between 0 and 1. Formula (5) calculates the BCS_{ji}.

$$\mathrm{BCS}_{ji} = \frac{\sum_{k=1}^{|QK^i|} \mathrm{NW}_{QK_k^i, CK^j}}{|QK^i|} \quad . \tag{5}$$

Definition 5: Degree Function, Impact Score and Total Impact Score. The degree Function (Deg) defines the number of sub-concepts a concept ***i*** has, and is expressed by formula (6).

$$\mathrm{Deg}_i = \begin{cases} \text{\# of all descendants (includes non-direct link node)}, & i \notin \text{leaf node} \\ 1, & i \in \text{leaf node} \end{cases} \tag{6}$$

The impact score, IS_{ip} denotes the degree of the semantic impact a basic concept ***i*** may have on its ancestor concept ***p***. On the other hand, for each ancestor, the total semantic impact on it is defined as the Total Impact Score (TIS) and calculated by formula (8).

$$\mathrm{IS}_{ip} = \left\{ \mathrm{BCS} \times \frac{\mathrm{Deg}_i}{\mathrm{Deg}_p} \;\middle|\; \text{concept } p \notin \text{basic concept} \right\} \tag{7}$$

$$\mathrm{TIS}_p = \left\{ \sum \mathrm{IS}_{ip} \;\middle|\; \begin{array}{l} \text{concept } i \in \text{BC and is a descendant of concept } p, \\ \text{concept } p \notin \text{basic concept} \end{array} \right\} \tag{8}$$

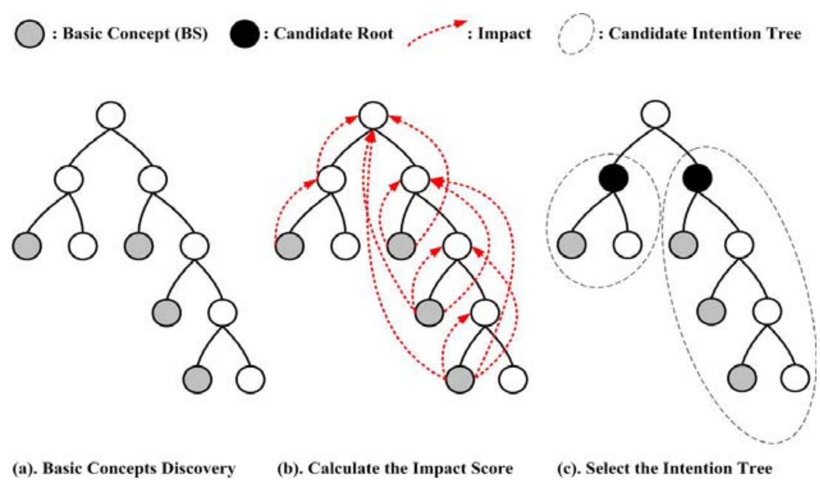


Figure 4. The process of constructing an UIT

Figure 4 shows the process of constructing an UIT. The main goal is to find an upper concept that is the root of a final intention tree associated with a user's query. First, in Fig. 4-(a), several basic concepts are discovered by matching the QK and CK sets; their BCSs are calculated by formula (5). Each BC in the ontology hierarchy is also semantically related to its parent concept to a certain degree. In fact the kindred will trace back all the way to the root. Fig. 4-(b) shows how a BC impacts on its ancestors. A parameter λ has to be set, which is a threshold to limit the upper bound of an UIT. As shown in Fig. 4-(c), an algorithm is used to calculate the Total Impact Score (TIS) of all BCs' ancestors. Propagating up along the hierarchy, if there is an ancestor concept whose TIS is the smallest larger than λ, then it is recognized as a root and all its descendants are constructed as a candidate intention tree. Several candidate intention trees may be constructed but the one with the highest TIS will be selected as the final UIT in this step.

STEP2: Expanding query keywords from UIT

This step expands the query keywords according to the UIT constructed in the previous step. Since the proposed algorithm is aimed to be domain or ontology independent and a UIT may be one flourishing tree in the case of extracting from a huge or heterogeneously integrated ontology, there are possibly many candidate query expansion keywords which describe the concepts in the explicit UIT. However, not all of them should be added to the set of final expanded keywords. The system should only select some important keywords, each of which has closer correlations with query keywords. To determine the degrees of correlations between the candidate query expansion keywords and query keywords is equal to calculating the conditional probabilities between them (Cui, H. et al., 2003). In other words, that is the conditional probability of a candidate expansion keyword's appearance on the condition that the query keyword also appears in the LOM, and is denoted by $P(CK_x^j \mid QK_y^i)$ in which the concept keyword $CK_x^j \in UIT$. If a concept keyword CK_x^j is the ***x-th*** element of the concept keywords of concept ***j***, the query keyword QK_y^i is the ***y-th*** element of the query keywords of query ***i***, and let ***S*** be the set of LOMs in the learning objects repository, then, according to the Bayes' theorem, the conditional probability $P(CK_x^j \mid QK_y^i)$ can be defined as follows:

$$
\begin{aligned}
& P(CK_x^j \mid QK_y^i) \\
&= \frac{P(CK_x^j, QK_y^i)}{P(QK_y^i)} = \frac{\sum_{\forall LOM_k \in S} P(CK_x^j, QK_y^i \mid LOM_k) \times P(LOM_k)}{P(QK_y^i)} \\
&= \frac{\sum_{\forall LOM_k \in S} P(CK_x^j \mid LOM_k) \times P(LOM_k \mid QK_y^i) \times P(QK_y^i)}{P(QK_y^i)} \\
&= \sum_{\forall LOM_k \in S} P(CK_x^j \mid LOM_k) \times P(LOM_k \mid QK_y^i)
\end{aligned}
\tag{9}
$$

In formula (9), it considers only these correlations which appear in the LOMs belonging to the concepts in a UIT. Each LOM_k in the set S represents the metadata of learning object k. Since direct calculation of the $P(CK_x^j \mid QK_y^i)$ is difficult, it is transferred into two parts, the $P(LOM_k \mid QK_y^i)$ and the $P(CK_x^j \mid LOM_k)$, where the $P(LOM_k \mid QK_y^i)$ is the conditional probability of the learning object k being selected in case that the QK_y^i appears among the keywords of query ***i*** and the $P(CK_x^j \mid LOM_k)$ is the conditional probability of occurrence of the CK_x^j if the learning object k is selected. The evaluation of the conditional probability $P(LOM_k \mid QK_y^i)$ and $P(CK_x^j \mid LOM_k)$ are as follows in formula (10) and (11):

$$
P(LOM_k \mid QK_y^i) = \frac{Fre(LOM_k, QK_y^i)}{Fre(QK_y^i)} \tag{10}
$$

$$P(CK_x^j \mid LOM_k) = \frac{NW_{CK_x^j, LOM_k}}{\max\limits_{\forall T \in LOM_k} (NW_{T, LOM_k})} \qquad (11)$$

In formula (10) and (11), the $Fre(LOM_k, QK_y^i)$ is the frequency of the QK_y^i and the LOM_k (in selected learning object k) appearing together. The $Fre(QK_y^i)$ is the query frequency that contain the query keyword QK_y^i. The two factors were statistically obtained from the system logs. The $NW_{CK_x^j, LOM_k}$ is the normalized TF-IDF weight of the term CK_x^j in the LOM_k. The denominator of formula (11) is the maximum value of term weights in the LOM_k. By combining the probabilities of all query keywords, we can get the joint weight for each concept keyword in the following formula (12). Thus we can get a list of candidate expansion terms as well as the conditional probabilities between each terms and user query. The top-ranked terms are selected as the expansion terms.

$$W(CK_x^j, QK^i) = \log\left\{ \prod_{y=1}^{|QK^i|} (P(CK_x^j \mid QK_y^i) + 1) \right\}, \text{ where } CK^j \in \text{UIT} \qquad (12)$$

4.2 Recommendation Processes

After the query expansion process, a user intention tree can be found and an original query is turned into a new expanded query by adding more semantically related keywords. According to the expanded query, several concepts in the specific ontology are discovered. As mentioned, each learning object may belong to one or several corresponding concepts in the ontology hierarchy. Thus, each concept discovered may contribute many similar learning objects. All the learning objects from all the discovered concepts constitute the recommendation result that may possibly be a huge volume. Therefore how to recommend precisely according to a learner's profile becomes an important issue. In the proposed model, the query expansion process finds a semantic-related result containing many learning objects that, for the purpose of personalized recommendation, will be precisely ranked by two algorithms, the preference-based and the correlation-based algorithms. The ranking algorithms will adjust the order the learning objects being presented to a learner.

4.2.1 Preference-based algorithm

Generally speaking, people always have their own preference on things like cars, books, and among others. Things, which are accorded with their preferences, can always interest them most; there is no exception in E-learning. A system that can recommend learning objects according to a learner's preferences will attract the learner to come back for more. The values of a feature of a learning object can help determine if a learner may prefer the object. For example, under the feature name *language*, a value *Chinese* may be preferred by some learners while a value *English* by others. Another example is the presentation style of a learning object. Learning object may be composed of various media, such as text document, audio/video clips, picture or flash, and etc. Different learners may prefer different presentations and strategies of learning objects for a same kind of topic. The preference-based algorithm is to bias the learning objects with a learner's preferences. Learning objects tending to suit a learner's preference more will get higher priorities when recommended to the learner. Before introducing the preference-based algorithm, the learner preference pattern is defined first.

Definition 6: Learner Preference Pattern. The Learner Preference Pattern (LPP^{user}) of a learner is the preference history of the features for the learner, which contains a list of Feature Scores, the (FS_1, FS_2,..., FS_n), of 2-tuples of (*fv*, *fs*). The *fs* is a feature preference score which represents how important the feature value *fv* is. After a learner studied a learning object, the LPP^{user} is updated according to the learner's preference feedback. How a personal LPP is updated will be discussed in the next section. The LPP^{user} thus represents the preference history of a learner. Each learner can explicitly choose what features he/she is interested initially in the system registering step, and can implicitly be added a new feature when using a system recommended learning object with a feature not found in the LPP^{user} list. Formal definition is as follows.

$$LPP^{user} = \{FS_i\}^*$$
$$FS_i = \{(fv_k, fs_k)_{f_i} \mid \forall fv_k \subseteq \text{the set of feature values for the feature } f_i\}$$

ALGORITHM: Preference-based algorithm
INPUT: Learner's ID, a learning object
OUTPUT: Preference score of a learning object

```
float CalculatePreferenceScore(int uid, int lo) {
  for (each feature f_i in LPP^uid) {
    float pscore=0;
    for (each feature value fv_k in f_i ) {
      if ( lo_fi equal to fv_k) {
        pscore fs_k of fv_k += BPW(fv_k);
        break;
      }
    }
}
return 5*(pscore/|lo^F|);
}
```

Figure 5. Preference-based algorithm

Figure 5 shows the preference-based algorithm that calculates the preference score of one specific learning object *lo* when it has being used by a learner *uid*. The preference-based algorithm only calculates the preference score according to the features the learner *uid* has. If a feature value lo_{fi} of feature f_i in the learning object *lo* matches a record in the learner's LPP, the corresponding feature's preference score fs_k of feature value fv_k will be increased by a weight, the Basic Preference Weight that is defined, among others, as follows.

Definition 7: Basic Preference Weight. The Basic Preference Weight (BPW) is a weight to represent the degree of a learner's preference for a feature value in a feature. It is calculated by formula (13). The $\mathbf{fv_k^{fi}}$ represents the *k*-th feature value in the feature f_i and the $\mathbf{fs_k^{fi}}$ represents the feature preference score of the feature value $\mathbf{fv_k}$.

Definition 8: Preference Score. The preference score (PS) of a learning object is a score to represent the degree of a learner's preference for a learning object. The PS of each learning object is calculated according to the BPWs form a learner's LPP. After accumulating BPWs of feature values of all the features of a learning object, the preference score is the average of the sum divided by the number of features a learner currently has, the $|\mathbf{lo^F}|$. Formula (14) calculates a PS.

$$BPW(fv_k^{fi}) = \frac{fs_k^{fi}}{\max\{fs_j^{fi} \mid \forall fs_j^{fi} \in \text{the score of feature } f_i\}} \tag{13}$$

$$PS(lo) = 5 \times \frac{\sum BPW(fv_k^{fi})}{\#\text{ of the features } LO^F \text{ a learner currently has}} \tag{14}$$

4.2.2 Correlation-based algorithm

It is not comprehensive by considering only a learner's preference for a learning object. Helpfulness of learning objects to a learner is not taken into account by the preference-based algorithm. But to pre-analyze a learning object's helpfulness for a learner does not seem easy. It can only be judged by the learner after being used. However, suggestions from other learners who have a similar profile as the learner are helpful and, for this reason, a correlation-based algorithm is proposed to strengthen the precise of recommendations. This algorithm predicts how helpful a specific learning object will be for a learner by analyzing other similar learners' feedbacks. A similar learner group is defined as the group of learners who used the same learning objects in the past and returned similar feedbacks. In general, in a similar learner group each learner may have several characteristics in common with other learners. So the idea of calculating helpfulness score of a learning object for a learner by consulting other similar learners' suggestion can be justified if a similar learner group is formed properly. Two main steps are carried out in the correlation-based algorithm.

STEP1: Look for similar learners

This process is to find out a group of learners who have similar learning experiences as a learner is summarized in Figure 6. The **s_threshold** is set as a similarity threshold. Those learners whose learning experiences are similar to a learner to a certain degree that is great or equal to the **s_threshold** are added to the set of similar learners, $\mathbf{Sim_{uid,lo}}$. In $Sim_{uid,lo}$, each element has two information, including a similar learner's ID, the **sl**, and his/her degree of similarity, the **sim(uid,sl)**, to the learner respectively. The value of **sim(uid,sl)** is calculated by formula (14) (Konstan, J. A. et al., 1997):

$$\mathrm{sim(uid,sl)} = \frac{\sum_{s \in S_{uid/,sl}} (r_{uid,s} - \overline{r_{uid}})(r_{sl,s} - \overline{r_{sl}})}{\sqrt{\sum_{s \in S_{uid,sl}} (r_{uid,s} - \overline{r_{uid}})^2 \sum_{s \in S_{uid,sl}} (r_{sl,s} - \overline{r_{sl}})^2}} \tag{14}$$

Where $\mathbf{S_{uid,sl}}$, is an intersection set that contains learning objects that both learners **uid** and **sls** have studied and returned their feedbacks. The $\mathbf{r_{uid,s}}$ and $\mathbf{r_{sl,s}}$ represent the returned scores for an identical learning object **s** from learners **uid** and **sl** respectively. The $\overline{\mathbf{r_{uid}}}$ and $\overline{\mathbf{r_{sl}}}$ are the averages of feedback scores of these learning objects that learners **uid** and **sl** have studied so far respectively.

ALGORITHM: algorithm of looking for similar-learners
INPUT: A learner's ID, a specific learning object, the similarity-threshold
OUTPUT: a group of similar learners

```
LookforSimilarLearners(int uid, int lo, float s_threshold) {
  Collect learners sls who have assigned feedbacks to learning object, lo;
  assign these learners sls to the set Sim_uid,lo;
  for (each learner sl in the Sim_uid,lo) {
     calculate the value of sim(uid, sl);
     if (sim(uid, sl) is equal to / greater than s_threshold)
       assign (sl, sim(uid, sl)) to Sim_uid,lo;
  }
  return the set Sim_uid,lo;
}
```

Figure 6. Look for similar-learners algorithm

STEP2: Calculate the helpfulness score

This second process is to calculate for a learner the helpfulness score for each learning object in the $\mathbf{LO_{qe}}$, which is the set of learning objects discovered by the query expansion algorithm. The detailed steps are shown in Fig. 7.

Different learners may evaluate a same learning object on different basis due to inherent characteristic differences. This relative error should be corrected to counterbalance the different learner attitudes toward a same learning object. So, a relative error score **rErrorScore** is calculated first by formula (15) for this purpose. In other words, formula (15) uses the learning experiences of other similar learners to decide how interested a target learner is possibly in a learning object.

$$\mathrm{rErrorScore}(\mathrm{uid}, \mathrm{Sim}_{\mathrm{uid,lo}}) = \left(\sum_{\mathrm{sl} \in \mathrm{Sim}_{\mathrm{uid,lo}}}^{|\mathrm{Sim}_{\mathrm{uid,lo}}|} (r_{\mathrm{sl,lo}} - \overline{r_{\mathrm{sl}}})\,\mathrm{sim}(\mathrm{uid}, \mathrm{sl}) \right) \left(\sum_{\mathrm{sl} \in \mathrm{Sim}_{\mathrm{uid,lo}}}^{|\mathrm{Sim}_{\mathrm{uid,lo}}|} |\,\mathrm{sim}(\mathrm{uid}, \mathrm{sl}) \right) \qquad (15)$$

Definition 9: Helpfulness Score. The helpfulness score (HS) is the score which is calculated by considering other similar learners' learning experiences. In other words, the helpfulness score of a learning object **HS(lo)** is predicted by aggregating and revising other similar learners' feedbacks. Formula (16) shows how to calculate the HS. Among, the rErrorScore is a relative value, so the average of past feedbacks of a learner (ex. the value $\overline{r_{\mathrm{uid}}}$ at line 2 in Figure 7) must be added to it and an absolute helpfulness score is produced.

$$\mathrm{HS(lo)} = \mathrm{avg}(\mathrm{FB}_{\mathrm{uid}}^{\mathrm{all}}) + \mathrm{rErrorScore}(\mathrm{uid}, \mathrm{Sim}_{\mathrm{uid,lo}}) \qquad (16)$$

ALGORITHM: *algorithm for calculating helpfulness score*
INPUT: A *learner's ID, the set of similar learners for ID*
OUTPUT: *Helpfulness score of a lo*

```
01  CalculateHelpfulnessScore (int uid, Set Sim_uid,lo) {
02    float hScore=0;
03    hScore = r̄_uid + rErrorScore(uid, Sim_uid,lo);
04    return hScore;
05  }
```

Figure 7. The helpfulness score calculation algorithm

4.2.3 Learning objects rating

For each learning object in the $\mathbf{LO_{qe}}$, the recommendation score (**RS**) is the aggregation of both the preference score and the helpfulness score, which are calculated according to a learner's preference and other similar learners' feedbacks. The two scores are aggregated by formula (17). All candidate learning objects in a $\mathbf{LO_{qe}}$ will be ranked by their **RSs**. The larger the RS a learning object has, the higher the priority the learning object will get.

$$\mathrm{RS}_{\mathrm{lo}} = \mathrm{wPS} + (1 - \mathrm{w})\mathrm{HS} \qquad (17)$$

The parameters, the **w** and the **(1-w)**, are used to weight complementarily the preference score and the helpfulness score. Although static values can be assigned to them (e.g. w=0.5), it is better to tune the optimal ratios for the two weights dynamically. To achieve true adaptive personalized recommendation, the proposed model adjusts values of w dynamically and periodically. Experiments will show some of the result of tuning.

4.3 Learner feedback

Feedbacks are the important information for this model to recommend learning objects. For the time being, after learning a learning object, a learner may return two kinds of feedbacks, the **content feedback** and the **preference feedback**. The former is to report whether the content of a learning object is helpful for a learner and is accorded with the learner's ability while the latter is to say whether a learner prefers the style of a learning object. For the content feedback, it can be intuitive, but for preference feedback, the evaluation is more difficult. Since the LOM of a learning object contains so many features, it's difficult to figure out exactly which features a learner prefers. Hence, two rules and a formula are designed to solve this problem.

Rule1. If a learner chooses one learning object to study, but later returns no feedback or the preference feedback is less than 3, then no increase is made to each feature value of the learning object in the learner's LPP.

Rule2. If a learner chooses one learning object to study and later returns a preference feedback greater than or equal to 3, then increase is made to each feature value of the learning object in the learner's LPP. The magnitude of the increase Δs is calculated using formula (18).

$$\Delta s = pf \times FVS \text{ , where}$$
$$FVS = \log \frac{|LO_{qe}|}{\text{\# of the LOs which own the same feature value in } LO_{qe}} \quad (18)$$

It is assumed that the distribution of feature values in all LOs is a uniform distribution. Thus, formula (18) assumes that the distribution of the feature values in LO_{qe} is also a uniform distribution. The value **pf** represents the preference feedback and the value of **FVS** represents the significance of the feature value in a LO. The value of **FVS** is higher if the feature value appears in fewer learning objects and vice versa. In other words, the feature value is seen as an important preference for the learner or not. The **FVS** might need to be revised if the distributed of the feature values is not a uniform distribution. The revision is done by formula (19). It is clear that the distribution of feature values in all LOs are considered directly and the cost in calculation is huge if there are many LOs in the LO repository.

$$FVS = \log \frac{|LO|}{\text{\# of the LOs which own the same feature value in LO}} \quad (19)$$

The purpose of the rules is that the system must understand whether a learner really prefers the style of a learning object or not. With them, the system can give and increase each feature value of a learning object a suitable score when a learner returns feedbacks for these learning objects the learner has used.

5. Experimental Evaluation

Several experiments are conducted to evaluate our approach to show its feasibility, effectiveness, and benefits. Through them the results will be analyzed in order to observe whether the learning objects recommendation model can offer adaptive and proper learning objects to learners. As mentioned before, for the experimental domain ontology in the proposed framework, an introductory java programming ontology has been built and learning objects are collected and classified to associate them to the domain ontology. It currently has totally 158 concepts and 94 relations that cover the concepts of [Data Models], [Control Structures], [Order of Execution], [Encapsulation], [Relationships among Encapsulated Components], and [Testing and Debugging], which were defined in the field of introductory curriculum in CC2001. The experiments will also introduce the evaluative measures and dynamically adjust several parameters in the recommendation algorithms to tune the variations of the model to an optimal status. To see how the experiments are evaluated, the recommendation procedures are summarized again as follows.

1. A learner enters the some query keywords (are also called original query keywords) from the user interface.
2. These query keywords are inferred and expanded by using the JAVA ontology, the JLOO, to form a new expanded query. By executing the semantic-aware concept discovery algorithm, a set of learning objects LO_{qe} will be returned.
3. For each learning object in the LO_{qe}, two kinds of score the preference score (PS) and the helpfulness score (HS), are calculated. For the preference score, the preference-based algorithm will compare the feature values of each learning object in the LO_{qe} with the preference in a learner's LPP and each learning object in the LO_{qe} will be assigned a preference score, which indicates the degree of the preference a learner is for a learning object. For the helpfulness score, the correlation-based algorithm will look for these users who are similar to a learner and calculate the helpfulness score for each learning object according to the similar users' feedbacks.

4. Lastly, the two scores, the PS and the HS, are aggregated into a recommendation score (RS) for each learning object in the LO_{qe}. Then the recommendation module uses the RS score to rank the learning objects and present the top 10 ones to the learner.

5.1 Evaluation Measures

The effectiveness of an information retrieval system is usually measured by two criteria, the "**Recall**" and the "**Precision**" rate. The definition of "**Recall**" rate is the number of retrieved relevant documents divided by the number of all the relevant documents, which are previously identified by domain experts. The definition of "**Precision**" rate is the number of retrieved relevant documents divided by the number of all retrieved documents. For the proposed model, if *Relevant* is the set of relevant learning objects for a specific query and *Retrieved* is the learning objects retrieved by the system for the specific query, then the formal definitions of **Recall** and **Precision** can be represented as the following forms:

$$\text{Recall} = \frac{\text{number of retrieved relevant LOs}}{\text{number of all relevant LOs}} = \frac{|\text{ Relevant LOs }| \cap |\text{ Retrived LOs }|}{|\text{ Relevant LOs }|}$$

$$\text{Precision} = \frac{\text{number of retrieved relevant LOs}}{\text{number of all retrieved LOs}} = \frac{|\text{ Relevant LOs }| \cap |\text{ Retrived LOs }|}{|\text{ Retrieved LOs }|}$$

In addition to the comparisons with other approach, experiments are also conducted to measure the precision of the model, in which the original learner's feedbacks and the **Mean Absolute Error (MAE)** are used to evaluate the recommendation results. Two different learner's feedbacks, the preference feedbacks and the content feedbacks, which are returned from similar learners, are employed. The preference feedback is defined as the degree of preference indicating how much a learner prefers a specific learning object, while the content feedback is to represent the degree of the preference and helpfulness other similar learners feel on a specific learning object. The MAE is the error between a learner's feedback and the system's prediction, shown as follows:

$$\text{MAE} = \frac{\sum_{i=1}^{N} |p_i - q_i|}{N},$$

where, N represents the number of comparisons. In each comparison, two kinds of MAEs are compared, the preference MAE and the helpfulness MAE. The prediction accuracy is better when the MAE value is lower.

5.2 Experiment Results and Discussion

Two series of experiments are conducted. The first one is focused on how to discover suitable learning objects for a learner. In this series, comparisons are made on the Keyword Based Discovery (KBD) and the proposed Semantic-Aware Discovery (SAD). The KBD uses a simple discovery mechanism that only calculates the degree of syntactic similarity between keywords in a learner's query and those in the descriptions of learning objects. The SAD, however, considers semantically the relations between keywords in a learner's query and those in the descriptions of learning objects by consulting the domain ontology, the JLOO. The second series use the preference-based, and the correlation-based algorithms to recommend learning objects for a learner. The experiments will demonstrates the benefits of these recommendation algorithms and checks whether the features and contents of recommended learning objects are in accord with learners' preferences and are helpful for them.

Keyword Based Discovery & Semantic-aware Discovery

In these experiments, retrieval effectiveness of different discovery approaches is quantified by standard measures of average recall and precision rates. Two aggregate metrics are used: (1) the interpolated 11-point average precision and (2) the mean average precision over the cutoff value of 2, 4, 6, 8, and 10 expanded keywords. Figure 8 shows the interpolated 11-point recall-precision curves for the SAD approach using different number of expanded keywords and the KBD approach. Obviously the SAD approach performs better than the KBD approach in precision by at least

66% improvement in average, and, when limiting the number of expanded keywords to between 2 and 6, it yields better precision than the KBD approach regardless of the recall rates. On the other hand, the result shows that the algorithm performs well while the number of expanded keyword is limited to 2, 4 and 6. When the recall is less than 10%, expanding 6 keywords yields the best performance. However in the query expansion phase, using an average precision is more adequate than using the top-ranked precision. Thus, in the second series of the experiments, the number of expansion terms was set as 4, as can be seen in the figure that SAD-4 shows the better performance than others in average.

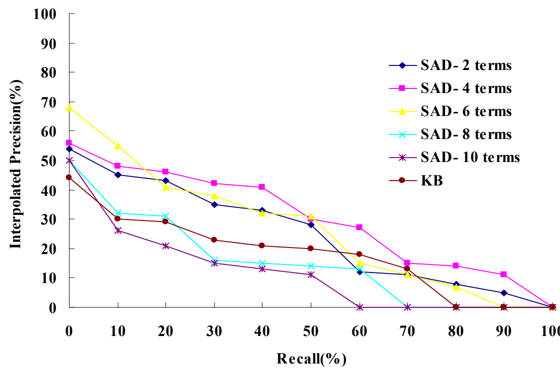


Figure 8. Interpolated Recall-Precision curve for different expanded terms (2~10) and KB

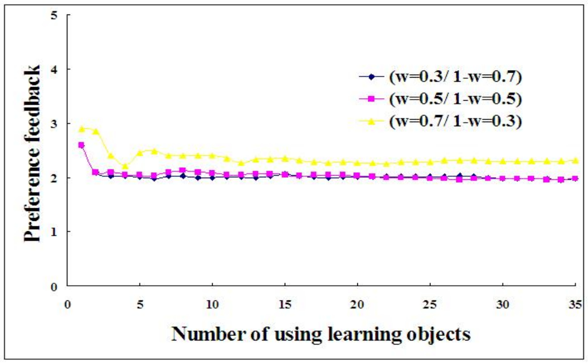
Recommendation Based on Preference and Helpfulness with Different Weights

In this series of experiments, learning objects are recommended for learners. Candidate learning objects are selected by the semantic-aware discovery algorithm (SAD) and placed to into LO_{qe} and feedbacks from learners are evaluated according to the preferences of and helpfulness for the learners. The default number of learning objects for recommendation is set to 10 and each learner has to return two kinds of feedbacks, the preference feedback and the helpfulness feedback after he/she has studied every learning object received. The system will calculate the preference and helpfulness of each learner afresh. For learners to feedback easily, the range of feedback values is divided into five levels representing *very bad, bad, common, good* and *very good* respectively. To understand how the recommendation results affect learners, not only the learners' feedbacks are observed but also the MAE values are measured between the learners' feedbacks and system predictions. Observing the learner's feedbacks directly is to understand whether the proposed model recommends learning objects in accord with learners' desire, while calculating MAEs shows whether it can infer learner's preference and interest accurately or not. In the experiment, different weights are used between the preference and the helpfulness; they are set to a proportion of *w and 1-w* where *w* is the weight of the preference and *1-w* represents the weight of the helpfulness.

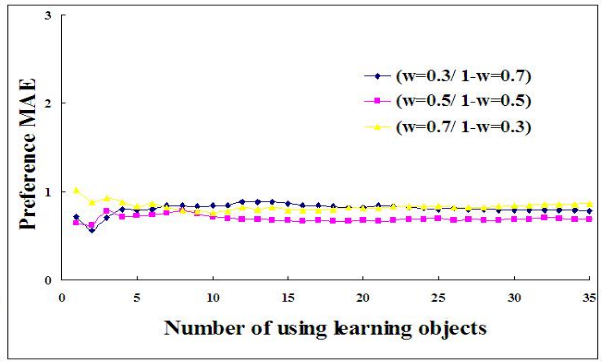
Experiment Result 1 –Analysis variation of preference feedbacks with different weights

This experiment observes the variation of preference feedbacks for the learners with different weights, i.e w= 0.3 and 1-w=0.7, w= 0.5 and 1-w=0.5, and w= 0.7 and 1-w=0.3. The results are shown in Figure 9.

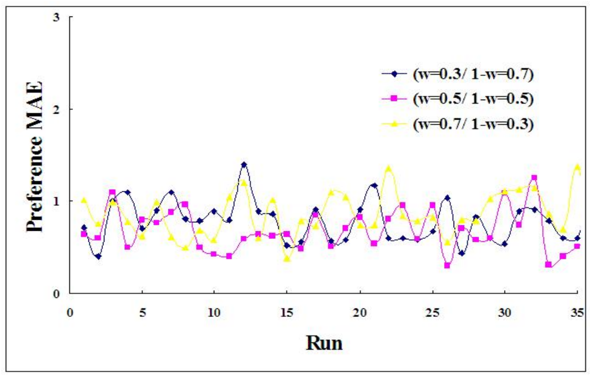
Figure 9(a) displays how soon the learners' preference patterns are formed. The x axis represents the number of learning objects studied. For example, (Y=2, X=5) means that the average score of preference feedbacks for the first 5 uses of learning objects is 2. Obviously, the (0.7/0.3) proportion performs slightly better than the others. The best average preference feedback score is about 2.3, but it does not seem to be a satisfying result. The preference MAE has to be observed to understand the reasons that result in poor results of low preference feedback score. Figure 9(b) shows how the preference MAE varies against the number of learning objects studied. All three weight proportions have their average MAEs lower than 1. This means in fact the system can infer learners' preferences accurately to recommend suitable learning objects. The reason behind the poor performance is probably that the feature values of candidate learning objects are not completely in accord with learners' preferences. Figure 9(c) demonstrates how the preference MAE varies against the number of experiments. The values oscillate between 0.5 and 1 and this proves again that the algorithms can infer learners' preferences accurately.



(a)



(b)



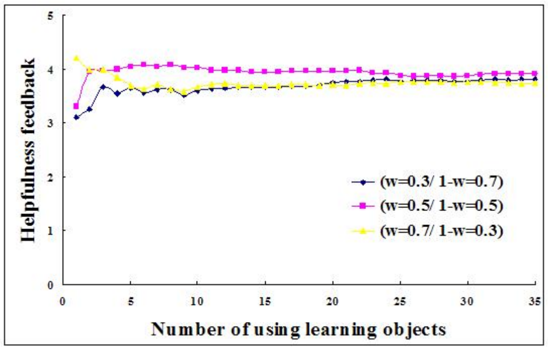
(c)

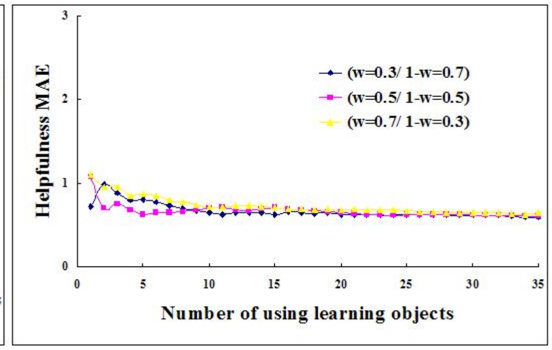
Figure 9. Comparison of preference feedbacks. (a) Direct preference feedbacks
(b) Preference MAE varies against the number of learning objects studied.
(c) Preference MAE varies against the number of experiments.

Experiment Result 2 –Analysis the variation of helpfulness feedbacks with different weights

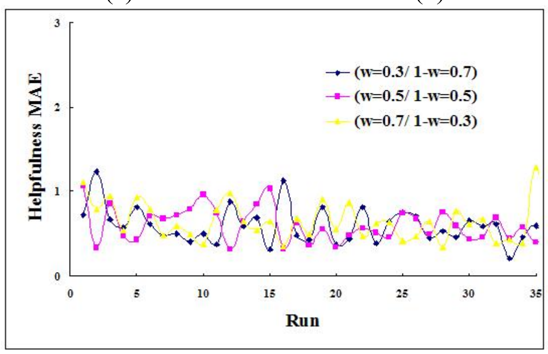
This experiment observes the variation of preference feedbacks for the learners with the same set of weight proportions as the first experiment. Learners send feedbacks according to how they feel on the content of learning objects recommended for them, helpful or not. As mentioned, five levels have been defined for the values of feedback. The results are shown in Figure 10.

In Figure 10(a), it's clear that the helpfulness feedbacks of three different weight proportions are between 3.5 and 4. As shown in Figure 10(b) the helpfulness MAE is close to 0.7 with increasing number of learning objects studied. And in Figure 10(c), it can be seen that, with more learning objects studied, the variation of content MAE becomes milder. This indicates that the system can accurately predict learners' preference and learning objects' suitability when it becomes more stable. The so-call cold-start problem can be observed here that erroneous predictions reduced when there are enough feedbacks from learners in the system. The experiment also shows that this problem can be reduced or eliminated even faster in the proposed model when learning objects are also ranked according to the average of other learners' feedbacks.





(a) (b)

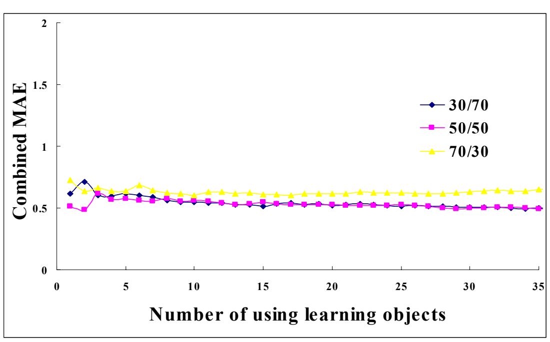


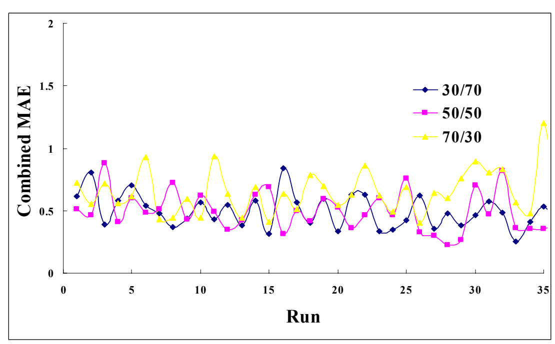
(c)

Figure 10. Comparisons of helpfulness feedbacks. (a) Direct helpfulness feedbacks.
(b) Helpfulness MAE varies against the number of learning objects studied.
(c) Helpfulness MAE varies against the number of experiments.

Experimental Result 3 – Analysis variation of combined feedbacks with different weights

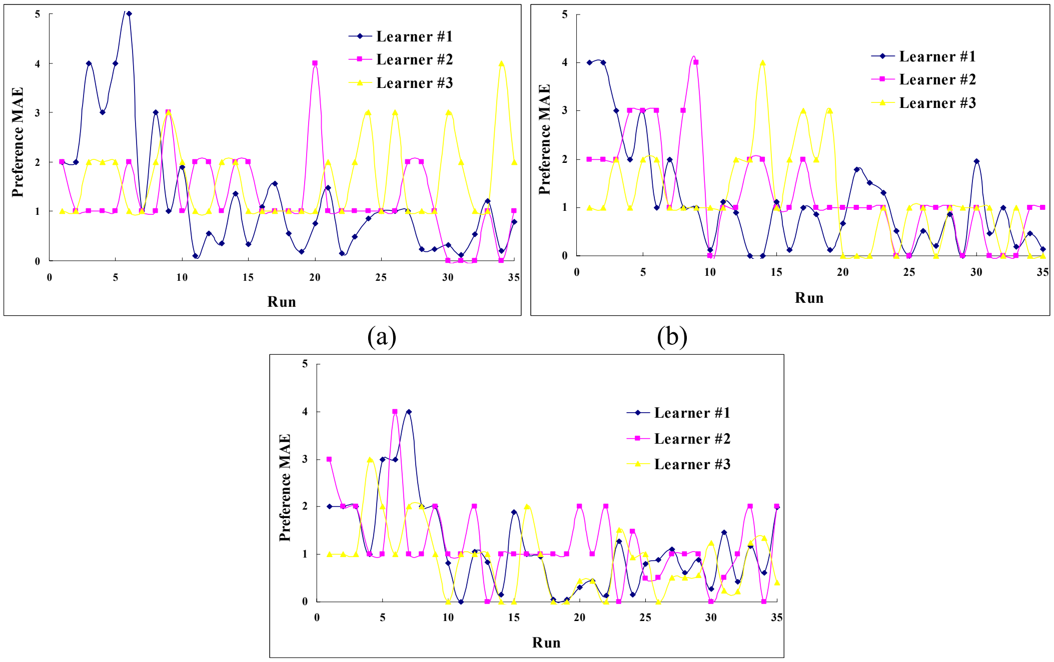
Figure 11(a) and (b) show how the aggregated MAE of both preference MAE and helpfulness MAE vary. Figure 11(a) reveals that when w=0.5/1-w=0.5 and w=0.3/1-w=0.7 better recommendations can be obtained. Similarly, the oscillations of MAE in both cases are also milder. This means that there is only a minor error at each prediction when using both proportions.





(a) (b)

Figure 11. Comparison of combined feedbacks.
(a) Combined MAE varies against the number of learning objects studied.
(b) Combined MAE varies against the number of experiments.



(a) (b)

(c)

Figure 12. Variation of preference MAE in the learners' LPP (a) Preference weight = 30% (b) Preference weight = 50%. (c) Preference weight = 70%.

Experimental Result 4 – Construction of a learner's preference pattern

In the last experiments, we describe the process of forming the learner's preference patterns (LPP). The Figure 12(a), (b) and (c) describe variations of the preference MAEs of three different weights. When the preference aspect is assigned to higher weight likes 50% or 70%, the preference patterns seem to be formed more quickly. The result displays in Figure 12(b) and (c). Although, certain of recommendations still obtain the high errors, the preference MAE of majority of recommendations are close to 1 or less than 1.

6. Conclusion

In the near future, E-learning will become more and more popular. Issues have to be solved before a learner can be really benefited from the vast amount of E-learning object repositories on the Internet. This paper proposes an adaptive recommendation model for retrieving and recommending for a learner suitable learning objects. First, the system correctly classifies learning objects to the corresponding concepts within the JLOO. Next, the intention of learners is understood by semantic-aware discovery algorithm that uses knowledge in JLOO to infer what learning objects a learner should study and what candidate learning objects the system should retrieve automatically from the repository. These suitable learning objects retrieved are presented to a learner according to the result of a ranking mechanism that employs the preference-based algorithm and the correlation-based algorithm, which not only infer a learner's preference periodically but also predict the suitability of a learning object by referencing the history of usages of other similar learners. The model has been experimentally proved efficient in the adaptive personalized learning object recommendations, and can be easily embedded into an ontology-based E-learning tutoring system of repositories.

References

ADL-1 (2001). Advanced Distributed Learning (ADL) initiative. *SCORM Specifications – The SCORM Content Aggregation Model Version 1.2*, Retrieved June 7, 2007, from, http://www.adlnet.gov/scorm/history/Scorm12/

index.aspx.

ADL-2 (2001). Advanced Distributed Learning (ADL) initiative. *SCORM Specifications – The SCORM Run-Time Environment Version 1.2*, Retrieved June 7, 2007, from, http://www.adlnet.gov/downloads/downloadpage.aspx ?ID=218.

ADL (2003). Advanced Distributed Learning (ADL) initiative. *SCORM Specifications – SCORM Version 1.3 Application Profile Working Draft Version 1.0*, Retrieved June 7, 2007, from, http://www.adlnet.gov/News/articles/ index.aspx?ID=126.

ARIADNE (1998). *The Alliance of Remote Instructional Authoring and Distribution networks for Europe*, Retrieved June 7, 2007, from, http://ariadne.unil.ch/.

Belkin , N., & Croft, B. (1992). Information Filtering and Information Retrieval. *Communications of the ACM, 35*(12), 29-37.

CC2001 (2001). *Computing Curricula of The Joint IEEE Computer Society/ACM Task Force*, Retrieved June 7, 2007, from, http://www.computer.org/education/cc2001/.

Cui, H., Wen, J. R., Nie, J. Y., & Ma, W. Y. (2003). Query Expansion by Mining User Logs. *IEEE Transaction on Knowledge and Data Engineering, 15*(4), 829-839.

Hofmann, T. (2003). Collaborative Filtering via Gaussian Probabilistic Latent Semantic Analysis. *Paper presented at the 26th Annual International ACM SIGIR Conference,* July 28-August 1, 2003, Toronto, Canada.

Hofmann, T. (2004). Latent Semantic Models for Collaborative Filtering. *ACM Transactions on Information Systems, 22*(1), 89-115.

Jin, R., Si, L., & Zhai, C. (2003). Preference-Based Graphic Models for Collaborative Filtering. *Paper presented at the 19th Conference on Uncertainty in Artificial Intelligence (UAI 2003)*, August 7-10, 2003, Acapulco, Mexico.

Jin, R., Si, L., Zhai, C., & Callan, J. (2003). Collaborative Filtering with Decoupled Models for Preferences and Ratings. *Paper presented at the International Conference on Information and Knowledge Management*, November 2-8, 2003, New Orleans, Louisiana, USA.

Jung, S. Y., Hong, J. H., & Kim, T. S. (2005). A statistical model for user preference. *IEEE Transactions on Knowledge and Data Engineering, 17*(6), 834-843.

Konstan, J. A., Miller, B. N., Maltz, D. J., Herlocker, L., Gordon, L. R. & Riedl, J. (1997). GroupLens: Applying Collaborative Filtering to Usenet News. *Communications of the ACM, 40*(3), 77-87.

Lee, M. C., Ye, D. Y., & Wang, T. I. (2005). Java Learning Object Ontology. *Paper presented at the 5th IEEE International Conference on Advanced Learning Technologies*, July 5-8, 2005, Kaohsiung, Taiwan.

Lee, M. C., Tsai, K. H., Ye, D. Y., & Wang, T. I. (2006). A Service-Based Framework for Personalized Learning Objects Retrieval and Recommendation. *Lecture Notes in Computer Science, 4181*, 336-351.

Lee, M. C., Tsai, K. H., & Wang, T. I. (2006). An Ontological Approach for Semantic-Aware Learning Object Retrieval. *Paper presented at the 6th IEEE International Conference on Advanced Learning Technologies*, July 5-7, 2006, Kerkrade, The Netherlands.

LOM (2002). *Final LOM Draft Standard*, Retrieved June 7, 2007, from, http://ltsc.ieee.org/wg12/20020612-Final-LOM-Draft.html.

Melville, P., Mooney, R. J., & Nagarajan, R. (2002). Content-Boosted Collaborative Filtering for Improved Recommendations. *Paper presented at the 18th National Conference on Artificial Intelligence*, July 28–August 1, 2002, Edmonton, Canada.

Mooney, R. J., & Roy, L. (1999). Content-Based Book Recommending Using Learning for Text Categorization. *Paper presented at the ACM SIGIR '99 Workshop on Recommender Systems: Algorithms and Evaluation*, August 19, 1999, Berkeley, USA.

Peat, H. J., & Willett, P. (1991). The limitations of term co-occurrence data for query expansion in document retrieval systems. *Journal of the American Society for Information Science, 42*(5), 378-383.

Popescul, A., Ungar, L. H., Pennock, D. M., & Lawrence, S. (2001). Probabilistic Models for Unified Collaborative and Content-Based Recommendation in Sparse-Data Environments. *Paper presented at the 7th Conference in Uncertainty in Artificial Intelligence*, August 2-5, 2001, Seattle, Washington, USA.

SCORM (2003). *Sharable Courseware Object Reference Model*, Retrieved June 7, 2007, from, http://www.adlnet.gov/downloads/downloadpage.aspx?ID=243.

Smeaton, A. F., & Rijsbergen, C. J. (1993). The retrieval effects of query expansion on a feedback document retrieval system. *The Computer Journal, 26*(3), 239-246.

Soboroff, I., & Nicholas, C. (1999). Combining Content and Collaboration in Text Filtering. *Paper presented at the International Joint Conference on Artificial Intelligence – Workshop on Machine Learning for Information Filtering*, August 1, 1999, Stockholm, Sweden.

Tran, T., & Cohen, R. (2000). Hybrid Recommender Systems for Electronic Commerce. *Proceedings of the AAAI-00 Workshop on Knowledge-Based Electronic Markets,* Technical Report WS-00-04, AAAI Press.

Wolpers, M., Najjar, J., Verbert, K., & Duval, E. (2007). Tracking Actual Usage: the Attention Metadata Approach. *Educational Technology & Society*, 10 (3), 106-121.

Tracking Actual Usage: the Attention Metadata Approach

Martin Wolpers, Jehad Najjar, Katrien Verbert and Erik Duval
Katholieke Universiteit Leuven, Belgium // {martin wolpers, jehad.najjar, katrien.verbert, erik.duval}@cs.kuleuven.be

ABSTRACT

The information overload in learning and teaching scenarios is a main hindering factor for efficient and effective learning. New methods are needed to help teachers and students in dealing with the vast amount of available information and learning material. Our approach aims to utilize contextualized attention metadata to capture behavioural information of users in learning contexts that can be used to deal with the information overload in user centric ways. We introduce a schema and framework for capturing and managing such contextualized attention metadata in this paper. Schema and framework are designed to enable collecting and merging observations about the attention users give to content and their contexts. The contextualized attention metadata schema enables the correlation of the observations, thus reflects the relationships that exists between the user, her context and the content she works with. We illustrate with a simple demo application how contextualized attention metadata can be collected from several tools, the merging of the data streams into a repository and finally the correlation of the data.

Keywords

Context, Attention Metadata, Usage Data, User Behaviour, Attention Recorders

1. Introduction

Knowledge intensive work like teaching and learning requires the handling of large amounts of information in a personalized way. Therefore, learning management systems need detailed user profiles to be able to provide personalized services (Duval & Hodgins 2003). Instead of basing personalization on stereotypes (Henze & Nejdl 2003), such systems utilize detailed information about a specific user including observations on the handling of digital content and the user attention. This allows information systems to more correctly conclude on the user aims and goals (Jones et al., 2000, Najjar, et al., 2004).

Recent research focuses on the attention of users based on the hypothesis that attention information supports correct conclusions on the user aims and goals. Attention here refers to which activities the user carries out on her computer with which content and in which context.

Two examples illustrate how observations about the attention of a user can help her to deal with large amounts of digital information. The first example, consider the scenario to enable personalized access to information. Martin is a lecturer and assembles course material for his course on “Multimedia Modelling and Programming”. By analyzing what he has done so far, and by looking at what other people following the same task have done, the system can help him find suitable learning material – suitable with respect to the course but also with respect to Martin’s knowledge and preferences derived from his previous interactions. By also taking the previous interactions of his students with the content of the course into account, the system can help Martin identify the knowledge that the students are still missing so that he can then include it in his course. Furthermore, based on the observations how the students deal with the course material Martin has provided so far, he is able to tailor the material to their needs. For example, if the majority of students prefer to work with graphical representations, Martin can tailor his course material to this need by including more images, videos, tables, etc. Without this information, Martin would include the material he thinks (but not knows) is best suited for his students.

The second example deals with the support of the system in managing the vast amount of available information, by driving the information provision through analysis results of the information sources and their handling. While Martin works with the course material, he wants to receive emails related to his course only, but wants to block out any other communications. Therefore, incoming emails from his students are shown but emails from colleagues related to completely other subjects are suppressed. In addition, if a student email asks for an appointment, the email will be automatically annotated with possible meeting times that, if acknowledged, are automatically inserted into Martin’s diary. Furthermore, while working, Martin likes to listen to music from musicals. The system has already observed this behaviour and therefore provides him with a selection of suitable titles. Incoming chats are blocked unless related to the course. The system also helps Martin find appropriate course material: while searching for course material, he is automatically pointed to recommended sources of material. The necessary recommendations are, for example, extracted from emails, documents and chats and ranked according to how Martin appreciated the sender and/or author.

What is needed to enable such scenarios is a technology that easily spans across system boundaries and captures the attention a user spends on content (Wolpers et.al. 2006). We propose a framework that is able to capture the observations about the user activities with digital content. We explain our understanding of attention, observations about the user, digital content and context in chapter 2. In order to describe the observations, we developed a metadata schema that is outlined in chapter 3. A case study in section 4 provides first examples on how advanced services use the observations made about the user, her attention and her context. Concluding this paper, section 5 discusses first results and future work.

2. Attention

Collecting appropriate data to enable improved personalized services is the focus of this paper. This is achieved by collecting and formalizing observations on how and what the user spends her attention and in which context. In general, there is no agreed definition of attention. Nevertheless, as Roda and Thomas point out (Roda & Thomas, 2006), "most researchers refer to attention as the set of processes enabling and guiding the selection of incoming perceptual information." We follow this interpretation and apply it to the everyday handling of digital content. By limiting our approach to unobtrusively observing user behaviour in dealing with information, the computer of the user is used as the major source of observations. Note, that when referring to digital content, the term document is used in the remainder of this paper. A document can be a web page, a word file, a jpeg images, an email, a chat session, an mp3 music file, etc.

The user deals with the documents in a particular way that is specific only to her. By capturing and generalizing her behaviour, emerging patterns of her behaviour can be used to describe her. For example, such patterns can be derived from data observing how the user gets the documents, e.g. via email, chat or if she found them through web search services, etc. Her behaviour while working with the documents provides further data; e.g. just storing it or copy parts to be used on a slide show, etc.

The observations can be generalized into behavioural patterns. Behavioural patterns describe in general how a user handles information, e.g. which activities she carries out with them. The comparison of behavioural patterns from various users allows clustering similar users. Based on such clusters, we expect to be able to precisely predict future steps and goals of user.

2.1 Capturing User Attention

Capturing observations about the attention of users requires solving two problems: First, applications need to be developed that capture the observations of the user attention. Such applications need to integrate into the user daily working environment without disturbing or interrupting her. Moreover, the applications need to capture the observations from existing applications of daily use, e.g. the Microsoft Office Suite, Web Browsers, Mail Clients, the WINAMP Music Player or MSN Messenger. A number of suitable tools are provided in chapter 4. Each of these tools continuously provides observations, thus generates a stream of information on the interactions of the user with the respective application.

Furthermore, user observations need to be captured in a generalized format that allows merging and processing of the various streams of observations. By merging the observations, it is possible to contextualize each observation, e.g. by identifying which activities the user carried out simultaneously or within a short time-span. For example, a context that can be identified is which music the user listened to while writing an email, with which content and to whom. Another example is with which keywords the user found relevant documents which she really wanted. We therefore speak of contextualized observations of the user attention. We broaden our notion of context by describing the context through all additional information (e.g. information about parallel activities) available at the time the user activity is taking place. For example, consider our previously outlined scenario where Martin puts course material together for his course on "Multimedia Modelling and Programming." He might stop this activity to resume it a couple of days later. We aim to keep the context in which the course material is assembled thus must also capture when Martin is resuming working on the respective course material. Therefore, from our perspective, contextual information is related to the observed user activity in time and/or content.

There are numerous approaches to capture observations about the user attention; e.g. within the European projects Nepomuk (2006), Aposdle (Lindstaedt, et al., 2006), Gnowsis (Sauermann, 2005) as well as others (Völkel & Haller, 2006), (Holz, et. al., 2006), (Braun & Schmidt, 2006), (Garofalakis, et al., 2006), (Broisin, et al., 2005), (Roda & Thomas, 2006). The focus lies on the classification of the observations according to some predefined taxonomy or ontology. The predefined ontology(ies) usually describes a specific set of activities that is usually related to some task or process. Furthermore, the underlying tasks and processes are also described through pre-configured ontologies. As this works perfectly for the purposes for which the ontologies were made, the approaches fail when the general and usually less predictable activities of users are to be observed. Therefore, observations that do not fit the classification are disregarded in these systems.

Other approaches focus on capturing observations about the user by monitoring key strokes, mouse gestures, click-streams, etc. These approaches provide a vast amount of data that is highly fine-grained. This fine-grained data is highly valuable to examine how a user used a website (Weinreich, et al., 2006a) or an information system. Nevertheless, it is quite problematic to derive user interest and behavioural patterns from such data. One reason is the noise included in the data (Weinreich, et. al., 2006b), the other is that it is not related to the user working contexts. The data is captured without keeping track of and without relating the activities where the content in question was involved in, usually because of its highly granular structure. In addition, this data is provided from one tool without taking the content into account on which the activities are performed. Therefore, the data cannot really support contextualizing the streams.

Our approach is more general, because it observes the user at the application level instead of the key-stroke level. Furthermore, our approach specifies a common schema in which the observations should be captured. This enables correlating the various application specific data streams and thus contextualizes them.

We have developed the contextualized attention metadata (CAM) schema to capture the observations. Previous versions have been published in (Najjar et.al. 2006a,b). It is based on attentionXML (2004), which is an open specification to capture data on how people use information in browsers, web pages, news feeds and blogs. This data is then analysed and provides interested users with statistical information on their interests and activities over time. Furthermore, interested parties use the data to predict trends, to identify trend setters, etc.

AttentionXML is an XML-based schema that groups the captured observations according to users. Each user has one or more feeds. A feed can be a click stream within a browser, news feeds, etc. thus all information obtained and exchanged through the web asynchronously, therefore without regarding email and chat as observation sources. Each feed has a number of properties attached that can but must not be used, e.g. the title, the URL, etc. Furthermore, some user-specific data is captured like the date and time when it caught the user attention and when the user discarded it, user specific arbitrary tags, voting information, etc. Each feed consists of one or more items which are described through a number of properties such as the global identifier (GUID), the title, when it was last read, when it was last updated, its duration, its MIME type, if the user followed any links within this item, voting data and tags.

AttentionXML is targeted to capture observations of users related to browsing behaviour and information consumption in blogs and news feeds. It therefore does not allow capturing observations related to activities like searching and downloading documents on the web, reading, writing and editing documents, listening to music, communication messages (e.g. chats), etc. Furthermore, it does not allow capturing the context within which an activity took place. We therefore propose an extension to AttentionXML that allows us to significantly broaden the types of observations that can be captured and described and the context where they occur. Our extension enables capturing the type of event (including all relevant properties) that occurs with each item. The type of event allows us to classify the event that belongs to each item. We therefore break the implicit assumption of AttentionXML up, that each item is either a news-feed, a wiki or blog item. This approach allows us to capture observations about user activities in any kind of tool, not just a browser or newsreader as in AttentionXML. We call the extension Contextualized Attention Metadata (CAM) and explain it in detail in chapter 3.

2.2 Collecting Contextualised Attention Metadata

As outlined above, we aim to collect observations in the CAM format from all applications available in the user computer environment. We identify sources along the dimensions: location of the observation generating application and its social type. The location describes where the CAM data is generated, either on the user desktop or at the server-side. The social type describes if the observations relate to the user alone or to her social interactions with other users. For example, the MS Office application or a web browser focus on the user alone, while an email and chat client provides CAM data that describes her social relations with other users. This simple classification is used to identify the various possible types of correlations of observation data streams.

Our main focus, for the moment, is on applications that are used on a daily basis by the user, like MS Office, Browsers, etc. Web browser extensions like Slogger (2003) already enable the capturing of the user browsing behaviour in web environments. Tools based on ALOCOM (Verbert, et al., 2005) enable the capturing of CAM data from MS Office tools. Examples of their application are given in chapter 4.

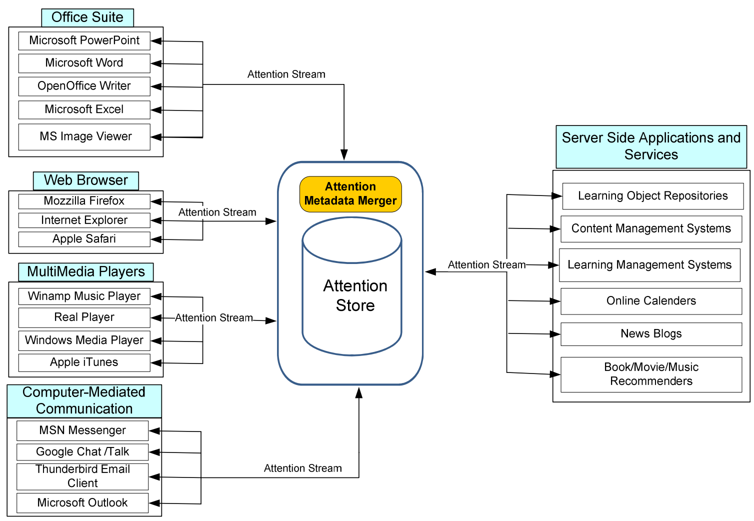


Figure 1: The CAM framework

Apart from desktop applications as sources, log files from centralized systems like web search engines, information repositories or virtual worlds like "Second Life" (2006) and online games like Warcraft (2006) provide highly valuable sources for observations about users. Recently, more and more network systems use the open log file format of the Apache foundation. Therefore, we will map the Apache open log file format to CAM and thus be able to correlate CAM data from desktop applications to CAM data from web-based systems.

The CAM framework is developed, shown in figure 1, to collect, merge and store the various streams of observations in CAM format. Each desktop application (left side of the above figure) generates a stream of observations that captures activities within the application with timestamp and content-related data. These application-related streams are collected and merged into a single stream per user. The CAM format enables therefore the provision of attention metadata streams on a per user basis that is further categorized into the various applications. Merging is therefore rather simply done based on the user category of CAM. Afterwards, the streams are stored in the CAM store.

CAM streams from central systems like web servers (right side of the above figure) leave the user category of the CAM stream empty. These streams are already merged on the application category and can simply be stored in the CAM store.

3. Contextualized Attention Metadata schema (CAMs)

Figure 2 shows the CAM schema developed to allow tracking user activities across different systems.

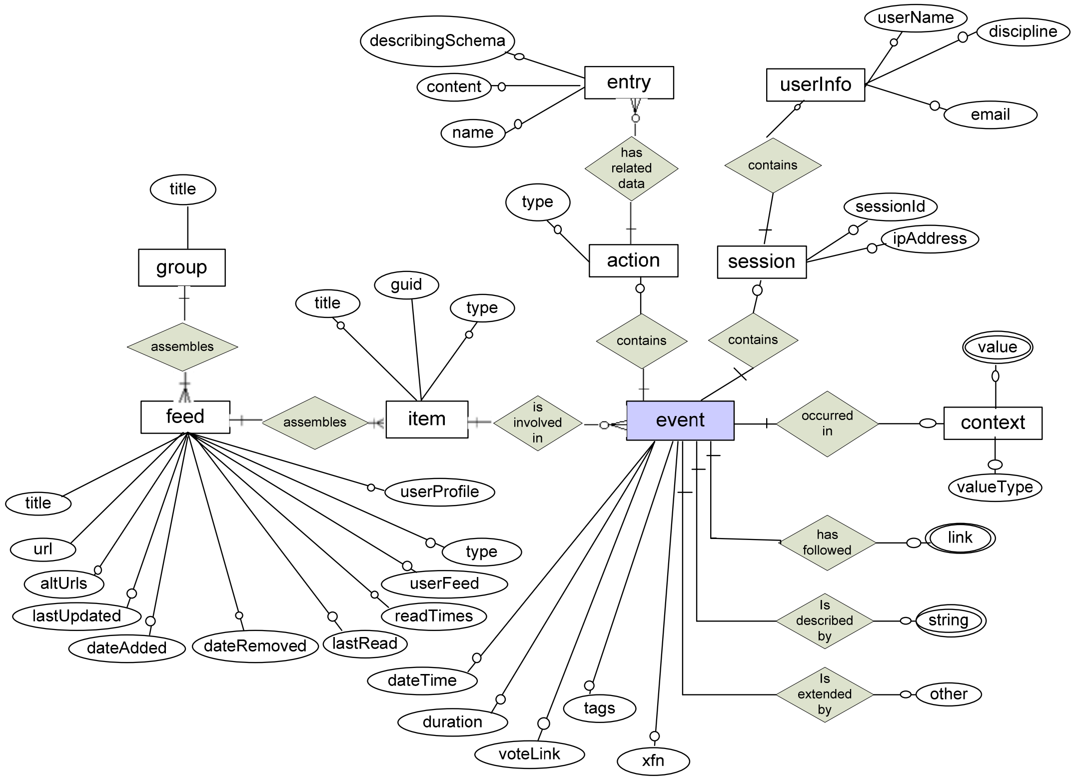


Figure 2: The CAM schema elements (in ER notation)

The CAM schema is designed to allow tracking user activities in all systems she may interact with while working with documents. As shown in figure 2, CAMs collects user attention in all systems within one *group* element. The purpose of the *feed* element is to group the attention of the user in one specific system. The *item* element collects the attention given to one specific digital document. Because of the fact that every digital document may be accessed on different occasions and be involved in different tasks (reading, editing, updating, listening to, etc.), it requires capturing information related to every event in which the document was involved in. As this is not possible in AttentionXML, we extended AttentionXML at the *item* element level, by adding the *event* element. Each item may be involved in one or more event that has different relevant information. For example, in one event, the document can be edited in one system and afterwards, in another event, the same document can be read or updated. Note that the same document may also be accessed in another system. Each time a document is accessed, more attention metadata is collected, like access datetime, context, duration spent on working with the document and data actively created by the user (ranking, annotations and tags). A teacher may use the same document in her online courses for two different groups of students and in two different contexts (time, application, and topic). In each course where the document is used, different metadata information can be collected, like the time spent on learning it, the topic (computer, management, etc.) of the course and the teacher evaluation of the usefulness of the document to each group of students (it might be well perceived by computer science students but not by physics student).

Making the *event* element central in CAM schema allows the identification and relation of information about every event the document was involved in across different systems. As also shown in figure 3, in the CAM schema the elements *duration*, *voteLink*, *xfn* and *tags* are moved from the item element into the event element. This reordering enables the identification of the duration spent with the document, tags given to the document by the user, social relationship and user experience (*voteLink*; like-dislike information) per event.

We will now describe the *item* element and its sub-elements including the *event* element, where we extend AttentionXML. The *group* element groups all attention metadata of one user in all applications she may work with (all in one group instance) while the *feed* element groups the attention of one user in one specific tool (each tool in a separate feed instance). The group and feed elements of CAM schema are the same as in AttentionXML and therefore will not be further explained.

- **Item:** the *item* element groups attention metadata of one document. Each document can be involved in different actions (read, listen to, edit, etc.), in different dates, for different periods, and in different contexts.

The *item* element has three sub-elements that do not change over the different actions and events the document may be involved in; those elements record the properties of the document itself. The data is collected here to recognize and identify the document across different systems and contexts:

  - **Title:** the *title* captures a human readable name given to the document, when the document is created or edited. This element is necessary to enable users to easily recognize the document. For example, "Global warming - Wikipedia, the free encyclopedia" is a title of a document about global warming on wikipedia.
  - **GUID:** the *guid* element represents a global unique identifier to the document within a given context. For example, http://en.wikipedia.org/wiki/Global_warming is the unique identifier that is used to locate the document with the title mentioned above on the internet.
  - **Type:** the *type* element holds the MIME technical type of the document. For example, "html" is the correct MIME type of the above document on global warming.

On the other hand, all data about the different events the document may be involved in are grouped in the event element. This data describes the attention given to the document, like the time spent with it, tags attached to the document after reading it, and the context where it was used. Each event related data is grouped in one *event* instance.

  - **Event:** the *event* element groups attention metadata of each event the document was involved in. For every event instance the following attention metadata is collected:
    - **Action:** the *action* element provides information on the action that the document was involved in (e.g. if it was inserted into local file system or digital repository, opened in a viewer application, etc.):
      - **Action Type:** the *actionType* element holds the type of action (task) the document was involved in. Its value is normally a reference to a value in the action value space. For example, the URL http://.../Actiontype/insert can be a reference to the insert value if the action was inserting a document into a repository.
      - **Entry:** the *entry* element records data related to the action performed. About the same action one or more entries can be recorded. For example, if the document was found using a query, one instance of the *entry* element can store the query terms used by the user to form her query. Another entry can store the results list of that query. In case of insertion, it also records the name of metadata schema (for example IEEE LOM or Dublin Core) used to index the document. If the action was chat conversation with other person, this element can store name of the chat partner in one entry instance and the text of the conversation in another entry instance.
    - **Date Time:** the *dateTime* element holds the date and time at which the event took place. Unlike the *item.lastRead* element in AttentionXML, this element keeps all timestamps of events where the document was involved.
    - **Duration:** the *duration* element records the time spent with the document (in seconds).
    - **Session:** the *session* element holds the information that is needed to identify the working session.
      - **Session ID**: the *sessionId* element holds a unique identifier for the session.
      - **IP Address**: the *ipAddress* element holds the IP address of the user computer.
      - **User Info**: the *userInfo* element collects information about the user name, email address and scientific discipline of the user performing the action.

The session information (*sessionId* and *ipAddress*) are used to identify the user throughout the different events and tasks she may interact in with the document. The data about the user is collected per event because the same user may have, for example, different user name, IP address every time she works with the same document. Working with a document from the computer at work or at home may result in different IP addresses for the same user.

- **Context:** the *context* element captures information that describes the environments the user may interact with. For example, information about a course (discipline and description) where a user has uploaded a document. The title and description of a course about Human Computer Interaction in the Blackboard (2006) or Moodle (2006) systems are contextual information about the usage of a document. Data captured here can be extracted from the properties of the courses where the documents is used; each course in Moodle, for example, has a title and description, this data can be used to extract information about the context. This data is essential to identify the different contexts where digital content is used. This element has two sub-elements:
    - **Value Type:** the *valueType* element holds a reference to an element of an ontology or taxonomy that describes the discipline as derivable from the value element above. The topics might serve as search terms to identify the appropriate discipline with online services like Swoogle (Ding Et al., 2004).
    - **Value:** the *value* element holds a free text that is extracted, for example, from the title of the course in applications like Moodle or Blackboard. It describes the topics of other documents involved in working with the recent document, e.g. the topics of all documents involved in a course. This element takes multi string value description entries. Those string entries can be used to express the same value in more than one language.

In addition to the information captured in the above two elements more contextual information can be extracted from other elements described earlier. For example, *event.dateTime*, event.*action.actionType* and *event.session.userInfo.discipline* are rich contextual information. Such data enable identifying interesting patterns about user attention given to documents. For instance, using the element *event.action.actionType* we know if the user is browsing a webpage, working with PowerPoint slides or listening to music, or may do all at the same time. This data can, for example, enable identifying the songs that the user listens to when working with MS PowerPoint and when browsing the web. Using the *event.dateTime* element it is possible to identify the music a user listens to in the morning from the music she listens to in the evening. In addition, it is also possible to identify the web pages that a user consults when working with PowerPoint slides.

- **Followed Links:** the *followedLinks* element groups the set of URIs included in the document and followed by the user. This can be a link to a relevant webpage of a document that is currently read by the user.
- **XFN:** the *xfn* element tracks the social relationship of the author of the document to the reader consulting the document, if the value of *event.action.actionType* element is read in a web browser application. In a chat tool, for example, it can also record the relationship of the user with other persons involved in a chatting event.
- **Vote Link:** the *voteLink* element records the user interest (likes and dislikes). The element can take one of the following values:
    - vote-for: means “I like the document.”
    - vote-abstain: means “I have neutral opinion.”
    - vote-against: means “I did not like the document.”

The data can be used, for example, to recommend a user with documents that are similar (of similar author for instance) to the documents that a user voted positively. Documents that are similar to the *vote-against* documents can be hidden from the user. More interestingly, this data can be used to rank the document based on the votes of a set of users. If many users voted for one specific document, this means that the document is interesting.

- **Tags:** the *tags* element holds a free text label or keywords that is used to describe the document. For example, attention metadata, user data and user tracking are valid tags for this paper.
- **Description:** the *description* element covers descriptive annotations that might be provided by users to express their experience with the document. It uses the value space of the IEEE LOM (2002) “Description” element which is a multi string value, to allow providing the same information in different languages. This element is useful to collect reviews or descriptive data about user experiences about the read item. Some users are interested in annotations other users provide to digital content.
- **Other:** The *other* element is used to allow providing customised elements that are not covered by this schema.

In the next section, we illustrate how attention metadata is collected in four applications using the CAMs schema.

4. Case Study

In this section, our case study explains how attention metadata is collected from four tools and then managed in an attention repository. The respective tools providing CAM data are Microsoft PowerPoint, Mozilla Firefox browser, WINAMP music tool and MSN Messenger. As explained in section 2, these four tools cover four categories of applications (Office Suite, Web Browsers, Multimedia Players and Computer-Mediated Communication respectively) that are used on a daily basis by users. Therefore, collecting and merging user attention from the tools enable building a rich source of information about the user attention, expressed as observations about her behaviour and interest.

Figure 3 illustrates the technical framework of this case study. For Microsoft PowerPoint, we generate attention streams directly in CAMs XML format using the ALOCOM framework (Verbert, et.al., 2005). In the other three tools, right side of figure 3, (Mozilla Firefox, WINAMP and MSN Messenger) attention streams are first stored in the local XML formats of each application and then transformed into CAMs XML instances.

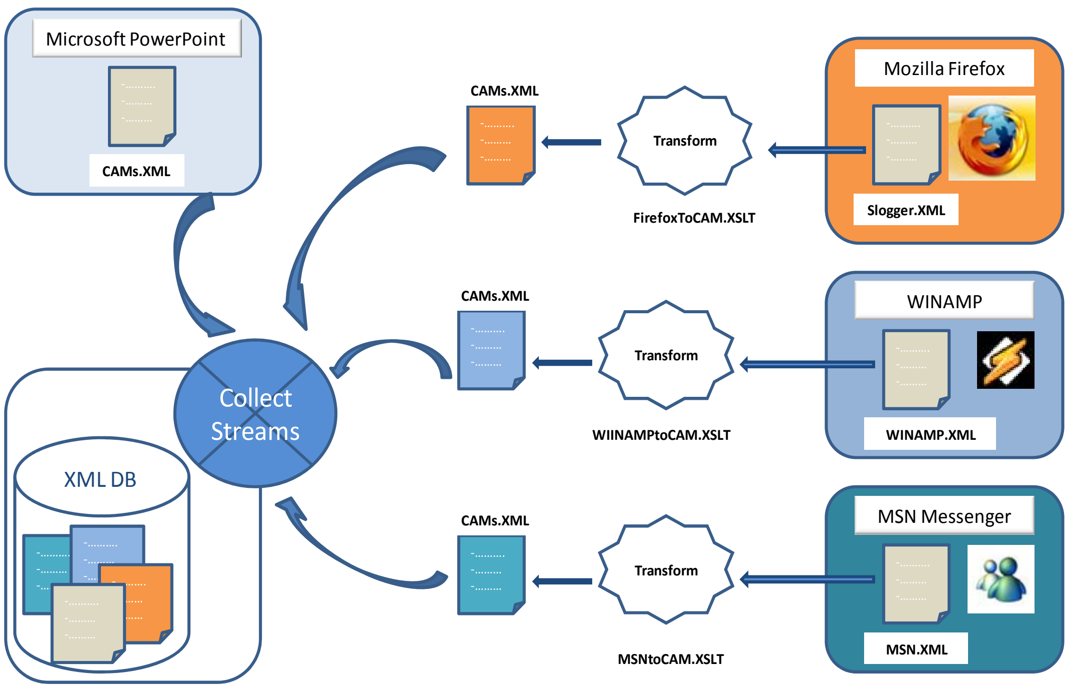


Figure 3: The framework used to collect, transform and manage attention streams

In Firefox, attention metadata is collected in the Slogger XML format, using the open source Slogger extension (Slogger, 2003). In the MSN Messenger, there is no need to install an extension to record user activities. MSN Messenger provides the tracking functionality build in: a user can simply enable or disable the logging of her messages. All user activities are logged in an MSN XML format. For WINAMP, a plug-in that was developed by (HMDB, 2006) to track user activities in WINAMP is used to collect usage information about user music activities. This data is also stored in a local XML format before transformed to CAMs.

In order to manage the attention streams in one place, we developed a component that uploads all CAMs valid streams (stored in folders on the user hard disk) into an XML database that is also installed at the client side.

In the next sub-subsections, the recording of attention metadata in each of the tools shown in figure 3 is described.

4.1 Generation of Attention Metadata in MS PowerPoint

The ALOCOM plug-in for MS PowerPoint supports capturing attention metadata from the users and the slides with which they work. The Microsoft PowerPoint .Net API (Khor, 2005) is used to extract properties from slide presentations such as the title, the author, the total editing time and the last save time, and to capture different events (open, save, print…). Other properties such as the user name and IP address are retrieved using the System.Environment and System.Net class libraries.

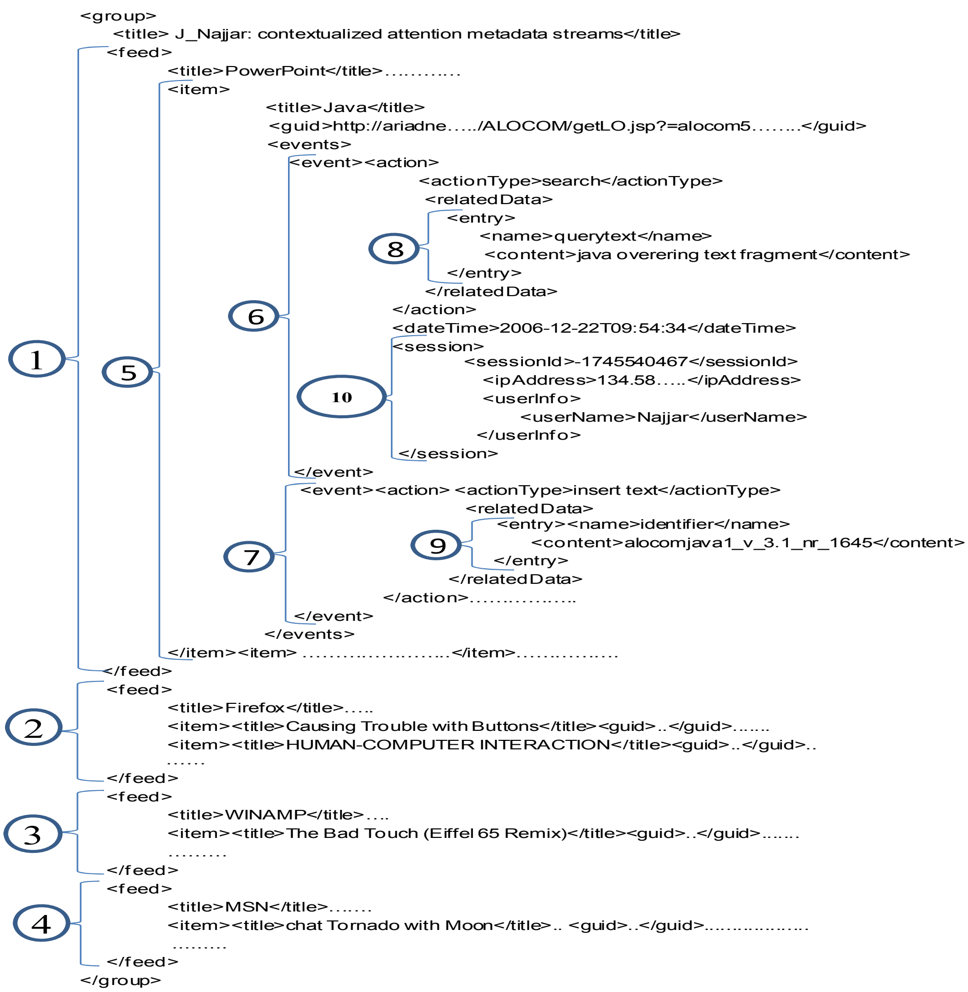


Figure 4: Part of one user CAMs instance

Furthermore, ALOCOM supports searching-for and repurposing existing documents (slides, images, text fragments, etc.). A user can specify the type of document component she is interested in (e.g. slide, diagram, table, image, text fragment), as well as keywords that best describe the component. All components that satisfy the specified search criteria are shown and the author can easily incorporate them into the presentation she is working on. Attention metadata relevant to those actions is captured directly into CAMs instances.

As shown in figure 4, all user attention information in PowerPoint is grouped in one *feed* instance (see 1 in figure 4). Data about every document (accessed slide presentation) is grouped in one *item* instance (see 5 in figure 4). For every accessed document, the following CAMs elements are captured among others:

- *group.feed.title*: the title of the presentation. The Microsoft PowerPoint API (Microsoft.Office.Interop.Powerpoint assembly) is used to retrieve this property.
- *group.feed.item.guid*: an identifier that is generated by the ALOCOM framework.

- *group.feed.item.type*: the MIME type of the document; application/powerpoint.
- *group.feed.item.lastUpdated*: the timestamp of last save time (Built in document property of the presentation document - "Last Save Time").
- *group.feed.item.event.duration*: The period of the total editing time in seconds. Its value is extracted from a built in document property of the presentation document named "Total Editing Time".

In the two events numbered 6 and 7 (shown in figure 4), attention metadata about the user interaction with the document in each event is recorded in a separate *event* instance. In the first event (6 in figure 4), the action "search" is recorded in the *actionType* element. Data related to this "search" action is stored in the *entry* element instances (see 8 in figure 4). This entry has two sub-elements; the *name* element stores the kind of the content to be stored- "querytext". The *content* element stores the real content of the data related to the search action; search terms used to search for the document. In the second event (see 7 in figure 4), the *action* element stores data about a user activity of inserting a text fragment into the slide. This text fragment is found using the ALOCOM plug-in. For this action the identifier of the document is stored in an *entry* element of *action.relatedData* element (see 9 in figure 4).

- *group.feed.item.event.session* (see 10 in figure 4):
    - *sessionIdentifier*: hash code of the time stamp
    - *ipAddress*: The System.Net API is used to retrieve this property.
    - *userName*: The System.Environment API is used to retrieve this property.
- *group.feed.item.event.dateTime*: time stamp of the event. This time is used to identify the different events that a document can be involved in.

The data recorded is data about either the document itself (e.g. *title*, *MIME type*, *guid*) or about the user (sessionId, ipAddress and userName). The reason for capturing the data is two-fold: to be able to recognize the documents and the users who worked with them. Furthermore, to identify and relate (using the *dateTime* and *session* information) the events where a user may have worked with each document.

4.2 Collection of Attention Metadata from the Firefox Browser

Figure 4 also presents part of an attention stream generated by using the Firefox browser. As described in the previous section, all Firefox attention streams are grouped in one *feed* element (see 2 in figure 4). This example shows the user attention given to web pages (items) she accessed while working on preparing a Human Computer Interaction lesson. The user has accessed a set of learning documents (figure 4 shows attention given to only two accessed pages). The first document is a paper about the design of buttons in interface design. The second document is a link to a book by the author of the paper.

In this context, the following elements of the CAM schema for each accessed web page are captured in the Firefox browser, using the Firefox Slogger extension. For each page (item), the following information is captured among others:

- *group.feed.item.title*: title of the accessed document (page). For example, see 2 in figure 4, the title of one webpage about the design of buttons in the interface design by Alan Dix is recorded.
- *group.feed.item.title.guid*: the primary URL of the webpage.
- *group.feed.item.dateTime*: the timestamp of access time.
- *group.feed.item.event.tags*: user tags given to the accessed webpage, free text tags in a folksonomy (Gruber, et al., 2004) approach. These tags can be provided as labels in Firefox Slogger.
- *group.feed.item.event.followedLinks*: the links to web pages (or any other documents) the user followed from the current web page; the navigated links get recorded as new items with their relevant attention data. By tracking and relating those followed links, relationship models between documents can be built. This data supports determining the user navigation and reading patterns and can be used to build relations between the accessed documents. For instance (see 2 in figure 4) while reading the paper about the design of buttons in interface design by Alan Dix, the user followed the link to Alan Dix book "HUMAN-COMPUTER INTERACTION" which is available as a reference in the webpage the user was initially busy with.

The recorded data help to determine the reading pattern of the user and to determine the topics she is interested in. This can be achieved, for example, by extracting popular keywords from titles and URLs of accessed web pages. In addition, such keywords can be extracted from the annotations (recorded in *event.description* element) and tags (recorded in *event.tags* element) a user may attach to those pages after reading them.

4.3 Collection of Attention Metadata from WINAMP Music Application

Data about the attention given to music files are captured using an attention plug-in developed by HMDB (2006) to visualize user attention in the WINAMP application. The following elements of the CAM schema are captured (see 3 in figure 4) for each accessed music item (file).

- *group.feed.title*: title of the accessed document (music file) which is in general the name of the accessed song generated by the used music attention plug-in.
- *group.feed.guid*: the primary URI of the accessed document. In this case study, we used the combination of the song title and the artist name as an identifier for each document. Both values are generated by the used music attention plug-in.
- *group.feed.item.event.dateTime*: timestamp of the event.
- *group.feed.item.event.duration*: the time duration the document was played.
- *group.feed.item.event.action*
    - *actionType*: the type of action that was applied on the song, for example, "play" if the user played the song, or actions like "volume up" and "volume down" can also be recorded. However, the used plug-in we used in this case study does not log such detailed data.
    - *relatedData*: here, we can use this element, for example, to store data about the artist, album or the genre of the played music. In case of the volume up/down actions, this element can store the relevant values.

Data logged about user attention given to the songs she listened to is a rich source of information that can enable building a music user profile. This profile represents the user quite precisely, because it is created based on the songs she actually played and the time she spent on listening to them. For example, the user may listen to the full song in her play list (e.g., 4:23 minutes); the actual length of the song can also be retrieved using the music attention plug-in. On the other hand, the same user may listen to only the first minute of the second song on the same play list. This data enables us to determine:

- The genre of the songs the user listens to. Also, what kind of music she listens to during different periods of the day.
- The artists she likes most because she listens most of the time to their songs.
- The songs the user skips at her play lists. This can be derived from the duration the song is played and the actual length of the song.

Using the above data, it is possible to determine the genre of music the user listens to when she works on different tasks. This can be achieved by combining the music attention of one user with her attention in other applications. For example, combing the Firefox attention data with the music attention of the same user specifies the kind of music she listens to when reading a specific type of web pages, e.g. news pages. It is also possible to determine the kind of music the user listens to when she chats with her colleagues or when assembling course material in Microsoft PowerPoint or other applications.

4.4 Collection of Attention Metadata from MSN Messenger

As mentioned earlier, the attention metadata is extracted from the MSN Messenger XML log files (local format) stored on the hard disk of the user. Mapping the collected data into CAM schema is different from the previously stated examples of MS PowerPoint and the Firefox web browser. In this case we deal with contacts (users) and messages only. In the previous tools, the focus was on documents that are accessed by users who are involved in different events. Here, the focus is on users who are involved in chat events; the chat messages themselves are the documents the users interact with. Therefore, we mapped the data as follows:

- *group.feed.item* element groups all chat events that a user has with one specific user.
- *group.feed.item.event* element groups the messages that occurred in one MSN session. A session in MSN Messenger ends by the time a user closed the chat window with the other chat partner.

- Every exchanged message text is stored in a separate entry under the *event.action.relatedData.content* element. In this case, the value for *event.action.relatedData.name* is "messagetext" and the value "chat" is stored in *event.action.actionType.*

4.5 Management and Usage of Attention Metadata

So far, we discussed the collection of attention metadata from different applications. The attention streams of the four tools in this case study are merged into one XML stream using the *group* element (see figure 4). Attention metadata of each tool is represented in one feed instance. The whole CAMs XML document representing the user attention metadata is stored in an Exist database (Exist, 2006). XQuery statements are used to identify and relate the different attention streams and group them into one document which is exemplified below.

```
xquery version "1.0";
{
for $i in 1 to 10
let $x := distinct-values(for $r in collection('/db/CAM')/group/feed/item[title ne
          '']/events/event/datetime order by $r descending  return distinct-
           values($r/../../../guid))
return
  <table id="{collection('/db/CAM')/group/feed/item[guid eq $x[$i]]/../title/text()}">
        <tr>
            <td>{let $u := collection('/db/CAM')/group/feed/item[guid eq $x[$i]] return
             distinct-values(collection('/db/CAM')/group/feed/item[guid eq
             $x[$i]]/title/text())
             {let $y:=collection('/db/CAM')/group/feed/item[guid eq
               $x[$i]]/events/event/datetime  return
                   $y[last()]} </td>
        </tr>
  </table>
}
```

Figure 5: An XQuery script to retrieve last 10 documents a user worked with

Figure 5 presents an XQuery example that lists the 10 last documents a user worked with in the four applications.

The script identifies the last 10 documents that a user worked with in all applications (using the *event.dateTime* element, see 1 in figure 5). It then lists the titles and access time of every relevant document (see 2 in figure 5). The query runs against the CAM collection (XML folder) where the XML CAMs document is stored.

The next step is making use of the collected rich attention metadata that tracks what a user was giving attention to and was interested in. The first obvious usage for this data is building a user attention profile that represent user actual interest based on her pervious interaction with different tools and the documents she worked with. In order to achieve this, users and documents need to be identified among different applications.

Identifying the user in this case study (desktop applications) is not a problem, since the client XML repository stores only the data of one user. Even if more users would store their attention metadata in the repository, the *group* element would allow the clear identification of each user. Here, we will consider each document with unique identifier a user worked with as a different document.

Figure 6 shows a screenshot of our simple demo tool that explores general information about user attention. The figure shows the last 10 documents (see 1 in figure 6) in the four tools that the user gave attention to; the XQuery script shown in figure 5 is used to retrieve those documents. At the left side of the tool, the keywords that represent the user interest are shown (see 2 & 3 in figure 6). Those keywords are extracted from the following elements captured about each document the user worked with in the four tools:

- Title of document.
- Descriptions a user gives to accessed documents, using the *event.description* element
- Tags a user may attach to accessed documents, using the *event.tags* element.

➢ Action related data, data about search terms a user used to find relevant information, artists of songs, chat text messages, etc, using the *event.action.relatedData* element.

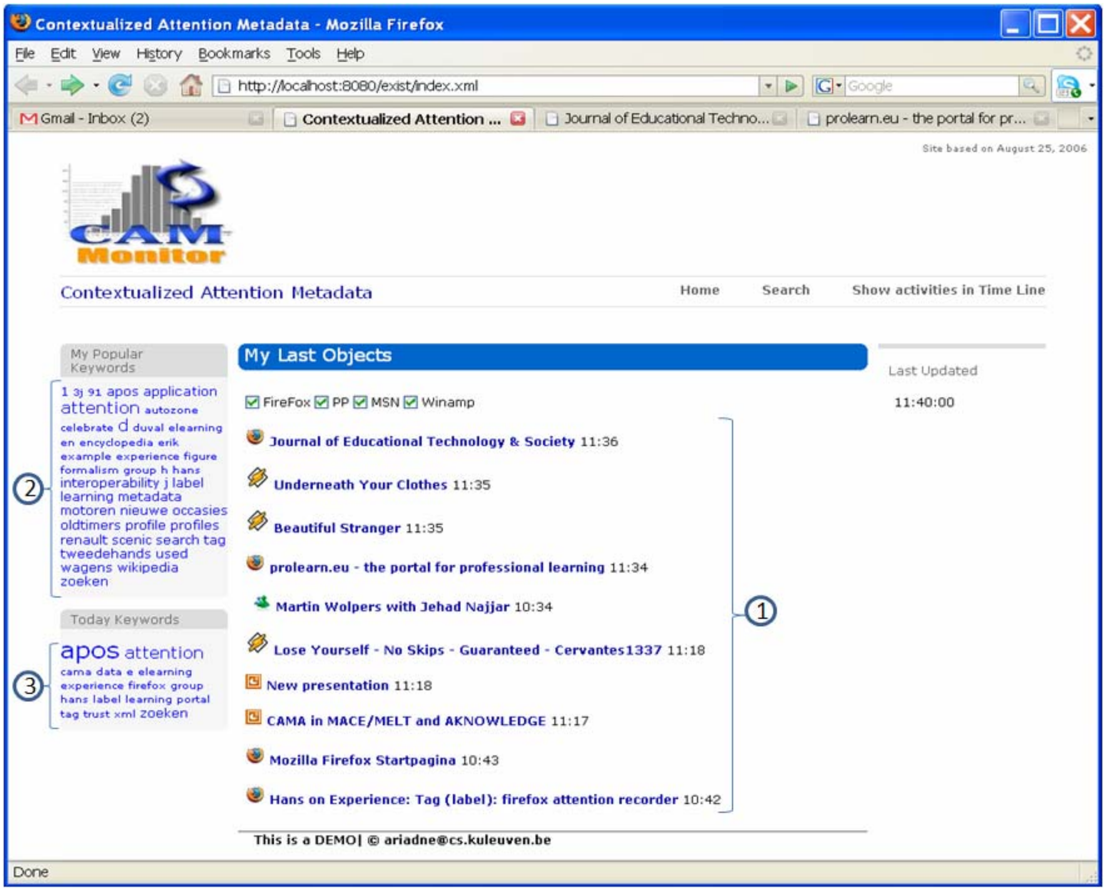


Figure 6: Screenshot of the Attention Monitor Tool

As shown in figure 6, the popular keywords represent user interest. The last documents used by the user reflect on the tasks the user was involved in. The data enables building user attention and interest profiles. Such profiles can later be related to other peoples' profiles. For example, the profile keeps information about the tools that a user frequently uses, the time spent (*duration*) in those tools and the respective documents, the datetime a user access the tools and documents (*dateTime*), the courses the user works on and the keywords that represent her interest.

As mentioned earlier the profiles of user attention represent user attention and interest across different systems. By mining the collected information from the different tools, the profile can hold information about her musical behavioural pattern, for example, "whenever a user works in Microsoft PowerPoint she listens to Classic music, while she listens to Rock music when browsing the web." Another pattern can be "website X and Y are accessed in about 80% of the times a user starts a new slide presentation in Microsoft PowerPoint" or "Slides X and Y are reused in about 85% of user created presentations". Such patterns can be used to alert or recommend relevant information based on the interest or task that the user is currently working on. Furthermore, such patterns enable the visualisation of user activities and attention to easily generate work reports.

5. Conclusions and Future Work

One of the main problems today is the large amount of information that teachers and learners need to deal with on a daily basis. We aim to use observations about the user and her attention to help her digesting the information flood.

This paper extends and builds on our earlier work on attention metadata. In (Najjar, et al., 2005), a simple conceptual attention metadata framework that uses the AttentionXML schema to capture attention metadata in learning systems is proposed. In (Najjar, et. al., 2006a), an extension for AttentionXML schema is proposed, to enable collection attention metadata from different sources. In (Najjar, et. al., 2006b), the use of attention metadata for technology enhanced learning was discussed. In (Wolpers, et. al., 2006), the use of attention metadata in knowledge management systems is discussed. In this paper, we present the stable version of the schema, which enables collection of contextualized attention metadata across systems boundaries, with a detailed explanation of its components and their use as well as a sample application demonstrating first correlation examples.

We start with the collection of contextualized attention metadata that describes in detail in which context a user spends her attention on which content. We therefore propose a conceptual framework and the contextualized attention metadata schema that enables the recording and management of rich and detailed sets of data about user attention given to documents in different applications. As a case study, we generate attention metadata from a number of desktop applications like MS PowerPoint, WINAMP music player, MSN Messenger and Firefox browser and show in a demo application a time-based sequence of activities. Such correlations of contextualized attention already indicate how useful its explanation can be for specific users; e.g. for personalization and information management in the learning context.

Future work includes the collection of more attention metadata from several applications to form a rich and large base of attention metadata from users. Based on this repository, we will develop further algorithms to extract knowledge about the user, the context and the content. A simple example is statistical data about the usage of learning documents. Advanced examples include the identification and extraction of patterns of behaviour, e.g. through the correlation of activities carried out by one user and related to one context and/or one content. In addition, the clustering of users based on observations about their behaviour in certain contexts provides information about the sequences of activities carried out by users. Such clusters would then allow the generation of recommendations of similar users, eventually combining them with the behavioural patterns to more precisely identify next steps. Ultimatively, behavioural patterns and similarity measures among users can be used to detect the finalisation of user goals and, subsequently, the identification of user aims and goals.

In parallel to the collection of large amounts of attention metadata, an empirical evaluation study will be conducted to determine the usefulness and efficiency of attention metadata in facilitating the user tasks, and in enhancing user experience with the tools she works with. However, the evaluation of such systems is quite challenging because attention metadata is about detailed information about user behaviour and interest. Therefore, the evaluation will be designed to determine the efficiency of the contextualized attention metadata approach, the used schema and framework. Furthermore, we will conduct research in applying existing solutions to the privacy and security issues at hand when dealing with this highly personal data. An example of our evaluation approach is the determination of the difference in task completion, before and after using attention metadata -supported systems. In addition, interviews and questionnaires may be used to determine the user satisfaction with the attention-supported systems; like comparing information retrieval attention-supported systems against current systems.

The CAM schema presented in this paper is now being implemented in a number of European projects like MACE (2006), MELT (2006) and AKNOWLEDGE (2006). The schema will be used to facilitate the collection, management and exchange of user attention metadata form different tools in those projects. By applying the schema in these projects, we will be able to evaluate our approach and identify further research questions related to contextualized attention metadata.

6. References

AKNOWLEDGE (2006). *Accessible & Open Knowledge Infrastructure for Flanders,* Retrieved June 8, 2007, from https://projects.ibbt.be/acknowledge/.

Aposdle (2006). *EU project APOSDLE*, Retrieved June 8, 2007, from http://www.aposdle.tugraz.at/.

AttentionXML (2004). *AttentionXML specifications*, Retrieved June 8, 2007, from http://developers.technorati.com/wiki/attentionxml.

Braun, S., & Schmidt, A. (2006). Don't annoy the Informal Teacher: Context-Aware Mediation of communication for Workplace Learning, *Paper presented at the 6th International Conference on Knowledge Management,* September 6-8, 2006, Graz, Austria.

Broisin, J., Vidal, P., & Duval, E. (2005). A Model driven Approach for the Management of Learning Object Life Cycle. *Paper presented at the Intelligent, Interactive, Learning Object Repositories Network (I2LOR)*, November 14-18, 2005, Vancouver, Canada.

Cardinaels, K., Meire, M., & Duval, E. (2005). Automating Metadata Generation: the Simple Indexing Interface. *Paper presented at the International World Wide Web Conference*, May 10-14, 2005, Chiba, Japan.

Chirita P. A., Firan, S. C., & Nejdl, W. (2006). Summarizing Local Context to Personalize Global Web Search. *Paper presented at the ACM Conference on Information and Knowledge Management (CIKM)*, November 6-11, 2006, Arlington, Virginia, USA.

Ding, L., Finin, T., Joshi, A., Pan, R., Cost, R. S., Peng, Y., Reddivari, P., Doshi, V., & Sachs, J. (2004). Swoogle: A Search and Metadata Engine for the Semantic Web. *Paper presented at the ACM Conference on Information and Knowledge Management (CIKM)*, November 8-13, 2004, Washington D.C., USA.

Duval, E., & Hodgins, W. (2003). A LOM Research Agenda. *Paper presented at the 12th International Conference on World Wide Web*, 20-24 May 2003, Budapest, Hungary.

Exist (2006). *Exist open source database,* Retrieved June 8, 2007, from http://exist.sourceforge.net/.

Garofalakis, J., Giannakoudi, T., & Sakkopoulos, E. (2006). Semantic Web Site Usage Analysis: The ORGAN System. *Paper presented at the World Wide Web 2006 Workshop Logging Traces of Web Activity: The Mechanics of Data Collection*, May 23, 2006, Edinburgh, UK.

Gonçalves, M., Panchanathan, G., Ravindranathan, U., Krowne, A., Fox, A. E., Jagodzinski, F., & Cassel, L. (2003). The XML Log Standard for Digital Libraries: Analysis, Evolution, and Deployment. *Paper presented at the Third Joint Conference in Digital Libraries*, May 27-31, 2003, Houston, Texas.

Gruber, T. (2005). Folksonomy of Ontology: A Mash-up of Apples and Oranges. *Paper presented at the First on-Line conference on Metadata and Semantics Research (MTSR'05)*. Retrieved June 8, 2007, from http://tomgruber.org/writing/ontology-of-folksonomy.htm.

Henze, N., & Nejdl, W. (2003). Logically Characterizing Adaptive Educational Hypermedia Systems. *Paper presented at the workshop on Adaptive Hypermedia and Adaptive Web-Based Systems, Session at WWW2003 Conference*, May 20, 2003, Budapest, Hungary.

HMDB (2006). *Case Study on Visualization of AttentionXML*, Retrieved June 8, 2007, from http://ariadne.cs.kuleuven.be/infovis/casestudies.php#attention.

Holz, H., Rostanin, O., Dengel, A., Suzuki, T., Maeda, K., Kanasaki, K. (2006). Task-based Process Know-how Reuse and Proactive Information Delivery in TaskNavigator. *Paper presented at the ACM Conference on Information and Knowledge Management (CIKM) 2006*, November 6-11, 2006, Arlington, VA, USA.

IEEE LOM (2002). *IEEE Learning Object Metadata*, Retrieved June 8, 2007, from http://ltsc.ieee.org/wg12/.

Jones, S., Cunningham, J. S., McNab, J. R., Boddie, J. S. (2000). A transaction log analysis of a digital library. *International Journal on Digital Libraries, 3*(2), 152-169.

Khor, M. S., & Leonard, A. (2005). *Installing and Using the Office 2003 Primary Interop Assemblies, Microsoft Office 2003 Technical Articles,* Retrieved June 8, 2007, from http://msdn2.microsoft.com/en-us/library/aa159923(office.11).aspx.

Lindstaedt, S., Ley, T., & Ulbrich, A. (2006). APOSDLE – New ways to work, learn and collaborate. *Paper presented at the 6th International Conference on Knowledge Management*, September 6-8, 2006, Graz, Austria.

MACE (2006). *Metadata for Architectural Contents in Europe*, Retrieved June 8, 2007, from http://www.mace-project.eu/.

MELT (2006). *Metadata Ecology for Learning and Teaching*, Retrieved June 8, 2007, from http://info.melt-project.eu/ww/en/pub/melt_project/about.htm.

Moodle. (2006). *Moodle Course Management System (CMS)*, Retrieved June 8, 2007, from http://moodle.org/.

Najjar, J., Meire, M., & Duval, E. (2005). Attention Metadata Management: Tracking the Use of Learning Objects through Attention.XML. *Paper presented at the ED-MEDIA conference*, June 27-July 2, 2005, Montreal, Canada.

Najjar, J., Ternier, S., & Duval, E. (2004). User Behavior in Learning Objects Repositories: An Empirical Analysis. *Paper presented at the ED-MEDIA conference*, June 21-26, 2004, Lugano, Switzerland.

Najjar, J., Wolpers, M., & Duval, E. (2006a), Attention Metadata: Collection and Management. *Paper presented at the World Wide Web 2006 Workshop Logging Traces of Web Activity: The Mechanics of Data Collection*, May 23, 2006, Edinburgh, UK.

Najjar, J., Wolpers, M., & Duval, E. (2006b). Towards Effective Usage-Based Learning Applications: Track and Learn from User Experience(s). *Paper presented at the IEEE International Conference on Advanced Learning Technologies (ICALT 2006)*, July 5-7, 2006, Kerkrade, The Netherlands.

Nepomuk (2006). *Nepomuk Semantic desktop*, Retrieved June 8, 2007, from http://nepomuk.semanticdesktop.org.

Neven, F., Duval, E., Ternier, S., Cardinaels, K., & Vandepitte, P. (2003). An Open and Flexible Indexation and Query tool for ARIADNE. *Paper presented at the ED-MEDIA conference*, June 23-28, 2003, Honolulu, Hawaii.

Roda C., & Thomas J. (2006). Attention Aware Systems: Theories, Application and Research Agenda. *Journal on Computers in Human Behaviour, 22*, 557-587.

Sauermann, L. (2006). The Semantic Desktop - a Basis for Personal Knowledge Management. *Paper presented at the 5th International Conference on Knowledge Management*, June 29 – July 1, 2005, Graz, Austria.

Second Life (2006). *Second Life Viewer*, Retrieved June 8, 2007, from http://www.secondlife.com.

Slogger (2003). *Mozilla Firefox Extension: Log Browsing History*, Retrieved June 8, 2007, from https://addons.mozilla.org/firefox/143/.

Verbert, K., Jovanovic, J., Gasevic, D., & Duval, E. (2005). Repurposing Learning Object Components. *Paper presented at the OTM 2005 Workshop on Ontologies*, *Semantics and E-learning*, November 3, 2005, Agia Napa, Cyprus.

Völkel, M., & Haller, H. (2006). Conceptual Data Structures (CDS) -- Towards an Ontology for Semi-Formal Articulation of Personal Knowledge. *Paper presented at the 14th International Conference on Conceptual Structures*, July 16-21, 2006, Aalborg, Denmark.

Weinreich, H., Obendorf, H., & Herder, E. (2006a). Data Cleaning Methods for Client and Proxy Logs. *Paper presented at the World Wide Web 2006 Workshop Logging Traces of Web Activity: The Mechanics of Data Collection*, May 23, 2006, Edinburgh, UK.

Weinreich, H., Obendorf, H., Herder, E., & Mayer, M. (2006b). Off the Beaten Tracks: Exploring Three Aspects of Web Navigation. *Paper presented at the World Wide Web conference 2006*, May 23-26, 2006, Edinburgh, UK.

Wolpers, W., Martin, G., Najjar., & Duval, E. (2006). Attention Metadata in Knowledge and Learning Management. *Paper presented at the 6th International Conference on Knowledge Management*, September 6-8, 2006, Graz, Austria.

El-Bishouty, M. M., Ogata, H., & Yano, Y. (2007). PERKAM: Personalized Knowledge Awareness Map for Computer Supported Ubiquitous Learning. *Educational Technology & Society*, 10 (3), 122-134.

PERKAM: Personalized Knowledge Awareness Map for Computer Supported Ubiquitous Learning

Moushir M. El-Bishouty, Hiroaki Ogata and Yoneo Yano
Department of Information Science and Intelligent Systems, Tokushima University, Japan // Tel: +81-886-56-7495 // Fax: +81-886-23-2761 // {mbishouty, ogata, yano}@is.tokushima-u.ac.jp

ABSTRACT

This paper introduces a ubiquitous computing environment in order to support the learners while doing tasks; this environment is called *PERKAM* (PERsonalized Knowledge Awareness Map). *PERKAM* allows the learners to share knowledge, interact, collaborate, and exchange individual experiences. It utilizes the RFID ubiquities technology to detect the learner's environmental objects and location, then recommends the best matched educational materials and peer helpers in accordance with the detected objects and the current location. This environment provides the learner with *Knowledge Awareness Map*, which visualizes the space of the environmental objects that surround the learner, the educational materials space, and the peer helpers' space. *PERKAM* system was implemented and an experiment was done in order to evaluate the system performance and the learner's satisfaction. This paper illustrates the design, the implementation and the evaluation of this environment, and it focuses on *Knowledge Awareness Map*, which is personalized according to the learner's current need and location.

Keywords

Ubiquitous Learning, Mobile Learning, Awareness, RFID, Collaboration

Introduction

Ubiquitous computing is a new information and communication technology that utilizes a large number of cooperative small nodes with computing and/or communication capabilities such as handheld terminals, smart mobile phones, sensor network nodes, contact-less smart cards, and RFID (Radio Frequency Identification)…etc (Sakamura & Koshizuka, 2005). The RFID system (Klaus & Rachel, 2000) consists of a tag, which is made up of a microchip with an antenna, and an interrogator or reader with an antenna. The reader sends out electromagnetic waves. The tag antenna is tuned to receive these waves. A passive RFID tag draws power from a field created by the reader and uses it to power the microchip's circuits. The chip then modulates the waves that the tag sends back to the reader and the reader converts the new waves into digital data.

Computing becomes ubiquitous. The knowledge, workers use in computing and communication services, is less limited to solitary moments at an office desk. Instead, it is extended in multifaceted ways to all aspects of the life, both public and private (Yoo & Lyytinen, 2005). The challenge of the future computer systems is therefore not to provide information at anytime and at anywhere but to say the right thing at the right time in the right way to the right person (Fischer, 2001; Fischer & Konomi, 2005). Ubiquitous computing evolution has recently been accelerated by improved wireless telecommunications capabilities, open networks, continuous increasing in computing power, improved battery technology, and the emergence of flexible software architectures. With those technologies, an individual learning environment could be embedded in daily real life (Ogata & Yano, 2004). Day after day, handheld devices became cheaper for a wide rang of people. Meanwhile, mobile devices are now being introduced as learning devices and some researches use them as collaborative tools (Cole and Stanton, 2003). The main characteristics of a Computer Supported Ubiquitous Learning (CSUL) environment are shown as follows (Chen, et al., 2002; Curtis, et al., 2002):

Permanency: Learners never lose their work unless it is purposefully deleted. In addition, all the learning processes are recorded continuously everyday.

Accessibility: Learners have access to their documents, data, or videos from anywhere. That information is provided based on their requests. Therefore, the learning involved is self-directed.

Immediacy: Wherever learners are, they can get any information immediately. Thus, learners can solve problems quickly. Otherwise, the learner can record the questions and look for the answers later.

Interactivity: Learners can interact with experts, teachers, or peers in the form of synchronous or asynchronous communication. Hence, the experts are more reachable and the knowledge becomes more available.

Situating of instructional activities: The learning could be embedded in our daily life. The problems encountered as well as the knowledge required are all presented in their natural and authentic forms. This helps learners to notice the features of the problem situations that make particular actions relevant.

Moreover, computer supported ubiquitous learning environment could be Computer Supported Collaborative Learning (CSCL) environment (O'Malley, 1994) that focuses on the socio-cognitive process of social knowledge building and sharing (Yoo & Lyytinen, 2005). The ubiquitous computing environments strongly support collaborative and situated learning approach. The use of ubiquitous computing tools within a situated learning approach, is recommended to facilitate the students' attainment of curricular content, technology skills, and collaboration skills (Lin et al., 2005).

Many teachers and learners believe that *learning by doing* (Schank, 1995) is the best way for learning. In *learning by doing* model, the teachers identify a specific set of skills to teach, embed that skills in a task, activity, or a goal that the student will find it interesting or motivational, then the teachers can evaluate the learner's understanding and skills according to how much the learner successes to reach to the goal. While the learner is practicing to reach to the goal, he/she usually looks for some knowledge. There are two logic ways to get the desired knowledge, one way is to refer to one or more of educational materials that match the learner's needs like books, journals, or video lectures. The other way is to ask for an aid from other learners who have enough knowledge about the learner's request. In last case, the learners can interact and exchange their knowledge in collaborative way. In a ubiquitous learning environment, it is difficult for a learner to know that the other learner has this knowledge even that they are at the same location. In this case, the learner needs to be aware of the other learners' interests that match his request.

The aim of this research is to support the learner with *Knowledge Awareness Map, which* is personalized according to his current need and location. Here, *PERKAMI* and *PERKAMII* models are integrated (El-Bishouty, Ogata & Yano, 2006a; 2006b). This system can recognize the environmental objects that surround the learner those he uses during his practice study. It uses RFID tags to detect the surrounding physical space objects then it generates the learner's digital space where each object in the physical space has its corresponding one in the digital space. The system matches between the educational materials topics and the learner's current task then recommends and visualizes the best matched materials according to how much they match the learner's current task and how near are their physical locations to the learner's current location. The system also matches between the current learner's need and the other learners' interests and locations, recommends the best peer helpers, and visualizes the relative distances between the learner's current need and the peer helpers interests and locations. The learner can refer to some educational materials or contact peer helpers, forward to them his *Environmental Object Map*, interact, and collaborate.

The outline of this paper is as the following: the main concept of the personalized *Knowledge Awareness Map* is illustrated, the system architecture and implementation are explained, and followed by the system evaluation and discussion. Finally, the conclusion and the future work are presented.

Personalized Knowledge Awareness Map

In order to get help from another learner you have to be aware of his interests and past actions. Therefore it is very difficult to find suitable partners at the beginning of the collaboration. Dourish and Bellotti (1992) defined *Awareness* as the understanding of the activities of others, which provides a context for your own activity. *Knowledge Awareness* (KA) is defined as awareness of the use of the knowledge (Ogata, Matsuura & Yano, 1996). KA has a close relation to the learner's curiosity (Ogata & Yano, 2000). Collaborative awareness is frequently achieved by means of lightweight messaging tools and dynamic information displays that function as notification systems (Carroll, et al., 2003). *Knowledge Awareness Map* graphically displays KA information. It displays the surrounding environmental objects, the matched educational materials, and the recommended peer helpers (El-Bishouty, Ogata & Yano, 2006b). This map plays a very important role in finding peer helpers and inducing collaboration (Ogata, et al., 1999). Hatano and Inagaki (1973) identified two types of curiosity: particular curiosity (PC) and extensive curiosity (EC). EC occurs when there is a desire for learning that makes the learner's stock of knowledge well balanced by widening the learner's interests. PC is generated by the lack of sufficient knowledge, and it is very useful because the learner can acquire detailed knowledge. *Knowledge Awareness Map* excites both types of curiosity.

In *PERKAM*, *Knowledge Awareness Map* is personalized according to the learner's need and the physical location. Personalization can be defined as the way in which information and services can be tailored in a specific way to match the unique and specific needs of an individual user (Renda & Straccia, 2005). Personalized applications lay more emphasis on specific needs, and location of individual learners in designing the learning contents on handheld devices (Cui & Bull, 2005). *PERKAM* satisfies the conditions that Cui and Bull (2005) posited for the personalized learning system:

1. Individualized according to the learner's knowledge.
2. Individualized according to the learner's location and needs in that location.
3. Mobility.

This type of learning systems supports the learners to make their own decisions based on the changed context or sensor information (Mitchell & Race, 2005). Therefore, it encourages *decision-making* and reflection (Song, 2006).

We assume that the knowledge space consists of a number of unique keywords. These keywords define the learners' interests, the environmental objects information and the educational materials contents. The keyword item is very important to recommend the educational materials, and the peer learners that augment the collaboration between them. Therefore, the system model consists of the following items.

Environmental Object

It represents the available real objects that may surround the learner. It may be computers, electronic parts, chemicals…etc. Each object has its own keywords that specify its configuration. One object may share one or more keywords with one or more other objects.

Learner

The learner is the actor in this system. The learner's interest is obtained from his profile and his educational materials folder. In this system, the learner's profile and folder are translated into a number of keywords that determine the user's interest.

Learner Profile

Each learner has his own profile. The learner profile is characterized using the following methods:

1. Learner explicit registration: The learner introduces his personal information and his interesting topics.
2. Learner academic level: The system detects the knowledge that the learner gained from his past academic records.
3. Learner actions: The system records the learners' actions while using it.

Learner Folder

The learner's folder contains the educational materials that the learner is aware of or intending to gain it.

Location

The location of the learners is represented by one dimension in the knowledge space. It is supposed that, everywhere there is a RFID tag to identify the location. The system can detect the learner's physical location using RFID tags. The relative physical distances between the different locations are predefined in the system.

Educational Material

It is the available educational material related to the education process. It includes book, lecture note, video or audio. Each material has its own keywords that specify its contents. One material may share one or more keywords with one or more other materials.

Environmental Objects Map

While a learner is interacting with other learners remotely trying to explain to them his current environment and situation, it may be difficult or at least need long time to describe exactly the available objects that he uses during his practice. The role of *Environmental Objects Map* is to map the physical space into the digital space, where each object in the physical space is detected, recognized and presented graphically by this system. The learner can forward this digital space to the peer helper in order to facilitate easy understanding of his environment, which augments the collaboration between them. For example, consider a learner (learner1 in Figure1) is doing an experiment at a chemistry lab, there are many objects surrounding him, each object is recognized, mapped into the digital space and forwarded to the peer helper. According to the *Environmental Objects Map* information, the peer helper can recognize the learner's situation and can efficiently collaborate with him.

a) Physical space b) Detection, recommendation and collaboration

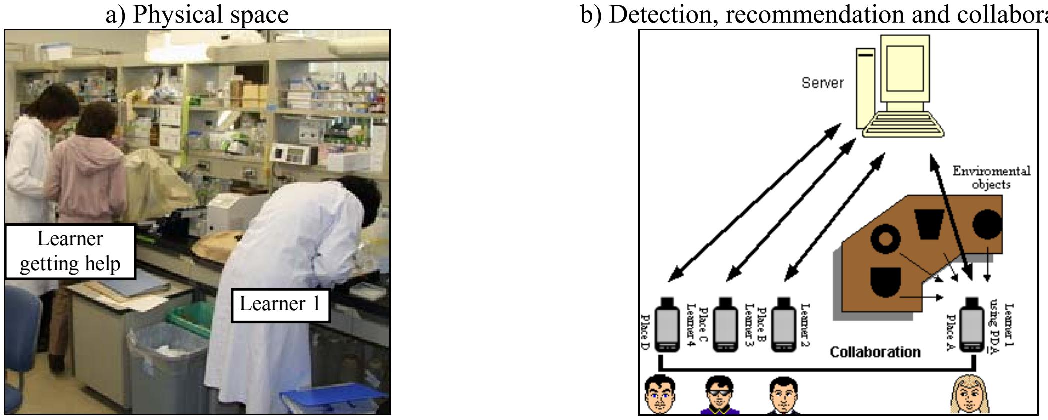


Figure 1. Environmental objects

Peer Helpers Map

This map displays a two dimensions knowledge space of the recommended learners who are using the system and have enough knowledge about the learner's request. This map represents the level of recommendation of each learner based on his interests. Consider that L is a certain learner, n is the number of keywords that a learner's request consists of, and n_L is the number of the matched keywords with a certain learner's interests. In *PERKAM***,** it is assumed that the Level Of Interest *(LOI)* is calculated as follows:

$$LOI = \left(\frac{n - n_L}{n}\right), \text{ where } 0 \le LOI \le 1$$

In case of *LOI* value is equal or close to zero, then *L* is recommended as a peer helper and will be close to the learner's request in the horizontal (x) dimension. The vertical dimension represents the relative physical distance (*RPD*) between the learner's location and the recommended peer helper's location, where $0 \leq RPD \leq 1$. The closer the recommended helper to the learner's request in the vertical (y) dimension, the nearer his physical location to the learner. In case that many peer helpers are matched, the system recommends the best three peer helpers according to the following helper recommendation score (*HRS*) formula:

$$HRS = 1 - \frac{LOI + RPD}{2}, \text{ Where } 0 \leq HRS \leq 1$$

Educational Materials Map

This map displays a two dimensions knowledge space of the suggested materials. It represents the strength of the relation between the suggested materials and the learner's request in one dimension, and how far their physical locations are from the learner's location in the other dimension. Therefore the learner can get information about the appropriate material that satisfies his need. Consider that *m* is a certain material, *n* is the number of keywords that the learner's request consists of, and n_m is the number of the matched keywords with *m* keywords. In *PERKAM,* it is assumed that the strength of the relationship *(STR)* between *m* and the learner's request is calculated as follows:

$$STR = \left(\frac{n - n_m}{n} \right), \text{ where } 0 \leq STR \leq 1$$

In case of *STR* value is equal or close to zero then *m* is recommended to the learner as a matched material and it will be close to the learner's request in the horizontal (x) dimension. The vertical dimension represents the relative physical distance (*RPD)* between the learner's location and the recommended materials locations where $0 \leq RPD \leq 1$. The closer the material to the learner's request in the vertical (y) dimension, the nearer the material to the learner's physical location. In case that many educational materials are matched, the system recommends the best three of them according to the following material recommendation score (*MRS*) formula:

$$MRS = 1 - \frac{STR + RPD}{2}, \text{ Where } 0 \leq MRS \leq 1$$

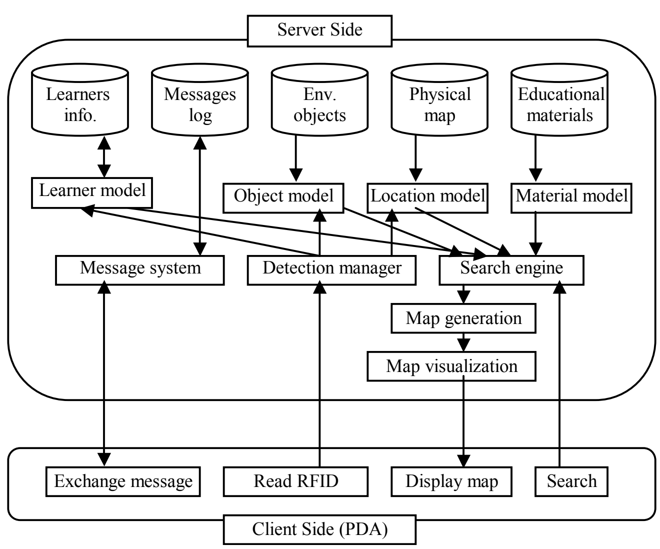


Figure 2. System architecture

System Implementation

In *PERKAM*, it is supposed that each learner has a PDA (Personal Digital Assistant) handheld device connected to the Internet through wireless connection, each device is equipped with a RF (Radio Frequency) reader, and for each object there is RFID (OMRON I.Code) tag attached to identify it. The learner can access the system anywhere and anytime, and face his PDA to all objects that surround him, then the system will recommend the related educational materials and the appropriate helpers who are aware of the requested knowledge. According to the level of recommendation, the learner can refer to an educational material or select the helper whom will interact with, forward his *Environmental Objects Map* to and exchange knowledge with him.

Architecture

PERKAM system consists of the following modules (as shown in Figure 2):

- Learner model: It contains the learner's information such as personal data, past actions, interests, folder…etc.
- Object model: It contains information about the physical educational objects that may be used by the learner.
- Location model: It contains information about the places (buildings and rooms) and the distances between them.
- Material model: It contains information about the education material as its title, author, type and keywords.
- Message system: It provides the learner with an easy tool to exchange messages with the other learners.
- Detection manager: It detects the location and the objects that surround the learner.
- Search engine: It matches between the learner's request, the available education materials and the peer learners.
- Map generator: It represents the surrounding environmental objects, the educational materials, and the recommended peer helpers' information according to the learner's need.
- Map visualization: It prepares the enough information to graphically visualize the KA maps.

Software Prototype

During the implementation of *PERKAM* prototype, the limited CPU speed and memory capacity of PDA devices is put in consideration. In order to get high performance software, most of the computing processes are done on the server side. Therefore, the PDA is mainly used to submit and receive data. Database schema is designed and implemented using MS-SQL2000 server in order to store all learners' profiles, actions, messages, and the environmental objects that surround the learner. The software consists of the following applications:

1. Detect-Tag: It is a client-server application, the client side application is developed using embedded C++ language. The target of this application is to read the stored data in the RFID tag (which represents the objects and the locations information) and send it to the server. The server side application is developed using visual C++ language. The function of this application is to listen on the network to the incoming client packets, receive client data (a particular learner's location or environmental object) and to connect to the database server in order to store the learner's current situation.
2. Search-Collaborate: This is the core of our system. It is a web based client-server application developed using ASP.Net and C# languages, where the learner can use anywhere using an Internet browser. A learner can login the system using his ID and password, browse his own folder, search about some knowledge, view *Knowledge Awareness Maps*, and exchange messages. This application contains a *Map generation module*, which generates the required information to build *Knowledge Awareness Map*. It passes this information to the *KA map visualization* module to display it graphically.
3. Visualize-KA-Map: It is an embedded flash object. Here, *Knowledge Awareness Map* is dynamically designed and displayed. The application is developed using Macromedia Flash ActionScript.

System Interface

After logging-in successfully, the system will redirect to *User Page* (Figure 3-a), where the learner can check the incoming messages. *New Messages Alert* list provides the learner with the new unread message. He can click on any message to read it then the read message will move to *Message History* list. The message takes the sign *(R)* after its title when the learner replies to this message.

Also, the learner can click on an educational material item in his own folder to get more information about it (such as its type, keywords, location). *User Page* is refreshed automatically every 30 seconds but the learner can refresh it any time by pressing *Refresh* button.

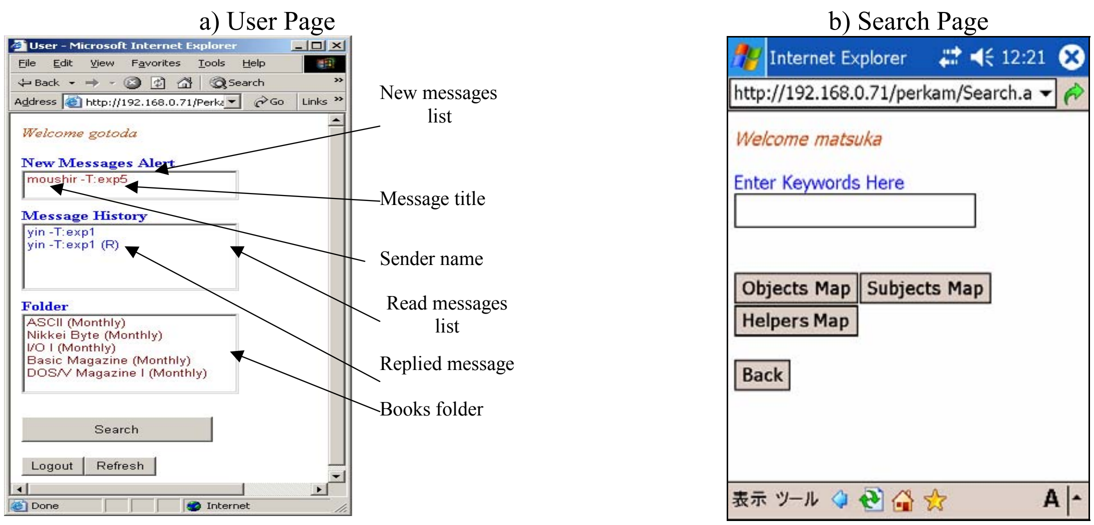


Figure 3. System Interface

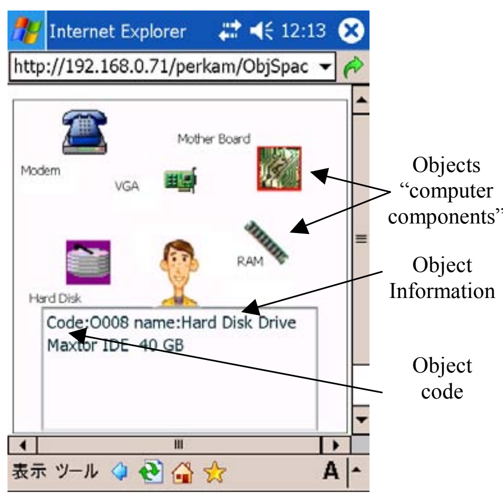


Figure 4. Environmental objects map

When the learner needs help, he can press *Search* button where the system will redirect to *Search* page (Figure3-b). In *Search Page*, the learner can enter some keywords that identify his request but he does not have to do that because the system can detect the environmental objects that he is using and translate it into a number of keywords that represent his query. In case of entering some keywords, these keywords will be combined with the detected environmental objects keywords to perform the learner’s query.

If the learner presses on *Objects Map* button, he will see his *Environmental Objects Map* (Figure 4) where each object in the physical space is detected, recognized and presented graphically as an icon. The learner can recognize the object type from its icon shape. When the learner moves the pointer over any of these objects, the object information will appear in the text box located at the bottom of the map. The person’s character represents the current learner who is doing a task and it indicates the learner’s request.

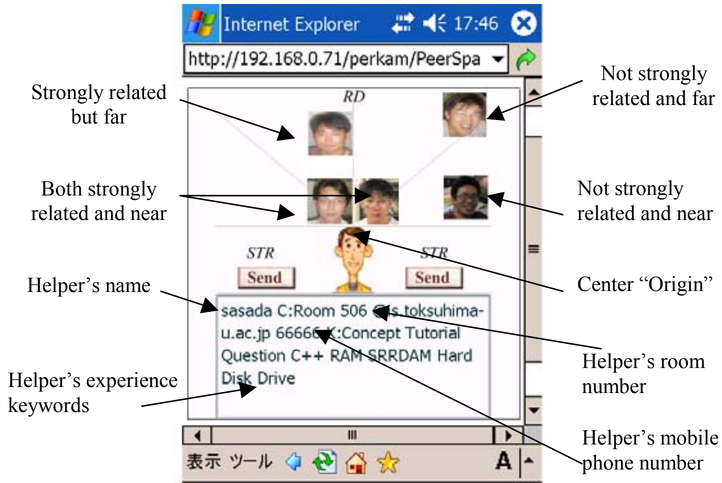


Figure 5. Peer helpers map

Returning to *Search Page*, if the learner presses *Helpers Map* button, the recommended *Peer Helpers Map* will be displayed (Figure 5), where each face represents one of the recommended peer helpers. The learner's name, information, and his matched interest keywords are displayed in the text box at the bottom of the map when the learner moves the cursor over his photo. The map shows how strong is the relation (*STR*) between the helper's knowledge and the learner's request in the horizontal dimension and how near his physical location is to the learner's location in the vertical dimension. Both left and right sides of the map have the same meaning. The best matched and nearest peer helper is the closest to learner's head (origin). The learner may select a suitable helper and press *Send* button then the system will redirect to *Mail Page* where he can send a message to this helper, attach his *Environmental Objects Map*, and ask the helper to reply to his question or to come to help him.

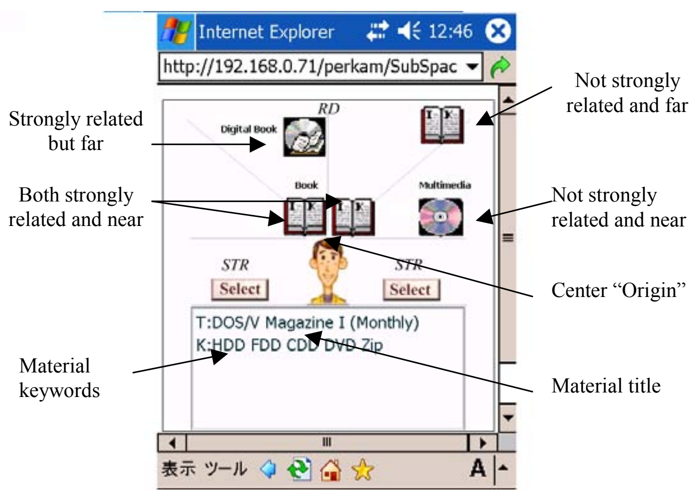


Figure 6. Educational materials map

Returning again to *Search Page*, if the learner presses on *Subjects Map* button, then *Educational Materials Map* will be displayed (Figure 6). He can click over any material icon to get its information in the text box under the map like, its title, keywords, and location. The learner can recognize the material type from its icon shape. The map shows how strong the relation (*STR*) is between the material content and his task in the horizontal dimension and how near its physical location is to his location in the vertical dimension. Both left and right sides of the map have the same meaning. The best matched and nearest peer material is the closest to learner's head (origin). The learner may select a suitable educational material, then the system will redirect to *Material Page* to get more information about it. It may be very close to his current location, so he can refer to it and complete his task.

System Evaluation

An experiment was done in order to evaluate the system usage, how much it can improve the learners' skills, and the learners' satisfactions. The proposed experiment is based on *learn by doing model*, where the teachers identify a specific set of skills to teach, embed that skill learning in a task, activity, or goal that the student will find interesting or motivational. Finally the teacher can evaluate the learner's understanding and skill according to the how much the learner successes to reach to the goal.

In this experiment, a teacher of computer hardware course is asking students to do tasks regarding personal computer assembling "examples of these tasks are illustrated in Table 1". Each student is given many hardware components. The teacher defines a fixed time to complete the task and to reach the final goal that the computer is working probably. The teacher supplies each learner with PDA connected to the wireless LAN and equipped with RF reader. While the learner tries to assemble the PC, he often has lack in some knowledge, for example, how to adjust a certain Hard Disk Drive (*HDD*) jumper to slave mode. In this case, he picks his PDA, and direct it to the location tag and all hardware components, then the *PERKAM* system detects his location and all environmental objects that surround him, and builds *Environmental Objects Map* (Figure 7). *Environmental Objects Map* represents each object by a small photo of the same object type in order to let it is easy for the learner to understand and recognize the physical objects. After building *Environmental Objects Map*, the learner can ask the system to recommend a number of related educational materials to refer, and peer learners who their interests and experiences are matching the information collected from the detected objects in order to collaborate and complete the task.

Table 1. Examples of the tasks

Name	Task
Task1	Plug a Hard Disk drive 40 GB as a Master device and a CD ROM as a Slave drive using one IDE cable.
Task2	Plug a Hard Disk drive 30.7 GB as a Master device and a CD ROM as a Master drive.
Task3	Plug an AGP VGA card 32 MB and 2x128 MB RAM.
Task4	Plug an AGP VGA card 16 MB and 1x256 MB RAM.

The Experimental Procedure

The main target of this experiment was to evaluate the learners' skills in PC assembling before and after using the system, and to measure how much they have learnt during using the system. This experiment consisted of five phases where16 students were involved. In its first phase the teacher asked each student to fill a questionnaire to evaluate his knowledge and experience about PC assembling, it included:

1. Learner's theoretical knowledge.
2. Learner's practical experiences.
3. Learner's references and his own educational materials.

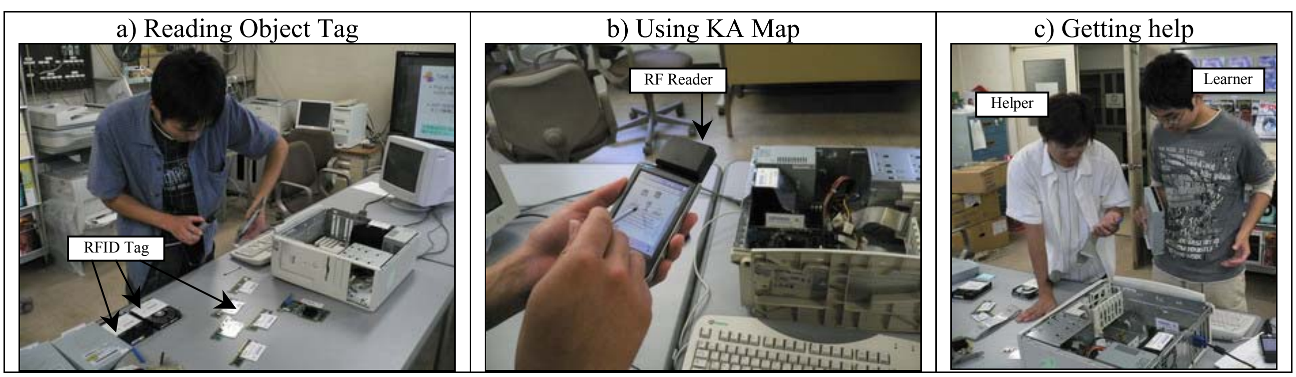


Figure 7. Using *PERKAM* system during the experiment

Depending on that questionnaire, the students were divided into two groups:
1. Experts group: 6 students who were experts and had a strong knowledge about PC assembling.
2. Learners group: 10 students who were beginners.

In the second phase, the teacher asked the experts group to do some tasks individually to be sure about their strong experiences in PC assembling. In the third phase, 5 students from the learners group were asked to do some tasks individually without using the developed system, and they were allowed to use an Internet connection to search for an appropriate material that may help them to complete the task in the fixed time (30 minutes). In the fourth phase, 9 students from the learning group (three of them were involved in the third phase and failed to do their tasks) were asked to do the tasks using *PERKAM* system, get recommendations and collaborate with the peer helpers to complete the tasks during the defined time, while the 6 expert students were asked to be online using *PERKAM* at different locations in the campus during their normal daily work, and to be ready to receive any message from the other learners. After completing the task, all students from both groups (experts and learners) were asked to fill in a questionnaire in order to measure the learner's satisfaction.

In the fifth phase after two months, all students who used the system in the fourth phase and successfully completed their task were asked to do their asks without getting any help to measure how much they have learnt while using the system.

Table 2. Sample of message dialog

Student	Message
A	I cannot understand. What does it mean Primary?
B	"Primary" is a plugging setting. What is the capacity of your task HDD?
A	The HDD capacity is 40GB.
B	Connect it to the motherboard in a place where "pri" small is written, and use one cable to connect both CDD and HDD.
B	Use the correct HDD; check its specification from the *Environmental Objects Map.*
A	I have plugged the two devices, what shall I do then?
B	After plugging in, you can find a teeny part called a "Jumper" adjust it as a Primary for the HDD and Slave for the CDD.
A	I cannot understand, could you please come now and show me how to do it?
B	Ok…

Results and Discussion

In the third phase of the experiment, 40% of the involved students (2 out of 5) hardly completed the task just in time (30 minutes) while getting help from related websites. They used search engines like *Google, Yahoo and AltaVista.* They entered some keywords to identify their requests such as, Primary, Slave, or SDDR RAM. Sometimes they entered wrong keywords, and other times the search results returned as unrelated websites.

In the fourth phase (while using *PERKAM* system), when the learners stopped doing their tasks because of shortage of some knowledge, they used the *Environmental Objects Map* to recognize the computer parts and tried to complete their tasks. If they still could not understand how to finish their tasks, they used *Peer Helpers Map* to get the system recommendation of the peer helpers. About 33% (3 out 9) of the learners depended on the *Environmental Objects Map*, while 67% (6 out 9) of the students asked for help from the recommended helpers in order to complete their tasks, where 66% (4 out 6) of them asked the peer helpers to come and interact face-to-face. They did not refer to any educational material and preferred to collaborate with the peer helpers other than to refer to the recommended education materials. They started to send messages using *PERKAM* message system, ask the peer helpers to recognize the computer components that they were using from their *Environmental Objects Map,* propose some questions, and try to use the helpers' answers to finish their tasks. Finally in case of failing to finish the tasks, they invited the helpers to come, interact face-to-face and to show them how to do that task. An example of message dialog between learner "A" who was doing Task1, and helper "B" is shown in Table 2.

In the fifth phase, 89% of the students (8 out of 9) completed their tasks during the allowed time. They did not get any kind of help. They depended only on what they have learnt while using *PERKAM* system before. It implies that there is obvious improvement of the students' knowledge and skills after and before using the system, and they have learnt and gained new experiences during using the system.

Table 3 illustrates the questionnaire results, from the answers of questions 1 and 2, it is clear that, all students agree that the system is easy to use and its performance is fast. From questions 3 to 6, the students indicate excellent understanding and a very effective use of *Knowledge Awareness Maps.* Questions 7 and 8 declare that most students prefer to collaborate with other learners to complete their tasks rather than to refer to related educational materials. From questions 9 and 10, it is clear that how efficient the system can recommend the peer helpers. Question 11 refers to the importance of the location dimension to recommend the peer helpers, where 50% of the students prefer to ask the helper to come and help them face-to-face, while the others prefer to communicate using the system email or the mobile phone. Questions 12 and 13 reflect the efficacy of using the system as a learning tool.

After completing the fifth phase, the learners were asked to score their skills improvement in the PC assembling. The average score was 91%. It indicates strong satisfaction of the learners for using the system as a learning tool. Also the peer helpers were asked about the main reason of offering their help and supporting the learners' requests with their experiences; 50% of them said that "they are looking forward to getting help from the learners in the future" while the others defined the main reason as, "they like to help any one". Both reasons guarantee keeping the collaboration between the students. Finally, some comments are given by the students to improve the system interface. The learners suggest allowing them taking photos and transferring them to the helpers, while the helpers recommend getting sound alerts when receiving new messages.

Table 3. The questionnaire results

Question	**For (Learner/ Helper)**	**Agree Percentage**	**Disagree Percentage**
1-Can you easily use the system?	Both	100%	0%
2-Is the system response time fast?	Both	100%	0%
3-Can you easily use *Knowledge Awareness Maps*?	Both	100%	0%
4-Can you easily get information about the computer components from the *Environmental Objects Map*?	Learner	100%	0%
5-Can you easily get information about the learner's surrounding computer components from the *Environmental Objects Map?*	Helper	100%	0%
6-Do you think that the *Environmental Objects Map* is useful to recognize the learner's problem?	Helper	100%	0%
7-Did you use only the *Environmental Objects Map* to complete your task?	Learner	33%	67%
8-Did you collaborate with a recommended peer helper to complete your task?	Learner	67%	33%
9-From whom have got peer helper recommendation, Can you get the suitable helpers related to your task from the *Peer Helpers Map*?	Learner	100%	0%
10-Do you think that the incoming message questions are suitable for your experiences?	Helper	100%	0%
11-Do you prefer to collaborate with the other learners face-to-face, or using the system email?	Both	50%	50%
12-Do you think that it is useful to use this system for learning?	Both	100%	0%
13-Have you learnt and got new experience while using the system?	Learner	100%	0%

Conclusion and Future Work

While a learner is doing a task to practice what he has learnt, he usually needs some help and instructions because of lack of some knowledge, but the problem is the difficulty for the learner to find the effective knowledge in time even if the source of this knowledge is very near to his physical location. In order to solve this problem a ubiquitous computing environment is presented to support the learner while doing a task, this environment is called *PERKAM.* It allows the learners to share knowledge, interact, collaborate, and exchange individual experiences. This environment provides the learners with *Knowledge Awareness Maps* that visualize the environmental objects space that surround the learner, the educational materials and the peer helpers' space. *PERKAM* recommends the educational materials according to how much their topics match with the learner's current task and how near their physical locations are to the learner's current location. On the other hand, it recommends the peer helpers according to how much their interests match with the learner's current task and how near are their locations to the learner's current location.

The experiment was done in order to evaluate the system usage, efficacy and the learner's satisfaction. The proposed experiment is based on *learn by doing model.* The experiment and the questionnaire results indicated that *Knowledge Awareness Map* is useful to understand the learner's situation and efficiently recommends the suitable peer helpers. Also, the results showed that it is useful to use the system in the collaborative learning and to improve the learners' knowledge and skills.

The proposed future work is to design more experiments to evaluate the system in different learning fields, add new features such as recommending video clips as learning materials, and to improve the peer helpers recommendation algorithm depending on the sameness between the learner's current situation and the peer helper's pervious situations.

References

Carroll, J., Neale, D., Isenhour, P., Rosson, M., & McCrickard, D. (2003). Notification and awareness: synchronizing task-oriented collaborative activity. *Journal of Human-Computer Studies, 58*(5), 605-632.

Chen, Y. S., Kao, T. C., Sheu, J. P., & Chiang, C. Y. (2002). A Mobile Scaffolding-Aid-Based Bird -Watching Learning System. *Proceeding of International Workshop on Wireless and Mobile Technologies in Education*, Los Alamitos: IEEE Computer Society, 15-22.

Cole, H., & Stanton, D. (2003). Designing mobile technologies to support co-present collaboration. *Personal and Ubiquitous Computing, 7*(6), 365–371.

Cui, Y., & Bull, S. (2005). Context and learner modeling for the mobile foreign language learner. *SYSTEM, 33*(2), 353-367.

Curtis, M., Luchini, K., Bobrowsky, W., Quintana, C., & Soloway, E. (2002). Handheld Use in K-12: A Descriptive Account. *Proceeding of the International Workshop on Wireless and Mobile Technologies in Education*, Los Alamitos: IEEE Computer Society, 32-30.

Dourish, P., & Bellotti, V. (1992). Awareness and coordination in shared workspaces. *Proceedings of Computer Supported Cooperative Work '92*, New York: ACM Press, 107-114.

El-Bishouty, M., Ogata, H., & Yano, Y. (2006a). Personalized Knowledge Awareness Map in Computer Supported Ubiquitous Learning. *Proceeding of the 6th International Conference on Advanced Learning Technologies*, Los Alamitos: IEEE Computer Society, 817-821.

El-Bishouty, M., Ogata, H., & Yano, Y. (2006b). Learner-Space Knowledge Awareness Map in Computer Supported Ubiquitous Learning. *Proceeding of the fourth IEEE International Workshop on Wireless, Mobile and Ubiquitous Technology in Education,* Los Alamitos: IEEE Computer Society, 116-120.

Fischer, G. (2001). User Modeling in Human-Computer Interaction. *Journal of User Modeling and User-Adapted Interaction, 11*(1/2), 65-86.

Fischer, G., & Konomi, S. (2005). Innovative Media in Support of Distributed Intelligence and Lifelong Learning. *Proceeding of the International Workshop on Wireless and Mobile Technologies in Education*, Los Alamitos: IEEE Computer Society, 3-10.

Hatano, G., & Inagaki, K. (1973*). Intellectual curiosity*, Chuo Koronsya Press.

Klaus, F., & Rachel, W. (2000). *RFID Handbook: Radio-Frequency Identification Fundamentals and Applications*, John Wiley & Sons.

Mitchell, K., & Race, N. J. P. (2005). uLearn: Facilitating ubiquitous learning through camera equipped mobile phones. *Proceedings of the Third IEEE International Workshop on Wireless and Mobile Technologies in Education 2005,* Los Alamitos: IEEE Computer Society, 274-281.

Ogata, H., Imai, K., Matsuura, K., & Yano, Y. (1999). Knowledge Awareness Map for Open-ended and Collaborative Learning on World Wide Web. *Proceeding of the International Conference on Computers in Education ICCE99*, 319-326.

Ogata, H., Matsuura, K., & Yano, Y. (1996). Knowledge awareness: Bridging between shared knowledge space and collaboration in Sharlok. *Proceeding of Educational Telecommunications 96*, 232-237, Retrieved June 7, 2007, from http://www-yano.is.tokushima-u.ac.jp/ogata/pdf/ed-media96.pdf.

Ogata, H., & Yano, Y. (2000). Combining Knowledge Awareness and Information Filtering in an Open-ended Collaborative Learning Environment. *The International Journal of Artificial Intelligence in Education, 11*, 33-46.

Ogata, H., & Yano, Y. (2004). Knowledge Awareness Map for Computer-Supported Ubiquitous Language-Learning. *Proceeding of the International Workshop on Wireless and Mobile Technologies in Education*, Los Alamitos: IEEE Computer Society, 19-26.

O'Malley, C. (1994). *Computer supported collaborative learning,* NATO ASI Series*,* Computer and Systems Sciences, 128.

Renda, M., & Straccia, U. (2005). A personalized collaborative Digital Library environment: a model and an application. *Journal of Information Processing and Management, 41*(1), 5-21.

Sakamura, K., & Koshizuka, N. (2005). Ubiquitous Computing Technologies for Ubiquitous Learning. *Proceeding of the International Workshop on Wireless and Mobile Technologies in Education*, Los Alamitos: IEEE Computer Society, 11-18.

Schank, C. (1995). What We Learn When We Learn by Doing. *Technical Report No. 60*, Northwestern University, Institute for Learning Sciences.

Song Y. (2006). What consequences have handheld educational uses brought about. *Proceeding of the International workshop on Mobile and Ubiquitous Learning Environments MULE in conjunction with ICCE2006*, Beijing, China, 1-7.

Lin Y., Swan K., & Kratcoski, A. (2005). Situated Learning in a Ubiquitous Computing Classroom, *Journal of the Research Center for Educational Technology,* Fall, Retrieved June 7, 2007, from http://www.rcetj.org/?type=art&id=3530&.

Yoo, Y., & Lyytinen, K. (2005). Social Impacts of Ubiquitous Computing: Exploring Critical Interactions Between Mobility, Context and Technology. *Journal of Information and Organization, 15*(2), 91-94.

Kaskalis, T. H., Tzidamis, T. D., & Margaritis, K. (2007). Multimedia Authoring Tools: The Quest for an Educational Package. *Educational Technology & Society*, 10 (3), 135-162.

Multimedia Authoring Tools: The Quest for an Educational Package

Theodore H. Kaskalis[1], Theodore D. Tzidamis[2] and Konstantinos Margaritis[2]
[1]Nursery Department, University of Western Macedonia, 3rd km Florina–Niki, 53100, Florina, Greece
[2]University of Macedonia, Thessaloniki, Greece, 156 Egnatia str. P.O. 1591, 54006, Thessaloniki, Greece
kaskalis@uowm.gr // tzidamis@uom.gr // kmarg@uom.gr

ABSTRACT

Since the explosion in multimedia computing, educators have been trying to work their way towards integrated human-computer interaction. Consequently, a large number of multimedia tools have been created, always following the trend of simpler and easier multimedia development. After outlining the transition from hardcore programming to modern multimedia authoring systems, this paper leads the way through a large variety of products, trying to determine the criteria upon which one should base a software investment. To facilitate this attempt, a series of variables is introduced and, based on these variables, a typical evaluation takes place. Following that pattern, each tool is examined separately so that a reasonable amount of data is gathered and treated as the basis for a 5-scale point system. Informal as this may be, it not only helps in ranking the tools examined, but also in extracting the necessary statistics. A black spot on this analysis is the absence of education-related data, since no software package was found to be able to play a clear educational role. As a result to all the above, a top-7 list is presented, always based on the previously stated subjective criteria. The purpose of this work is to shed light on the case of multimedia computing, aiming to find a tool that could serve a purely educational purpose in the field of live presentations. The absence of such a tool is the conclusion of the whole study.

Keywords

Multimedia authoring tools, Educational multimedia, Multimedia software review

Introduction

Since the 1990s, the promise of multimedia computing has been to change the way people and computers interact with each other. However, while new technologies have been introduced since that decade, the whole concept is still not nearly as clear as pure programming or word processing. Of course, there is no need to point out that composing live multimedia presentations (interactive or not) is a procedure far more complex than writing plain text (Bulterman & Hardman, 2005). Because of this, the universality that programming languages can offer in multimedia authoring is sacrificed in order to reduce complexity. Thus, multimedia development typically takes place in an interactive development environment (IDE) that efficiently hides (from the developer) low-level programming details that handle multimedia objects (Henry & Bodnar, 2000). These authoring systems, which are actually nothing more than specially designed simplified programming languages, offer simple, interactive techniques that allow the composition of a multimedia application without requiring the user to acquire specialized knowledge and expertise (Preclik, 2000) and, of course, without the necessary cooperation of various professionals (Bailey & Konstan, 2000).

Several versions of this concept are projected on a large number of multimedia authoring tools that usually do no more than limit the available features (especially commercial systems) in order to artificially reduce complexity (Bulterman & Hardman, 2005). Still, the fact remains that an all-purpose authoring tool does not exist in reality; all commercially available tools have been designed and implemented aiming toward a different audience. (Agnew & Palmer, 1992).

The problem gets worse when one looks for an appropriate, educational, multimedia authoring software (sometimes called courseware): Claiming that computer-assisted learning (CAL) is a serious option for many educators (due to the pressure for alternative forms of educational delivery) would only be an understatement (Dalgarno, 1998). However, it is crucial to really *assist* learning rather than merely use static presentations that do not incorporate users' responses. Such presentations practically force students to watch the same presentation, even if the computer has accepted input indicating that the topic has been understood (Shih et al., 1996).

Therefore, the question stands: How can an educator gain access to this kind of application? For one, purchase is too costly an option, available only to some schools and educational institutions. The other way is to develop an application for specific needs, which is also very expensive. Developing an application from scratch requires money and time, which are usually unavailable. On the other hand, buying a commercial package means complying with the features offered: even first-rate software, whose price cannot be met by everyone, encounters problems with localized habits of various countries, for example, language, educational needs, etc. (Preclik, 2000).

It is obvious that there is a wide variety of characteristics that are met (or not met) by each multimedia authoring tool. These characteristics are difficult to fully examine when a user/buyer is looking for the appropriate tool for a certain job. And, of course, the whole dilemma gets only harder when we are not referring to a computer expert but to an individual who only wishes to do a job quickly, easily, and in a cost-effective way.

The purpose of this article is to shed light on the criteria one should use in the quest for a multimedia authoring tool that best suits one's needs, especially when following an education-oriented approach. In this quest for educational multimedia authoring software, many multimedia authoring packages are evaluated through predefined points: a set of variables (cost, platform, image formats supported, etc.) that enable a typical evaluation. Finally, this paper discusses the lack of education-related data, which constitutes the ultimate goal of this study: to specify, if possible, an authoring package that can be used by an educator (with no particular expertise or financial background) in order to facilitate a course in any field or subject.

In simpler terms, this effort is about software selection: "How many kinds of image/sound extensions can a tool support," "Does it support some kind of animation?" "Do I need the program to run the files produced, or is it possible to make executable files?" "Do I need to pay for a license to use the program, or is it free?" All this has to be clear. This study sees to that. Summing up, the steps followed are:

- Background examination of the field
- Definition of all the criteria used to evaluate the authoring tools
- Data presentation for all 44 programs (the data were properly installed and examined separately)
- Grading scaled up to 5 (at first)
- Statistics examination
- "Top 7 tools" review/educational overview
- Summing up/Conclusions

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T:Which of the following is contained in triple sugar?
:
:       1. dextrose, maltose, and lactose
:       2. lactose, sucrose, and glucose
:       3. rhamnose, lactose, and glucose
:       4. glucose, arabinose, and lactose
:
A:
M: 1 , 2 , 3 , 4
J(&Y = 2):*RANS
T:Wrong, 2 is correct.
E:
*RANS
T:Right
E:
```

Figure 1. Code example in PILOT (Preclik, 2000)

Background

In the beginning, programming languages (such as Basic, Pascal, and C/C++) were the only tools for developing an educational multimedia application. However, while they were powerful enough to build almost anything, that same universality was their greatest disadvantage. After a while, this gap for simplicity was filled by authoring languages. In reality, authoring languages were about more specialized languages containing fewer commands. Unfortunately, the outcome was not much desired: The specialization — no matter how desired at first — was a major drawback. Coding anything out of the ordinary was extremely difficult and complicated, while some tasks were impossible. PILOT (an example of its code can be seen in Figure 1) was one of the first authoring languages (Preclik, 2000).

Apart from that, during the previous decade, authoring systems had come on the scene. Authoring systems are more complex development environments that allow users with no time or interest in programming to compose educational multimedia presentations interactively by clicking on objects, choosing menus, or following wizards. In comparison with traditional programming, only 1/8 of the time is needed to produce an educational presentation using an authoring system (Preclik, 2000). Of course, one can easily assume that the tools in question offer much fewer possibilities than traditional programming or authoring languages, due to the very same specialization that also constitutes authoring systems' greater advantage. A simple comparison of these three categories is shown in Figure 2 (Preclik, 2000).

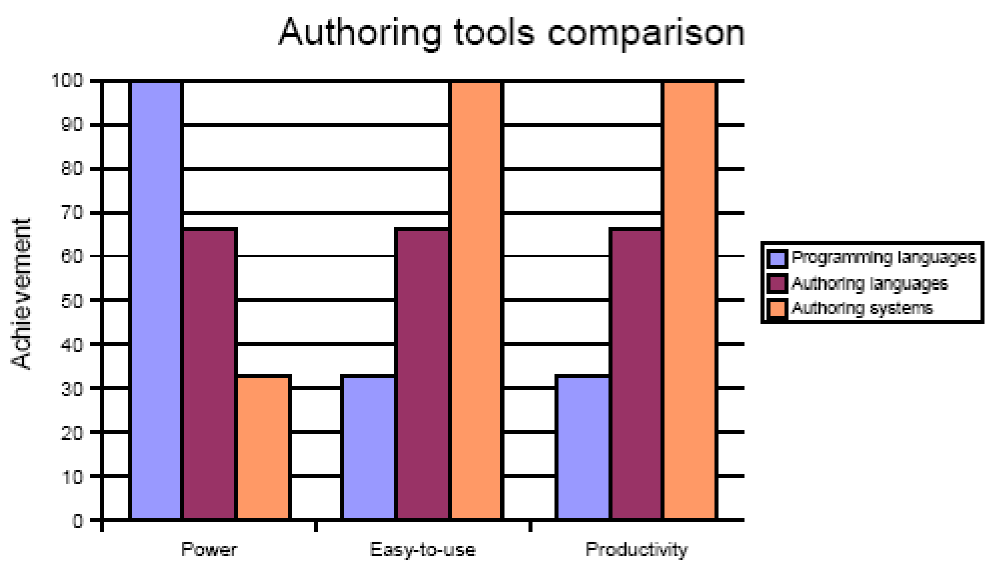


Figure 2. Authoring tools comparison (Preclik, 2000)

Having analyzed authoring systems further, we can state with certainty that, at first, it was all about applying interfaces onto authoring languages and nothing more. This merely meant materializing the idea of combining command modules for experienced users with GUIs (Graphic User Interfaces). However, future generations of similar packages were based on different concepts (Preclik, 2000).

Criteria

So far, we have argued that selecting an authoring system is a complex procedure. Therefore, locating a number of standards that a multimedia authoring package could meet would mean simplifying the whole concept.

A substantial effort by Preclik (2002) produced the following variables:

(1) *Variety of designed applications*: Usually, less sophisticated authoring tools offer only the ability to design applications identical to one another. Of course, this is a result of the efforts to minimize package complexity which leads to a subsequent drop of the abilities' standard.

(2) *User interface*: Normally, a good interface presents itself in two modes (at least): The "beginner mode," with only the basic capabilities, and the "expert mode," which offers all available features.

(3) *Test questions*: Rather than offering just plain multiple-choice questions, complex systems distinguish themselves by offering much more: hotspot questions, drag-and-drop questions, short-answer questions, true/false questions, etc.

(4) *Multimedia*: The truth is that even the most simplified software systems offer multimedia imports. However, what can be measured are the supported file types (BMP, GIF, JPEG, WAV, AVI, MPEG, etc). Needless to say, the sole number of file types may be misleading: an authoring system that supports only two image types (BMP and GIF) is perhaps far superior to one that supports 10 possible types but not these two.
(5) *Data communication with other applications*: This feature is useful when trying to extract or import data from and into the system. For example, sophisticated tools can export test data in the form of spreadsheet files, interact with databases (via ODBC drivers), and import a variety of file types (as DOC, RTF, HTML, XML, etc).
(6) *Branching*: Unlike simply linear systems, complex authoring tools connect independent screens or forms via links that can be followed at the user's will. Moreover, some systems even decide which screen will be presented next, depending on the user's answers or preferences.
(7) *Scripting*: Even when hypothetically using the "best tool for the job," sometimes there are ideas that cannot be materialized in a standardized way. This means that there has to be a more or less simplified way to program these tasks. Of course, that can only be realized through a kind of programming language, which can differ among cases. Some programs may offer traditional text-based scripting while others might host some kind of simplified visual programming that can be approached more easily by less-experienced users.

Having examined the above testimonies, one can easily determine that these variables can describe an authoring system in its entirety. Obviously, in some cases, there is a need for neutral measurements rather than questions such as "How good is...?" which are subjective by default. Therefore, always in coordination with the market status, each multimedia authoring tool examined by the research presented in this article is characterized by the following variables:
(1) Program and company name
(2) Price: Even if it's "the greatest tool ever built," if it's too expensive, people won't buy it. Price is perhaps the first factor buyers consider when looking for a multimedia authoring package.
(3) Platform: Assuming that the best solution has been spotted, the benefit is minimal if a certain operating system or architecture is pre-conditioned. For example, a tool that runs on Linux, Windows, and Mac-OS is substantially more "easy-going" than a system that runs only on Windows 98.
(4) Text editor: Usually, most programs offer basic text-editing capabilities. Of course, by no means does that mean that one could write a whole essay using that particular feature. Rather, in many cases, it means a simple textbox that can hold a certain "amount" of text and some basic formatting capabilities are offered.
(5) Text import formats: As stated above, most of the times it is far better to merely import a text than to write it again from scratch. Therefore, a decent tool has to import at least the basic text formats such as DOC, RTF, TXT, etc.
(6) Video formats: Of course, the same principle applies to video file types (after all, this is about "multimedia" applications). Thus, in accordance to the above, a system that allows AVI, MPEG, MOV, QT, and ASF imports, for example, outclasses one that can work only with MOV and AVI files. However, it would be an oversight if copyright issues weren't mentioned at this point: some video — as well as sound and image — formats are offered in exchange for money. This means that a program using the MP3 encoding has to pay copyright fees to the corresponding company, a cost that naturally has to be passed over to the final buyer.
(7) Sound formats: Considering that sound is a "must have" in multimedia presentations, the more supported sound formats, the better. Usual file types are WAV, MIDI, MP3, CDA, and Real Audio. The truth is that anything beyond that is a luxury, while anything far less is a handicap.
(8) Image formats: Even more important than the above, images can be imported in an application as pictures, diagrams, or even buttons. However trivial this may seem, there are tools that support as many as 32 image file types, as opposed to other tools that support only BMP and JPG. In actual practice, having to convert each image to BMP or JPG is a big deal.
(9) Drawing: This variable refers to whether the program lets the user draw his own shapes or pictures. Some systems do that. In most cases, however, the drawing tool includes only basic shapes and some systems do not support drawing at all. That means that the user must use another program to draw a graphic element (e.g., a simple arrow) and then import it as a picture, which may require converting the graphic element to a file type that is supported by the system.
(10) Export: While every tool can produce a fair multimedia presentation, an above-average package can export editable files in the form of executable files such as AVI, MOV, or animated GIF.
(11) Script: As stated earlier, scripting is a powerful feature for any authoring tool that claims to be an integrated "tool." By using a script editor, the user (usually the more experienced one) can alter little details or even

program the whole application from scratch. Without a script editor, the user can produce only the typical features offered by default, which is why one can find numerous presentations that are identical in design, color, buttons, shapes, navigational flow, etc. Unfortunately, it is not feasible to evaluate script editors for it would take too much time. In this study, what is questioned is the mere existence of a script editor and nothing more.

(12) 3D: This variable represents whether the program works with 3D images or not.

(13) Animation: Despite the fact that one of the main reasons a presenter chooses a computer-based authoring tool over regular transparencies is for its animation capabilities, several packages offer very little animation or no animation at all. Even if a package does offer animation capabilities, these capabilities may differ from other programs. Because of this, many questions have to be asked: "What kind of animation is offered?", "Is the system capable of handling animation without the help of external file types (SWF, for example)?", "Is there a need for third-party plug-ins?", etc.

(14) Effects: Extending the previous variable, most programs offer some effects (such as slide transitions, for example).

(15) Needs player: As controversial as this concept may be, the need for a separate player in order for a file to be executed can be a virtue, especially if the system cannot export editable files in the form of executable file types. For example, imagine a package that needs a large amount of disk space. This means that the same program has to be installed on one's laptop, even if that particular machine is used only for runtime mode rather than editing. On the other hand, the existence of a player means that the plug-in (which requires minimal disk space) can be installed on a specific portable computer. This may offer only playtime properties but this is the main purpose assuming that that particular PC is used only for presentations.

(16) Licence: Since cost is a great factor when looking for a sufficient tool, licensing is one thing that should not go unnoticed. Therefore, one has to wonder about many things: Is it 30-day-trial software? Shareware? Freeware? If not, is there an evaluation edition? Assuming that I buy it, do I need a separate licence for every computer or not? If I represent an educational institution, am I eligible for an academic licence?

(17) WYSIWIG Design: WYSIWIG (What You See Is What You Get) means that the user composes each application through the eyes of the final user. This may seem strange to most people as old design tools required the user to design in a strange GUI (Graphical User Interface), which had nothing to do with the outcome, or even work with plain code.

(18) Interactivity: Similar to branching (Preclik, 2002), interactivity has to do with the user's power to define the application's final outcome: Is the tool in the position to produce interactive applications or merely series of linear slide transitions?

(19) Address/Notes: Finally, the shading of all the selected authoring tools ends with an Internet address (for more information, downloads, etc.) and some notes that may be useful.

Data

In our study, 44 authoring packages were examined. At first, the survey was held only in a data-collecting manner. This means that the whole effort revolved around a catalogue core that was informed about the latest characteristics of all the packages analyzed. In simpler terms, the first stage was about collecting information about all 44 tools and nothing more.

The data is presented in table 1, with comments listed below the table.

Table 1: Package identity

	Program	Company	Price	OS
1	Authorware	Macromedia	$2,999	Windows/Mac
2	CBTMaster (Lessons)	SPI	$49	Windows
3	DazzlerMax Deluxe	MaxIT Co.	$1,995	Windows
4	Director	Macromedia	$1,199	Windows/Mac
5	EasyProf	EasyProf	€1,105	Windows

	Program	Company	Price	OS
6	eZediaMX	eZedia	$169	Windows/Mac
7	Flash	Macromedia	$499	Windows/Mac
8	Flying Popcorn	Parasys	$149	Windows
9	Formula Graphics Multimedia	FGX	$49.95	Windows
10	HyperMethod	HyperMethod	$190 (standard)–$390 (pro)	Windows
11	HyperStudio	Knowledge Adventure	$69.95 (student edition)–$199.95 (teacher edition)	Windows/Mac
12	InfoChannel Designer	Scala	$359	Windows
13	iShell 3	Tribeworks	$495	Windows/Mac
14	Liquid Media	SkunkLabs	$140–$200 (academic)	Windows
15	Magenta II	Magenta	$149	Windows
16	MaxMedia	ML Software	$50 (standard, CD-ROM)–120$ (pro, CD-ROM)	Windows
17	Media Make&Go	Sanarif	€399	Windows
18	Media Mixer	CD-Rom Studio	$75	Windows
19	MediaPro	MediaPro	$99	Windows
20	Mediator 7 Pro	Matchware	$399	Windows
21	MetaCard	MetaCard Co.	$995	Windows/Mac/ UNIX
22	Motion Studio 3	Wisdom Software	$39.95	Windows
23	MovieWorks Deluxe	Interactive Solutions	$99.95	Windows/Mac
24	MP Express	Bytes of Learning	$49.95	Windows/Mac
25	Multimedia Builder	Media Chance	$60 (with MP3 license)–$45 (without)	Windows
26	Multimedia Fusion	ClickTeam	$99	Windows
27	Multimedia Scrapbook	Alchemedia, Inc.	$89	Windows
28	MultimediaSuite		$649	Windows
29	Navarasa Multimedia 4	Navarasa Multimedia	$29.99	Windows
30	NeoBook	NeoSoft Co.	$199.95	Windows
31	ODS Players	Optical Data Systems	$229	Windows
32	Opus Pro	Digital Workshop	$249.95	Windows
33	Ovation Studio Pro	R.I. Soft Systems	$399	Windows
34	Platypus Multimedia Author	Platypus Software	$228 (standard, no VBScript)–$272 (pro, with VBScript)	Windows
35	PowerPoint	Microsoft	$229	Windows
36	Presentation Publisher	CMB Software	$89.95	Widows
37	Presentation Wizard	Alchemy Mindworks	$30	Windows

	Program	Company	Price	OS
38	Revolution	Runtime Revolution	$497.5 (educational)	Windows/Mac/ Linux
39	Shelldrake Developer	Shelldrake Technologies	Not available	Windows
40	Slim Show	PC Whole Ware	$49.95 (personal edition)	Windows
41	SuperLink	Alchemedia,Inc.	$129	Windows
42	Tactic!	BGW	Not available	Windows
43	ToolBook Instructor	Click 2 Learn	$2,599	Windows
44	TwinPlayer 3	CD-ROM Studio	$110	Windows

- Table 1
  - *Program*
  - *Company*
  - *Price*: While most packages are uniquely-priced, some companies offer two-level pricing. For example, Multimedia Builder without the mp3 licence costs $15 less, while SkunkLabs offers a $60 discount at Liquid Media for academic use.
  - *Operating System*: From a merely statistical point of view, all packages are offered for Windows, 10 for MacOS, while only MetaCard (by MetaCard Co.) and Revolution (by Runtime Revolution) can be installed onto Linux-based systems.

Table 2. Text and video

	Program	Text editor	Text import formats	Video formats
1	Authorware	Yes/RTF	TXT, RTF	Bitmap Sequence, Director, AVI, MPEG, WMP, MOV
2	CBTMaster (Lessons)	Yes	No	DIR, MPEG, MOV, AVI
3	DazzlerMax Deluxe	Yes, RTF	DOC, RTF, TXT	AVI, MPEG, MOV
4	Director	Yes	RTF, HTML, ASCII	Quick Time, AVI, RealMedia
5	EasyProf	Yes	RTF, TXT, HTML, DOC	MOV, MPEG, AVI, ASF, etc.
6	eZediaMX	Yes	No	MOV, AVI, MPG, etc.
7	Flash	Yes	No	AVI, MPEG, MPG, MOV, WMA, ASF
8	Flying Popcorn	Yes	TXT	AVI, MPG, MOV
9	Formula Graphics Multimedia	Yes	RTF, HTML	AVI, MOV, MPEG
10	HyperMethod	Yes	TXT, RTF, HTM, PDF	MPEG, MPG, AVI, MOV
11	HyperStudio	Yes	TXT, RTF	AVI, MOV
12	Infochannel Designer	Yes	TXT	MPEG, AVI, Quick Time
13	iShell 3	Yes	RTF/ HTML 2	AVI, MOV
14	Liquid Media	Yes	No	AVI, MPG, MPEG, MOV, MPE, SFK, IVF

	Program	Text editor	Text import formats	Video formats
15	Magenta II	HyperText	HTM, HTML, TXT, RTF	AVI, MOV, MPEG, MPG
16	MaxMedia	RTF, Plain text	RTF, TXT	AVI, MPEG, WMA, ASF
17	Media Make&Go	Yes (short text)	RTF, TXT, HTM	MOV, AVI
18	Media Mixer	Yes	HTM, HTML, RTF, TXT	AVI, MOV, MPG
19	MediaPro	TXT/RTF editor	TXT, RTF	AVI
20	Mediator 7 Pro	Yes	DOC, XLS, PDF, WRI, RTF, TXT	AVI, MPG, ASF, WMV
21	MetaCard	Yes	TXT	AVI, MPEG, Quick Time
22	Motion Studio 3	Yes	No	No
23	MovieWorks Deluxe	Yes	TXT	MOV, MW Video
24	MP Express	Yes	No	AVI, MOV
25	Multimedia Builder	Yes	TXT, HTML	AVI, MPEG, MOV, DAT, ASF
26	Multimedia Fusion	TXT, RTF	TXT, RTF, PCF	QuickTime, AVI, MPEG
27	Multimedia Scrapbook	Yes	No	AVI
28	MultimediaSuite	Yes	HTML	AVI, MPG, MPEG
29	Navarasa Multimedia 4	Yes	HTM	AVI
30	NeoBook	Yes	DOC, HTML, TXT, RTF, ASCII	AVI, MPEG
31	ODS Players	Yes	RTF	AVI, MPG
32	Opus Pro	Yes	TXT, RTF	MNG, AVI, MPEG, MPG, MOV, ASF, WMA, WMV
33	Ovation Studio Pro	Yes	RTF, TXT	AVI, MPE, MPG, MOV, QT
34	Platypus Multimedia Author	Yes	HTML, DOC, PDF, TXT, RTF, etc.	AVI, MOV, WMV
35	PowerPoint	Yes	HTML, DOC, TXT, RTF, etc.	AVI, MOV
36	Presentation Publisher	Yes	No	AVI, MPG
37	Presentation Wizard	Yes	No	No
38	Revolution	Yes	TXT, DOC	AVI, MPEG, QuickTime
39	Shelldrake Developer	Yes	No	AVI
40	Slim Show	One line only	TXT	AVI, MPG

	Program	Text editor	Text import formats	Video formats
41	SuperLink	Yes	TXT	AVI, MOV, MPG
42	Tactic!	Yes	TXT, RTF, HTM, HTML, ASF, PPT, PPS, DOC, XLS	AVI, MPG, MPEG, MOV, ASF, WMV
43	ToolBook Instructor	Yes	RTF, TXT	AVI, MOV, MPEG, MPG, ASF
44	TwinPlayer 3	Yes	HTM, HTML, RTF, TXT	AVI, MOV, MPG

- Table 2
  - *Text editor*: All systems offer some form of text editing, except for Slim Show (by PC WholeWare), which offers only one-line editing, and Media Make&Go, which can edit only short text.
  - *Text import formats*: Almost every package can support a text import of a usual kind (TXT, RTF) while in 10 cases, text importing is not permitted at all.
  - *Video formats*: Only Motion Studio 3 (by Wisdom Software) and Presentation Wizard (by Alchemy Mindworks) offer no video formats whatsoever. On the contrary, Opus Pro (by Digital Workshop) offers eight possible video extensions.

Table 3. Sound and image formats

	Program	Sound Formats	Image Formats
1	Authorware	MP3, WAV, AIFF, PCM, SWA, VOX	WMF, PICT, GIF, JPEG, xRes LRG, PNG, Photoshop 3.0, TARGA, TIFF, EMF, BMP
2	CBTMaster (Lessons)	AIFF, WAV, MP3, PCM, SWA, VOX	BMP, GIF, JPG, TIF, WMF, PNG, TGA
3	DazzlerMax Deluxe	WAV, MIDI, AU, MPEG	BMP, PCX, TIFF, TARGA, JPEG, EPS, PNG, WMF, PSD, PICT, SUN Raster
4	Director	MP3, WAV, AIF, RealAudio	BMP, GIF, JPEG, LRG (xRes), PSD, MacPaint, PNG, TIFF, PICT, Targa
5	EasyProf	WAV, MIDI, AU, MP3	PNG, GIF, JPG, JPEG
6	eZediaMX	WAV, MP3, AU, AIFF, MIDI, etc.	BMP, FPX, GIF, JPG, PNTG, PNT, MAC, PSD, PICT, PNG, QTIF, QIF, QTI, SGI, RGB, TGA, TIFF
7	Flash	MP3, WAV, AIFF	PNG, EPS, AI, DXF, BMP, DIB, EMF, GIF, JPG, WMF, PCT, PNTG, Photoshop 2.5/3, QTIF, SGI, TGA, TIFF
8	Flying PopCorn	WAV	BMP, JPG, GIF, HDC, CAL, EPS, IMG, JIFF, MSP, PCD, PIC, PCX, PSD, RAS, TGA, TIF, WMF, WPG
9	Formula Graphics Multimedia	WAV, AU, MIDI, Audio CD	BMP, PNG, JPG, GIF, TGA, VDO, WDO, XDO
10	HyperMethod	MIDI, WAV, MP3, AU, AIFF	BMP, GIF, JPG, WMF, EMF
11	HyperStudio	WAV	BMP, PCX, GIF, JPG, TIF, PCT, PIC, TGA, BIF, WMF, PNG, PSD
12	InfoChannel Designer	WAV, MIDI, MP3, CDA	BMP, GIF, IFF, JPEG, PCX, PNG, Targa, TIFF, WMF
13	iShell 3	MP3	BMP, JPG, GIF, PNG, PSD, FPX, TIF

	Program	Sound Formats	Image Formats
14	Liquid Media	WAV, MP3, WAX, WMA, WMV, WVX, CDA, MIDI, RMI, IVF, M1V, AIF, AIFC, AIFF, ASF, ASX	BMP, LBM, GIF, IFF, JPEG, JIF, JNG, KOA, PCD, MNG, PCX, PSD, PBM, PGM, PNG, PPM, Quick Time files, RAS, TIFF, TGA, WBMP, ICO, WMF, PCX
15	Magenta II	MP3, WAV, MIDI	BMP, ICO, JPG, JIF, JNG, KOA, IFF, LBM, MNG, PBM, PGM, PNG, PPM, RAS, WAP, WBMP, WBM, TIFF, TGA, TARGA, PSD, CUT
16	MaxMedia	MP123, WAV, MIDI, WMA, WAX	BMP, JPG, WMF, EMF, ICO
17	Media Make&Go	WAV, AIFF	TIFF, PSD, GIF, JPG
18	Media Mixer	WAV, MID, MP3, AIFF, AU, CDA	BMP, JPG, JPEG, GIF, ICO, EMF, WMF
19	MediaPro	WAV	BW, CEL, CUT, DIB, GIF, ICB, PCC, PCD, PDD, PCX, PIC, PBM, PGM, PPM, PSD, RGB, RGBA, RLA, RLE, RPF, SCR, SGI, TGA, TIF, VDA, VST, WIN, JPG, BMP, ICO, EMF, WMF
20	Mediator 7 Pro	MP3, WAV, MIDI, WMA	JPG, BMP, GIF, PNG, TIF, WMF, TGA, PCX
21	MetaCard	WAV, AIFF, AU	BMP, JPG, GIF, PICT, XWD
22	Motion Studio 3	WAV, MIDI, MP3, RMI	BMP, JPEG, JPG, PNG, GIF, ICO, CUR, ANI, TIFF, TGA, PCX, PGM, DIB, RLE, WMF, EMF
23	MovieWorks Deluxe	MIDI, WAV, AIF, CDA, MW Sound	BMP, GIF, JPG, PSD, PNG, Quick Time
24	MP Express	WAV	BMP, JPG, GIF
25	Multimedia Builder	WAV, MID, RMI, MOD, S3M, XM, IT, MP3, WMA	BMP, JPG, GIF, PCX, PNG, TIF
26	Multimedia Fusion	WAV, MIDI	BMP, DIB, JPG, JPEG, PCX, GIF, RLE, LBM, IFF…
27	Multimedia Scrapbook	WAV	BMP, PCV, PCJ, PCZ, JPG, GIF, DIB, PCX, PCM
28	MultimediaSuite	MP3, WAV	BMP, JPG, ICO, WMF
29	Navarasa Multimedia 4	WAV, MIDI, MP3	BMP, ICO, WMF, EMF, GIF, TIF, PNG, JPG
30	NeoBook	WAV, MIDI, MP3	BMP, JPG, GIF, PCX, PNG, TIFF, ICO, WMF
31	ODS Players	WAV, MID, MP3	JPG, BMP, GIF, TIF
32	Opus Pro	WAV, MP3, WMA, ASF, MIDI	BMP, CGM, JPG, PCX, PNG, TGA, TIF, GIF, PCD, WMF, EMF, CDR
33	Ovation Studio Pro	WAV/MIDI (audio mixing)	BMP, JPG
34	Platypus Multimedia Author	WAV, MP23, SND, AU, AIF, WMA, MIDI, CDA	BMP, PCX, GIF, DIB, RLE, TGA, TIF, JPG, PNG, WMF

	Program	Sound Formats	Image Formats
35	PowerPoint	MID, RMI, WAV, MP3, CDA	EMF, WMF, JPG, JPEG, JFIF, JPE, PNG, BMP, DIB, RLE, BMZ, GIF, GFA, WMZ, PCZ, PCD, PCX, MIX, CDR, CGM, PCT, PICT, EPS, FPX, TIFF, TIF, WPG
36	Presentation Publisher	WAV, MID, MP3, RMI	JPG, GIF, BMP, TIF, PNG, TGA, WMF, DIB, JIF, RLE
37	Presentation Wizard	WAV, MIDI	JPG, BMP, PCX, TGA, PNG
38	Revolution	WAV, AU, AIFF	BMP, JPG, JPEG, GIF, PNG (Windows)
39	Shelldrake Developer	WAV	BMP
40	Slim Show	WAV, MIDI, RMI	BMP, JPG
41	SuperLink	WAV	BMP, PC, GIF, JPG, FIF, DIB
42	Tactic!	WAV, MID, ASF, AU, MIDI, MP3, WMA	BMP, PCT, PCX, EPS, JPG, PCD, PNG, PSD, RAS, TIF, TGA, WMF, WPG, GIF
43	ToolBook Instructor	CDA, MP3, WAV	BMP, DIB, WMF, DXF, GIF, CDR, CH3, SY3, JPG, PCD, PIC, PCT, DRW, PCX, EPS, TIF, TGA
44	TwinPlayer 3	WAV, MID, MP3, AIFF, AU, CDA	BMP, JPG, JPEG, GIF, ICO, EMF, WMF

- Table 3
  - *Sound Formats*: Admittedly, WAV files (Waveform audio file) are supported by every tool except Shell 3 (by TribeWorks). However, only half of them support MP3 file types (which can be easily distributed over the web and occupy less disk space than WAV files).
  - *Image Formats*: In this section, there is a wide range of file modalities offered; from Ovation Studio Pro (by R. I. Soft Systems) and Slim Show (by PC Whole Ware), which support only BMP and JPG files, to Media Pro (by Media Pro) which supports 32 different file types.

Table 4. Other features

	Program	Image Painting	Export	Script	3D	Animation
1	Authorware	Yes	EXE, web	Java support	No	Limited/Flash, Animated Gif, FLC/FLI
2	CBTMaster (Lessons)	No	Installation program, web	No	No	SWF
3	DazzlerMax Deluxe	Yes	EXE (install), CD, web	Java (possibly)	No	Yes (can it be imported?)
4	Director	Yes	EXE, web, BMP, AVI, MOV, DCR	Yes	Yes	Flash, Animated GIF, PowerPoint
5	EasyProf	Shapes	CD, web	No	No	Animated GIF, Flash
6	eZediaMX	Shapes	CD, MOV, web (ZIP, self-extracted, EXE)	No	No	Yes, Animated GIF, SWF, FLI/ FLC
7	Flash	Yes	EXE, web, MOV	ActionScript	No	Yes

	Program	Image Painting	Export	Script	3D	Animation
8	Flying Popcorn	Many shapes	Web, screensaver, CD	No	No	Yes, Animated GIF
9	Formula Graphics Multimedia	No	EXE, web	Java	VRML,3DS	Animated GIF, FLC, VDO, WDO
10	HyperMethod	Basic shapes	web	HM Script	No	Flash, Yes (script)
11	HyperStudio	Yes	EXE, web	Yes	No	Yes, Animated GIF
12	InfoChannel Designer	Yes	CD, web, Animated GIF, AVI	Scala script	No	FLC, FLI, Animated GIF
13	iShell 3	No	CD	?	No	SWF
14	Liquid Media	No	Exe, CD, web	Yes (possibly)	3DS, LWO, DXF	Yes, Flash, Animated GIF, FLI/FLC
15	Magenta II	No	EXE, web	MPL	3D chart	Animated Bitmap, SWF
16	MaxMedia	Shapes	EXE, CD, screensaver	No	No	Limited, Flash
17	Media Make&Go	No	Director movie (.dir)/ export via director	Yes	No	SWF
18	Media Mixer	Open system drawing tool	EXE, CD	No	No	Animated GIF, Create
19	MediaPro	Shapes	—	No	No	No
20	Mediator 7 Pro	Shapes	EXE, CD, web, Flash, screensaver	No	No	Animated GIF, SWF
21	MetaCard	Yes	EXE	MetaTalk	No	No
22	Motion Studio 3	Yes	EXE, web	No	No	Yes
23	MovieWorks Deluxe	MW Paint	AVI, MOV for 1 scene (CD autorun)	No	No	Yes (MW Animator)
24	MP Express	No	—	No	No	No
25	Multimedia Builder	Basic shapes	EXE, CD	Yes	No	Animated GIF, Flash, Move object
26	Multimedia Fusion	Yes	EXE, screensaver, web	No	Yes	Animated GIF, Yes, FLI/FLC
27	Multimedia Scrapbook	Basic	Not verified	No	No	No
28	MultimediaSuite	No	CD	No	No	Flash
29	Navarasa Multimedia 4	Yes	Exe, CD, web	Nava/Java	No	Yes/Flash
30	NeoBook	Basic shapes	EXE, web, CD, screensaver	Yes	No	Animated Gif, Yes (very few actions)
31	ODS Players	No	CD	No	No	No
32	Opus Pro	Yes	EXE, web, screen saver	Based on Java	No	Yes, Animated GIF, Flash, FLC/FLI

	Program	Image Painting	Export	Script	3D	Animation
33	Ovation Studio Pro	No	EXE	Jive	No	Load SQS
34	Platypus Multimedia Author	System tool	EXE (make autorun and installation file)	VBScript	No	Animated Gif/SWF
35	PowerPoint	Yes	Web, setup	No	No	Yes, Animated GIF
36	Presentation Publisher	No	EXE, web, screensaver, ZIP	No	No	No
37	Presentation Wizard	No	EXE	Yes	No	MNG format
38	Revolution	Yes	EXE	Yes	No	Yes (script)
39	Shelldrake Developer	Yes	CD	Yes	No	Yes
40	Slim Show	No	EXE	No	No	import (.ss)
41	SuperLink	Basic shapes, SL Paint	—	Yes	No	Limited, Animated GIF (need scripting)
42	Tactic!	Basic	CD, web	No	No	Animated GIF
43	ToolBook Instructor	Yes	EXE, web, CD (setup)	Open Script	No	Flash, Animated GIF, FLI/FLC, Yes (script)
44	TwinPlayer 3	Open system drawing tool	EXE, CD, web, AVI, MPEG	No	No	Animated GIF, Create

- Table 4
  - *Image Painting*: Most tools offer some kind of image painting (usually in the form of basic shape drawing). However, 13 of the tested packages do not offer that specific feature at all.
  - *Export*: Most packages offer some kind of file types to which you can export your editable files.
  - *Script*: Almost half of the subjects show no scripting abilities, which means that one cannot alter a presentation in a way that is not specifically supported by the package. Because of this, presentations produced by such authoring tools tend to be almost identical in interface and functionality.
  - *3D*: As shown, most packages do not accept 3D inputs except for Formula Graphics Multimedia, Liquid Media, Multimedia Director, and Multimedia Fusion.
  - *Animation*: As shown in the table, most of the multimedia tools can work with animated GIF or SWF files, while only six are completely static.

Table 5. Effects, player, and licence

	Program	Effects	Needs player	Licence
1	Authorware	Yes	No	Trial (30 days, fully functional)
2	CBTMaster (Lessons)	Yes (auto)	Yes	Shareware (fully functional, limited use of 15 times)
3	DazzlerMax Deluxe	Yes	No	Evaluation (30 days)
4	Director	Yes	Yes	Trial (30 days, fully functional)

	Program	Effects	Needs player	Licence
5	EasyProf	Yes (actions)	Yes	Shareware (30 days, fully functional, 10 pages max)
6	eZediaMX	Yes	Yes	Demo (15 days)
7	Flash	Create	Yes	Trial (30 days, fully functional)
8	Flying Popcorn	Yes	No	Evaluation (30 days, 14 pages per file, 100 frames)
9	Formula Graphics Multimedia	Yes	Yes	Shareware
10	HyperMethod	Yes (actions)	Yes	Shareware/demo (time limit)
11	HyperStudio	Yes	Yes	Shareware (fully functional, limited to 4 cards)
12	InfoChannel Designer	Yes	Yes	Trial (fully functional, 30 days)
13	iShell 3	Yes	Yes	Trial (30 days)
14	Liquid Media	Yes	No	Freeware
15	Magenta II	Yes	No	Shareware
16	MaxMedia	Yes	No	Shareware/Freeware (light edition)
17	Media Make&Go	Yes	Yes	Evaluation (limited number of pages)
18	Media Mixer	Yes	No	Evaluation (fully functional for 20 runs)
19	MediaPro	No	Yes	Evaluation (30 days, fully functional)
20	Mediator 7 Pro	Yes	No	Demo (no time limit, 5 pages per project, project expires after 7 days)
21	MetaCard	No	No (.exe)	Shareware (fully functional limited number of statements in each project)
22	Motion Studio 3	Yes	No (.exe)	Shareware
23	MovieWorks Deluxe	Yes	Yes	Trial (15 days)
24	MP Express	Yes	Yes	Trial (time limit, fully functional)
25	Multimedia Builder	Yes	No	Shareware
26	Multimedia Fusion	Yes	No	Demo (fully functional, 15 days)
27	Multimedia Scrapbook	Yes	Not confirmed	Demo (fully functional, ca not save)
28	MultimediaSuite	Yes	Yes	Shareware (30 days)
29	Navarasa Multimedia 4	Yes	No (.exe)	Shareware (30 days limit, 10 topics, 5 screens)
30	NeoBook	Yes	No	Shareware
31	ODS Players	No	Yes	
32	Opus Pro	Yes	No (.exe)	Evaluation (fully functional)

	Program	Effects	Needs player	Licence
33	Ovation Studio Pro	Yes (pages)	No	Trial (30 days)
34	Platypus Multimedia Author	Yes	No (.exe)	Trial (limited number of saved objects)
35	PowerPoint	Yes	Yes	
36	Presentation Publisher	Yes	No	Shareware (5-slide limit)
37	Presentation Wizard	Yes	No (.exe)	Shareware
38	Revolution	?	No (.exe)	Evaluation (fully functional 30 days, free edition download)
39	Shelldrake Developer	?	Yes	Freeware
40	Slim Show	Yes	No	Shareware
41	SuperLink	Yes (script)	Program needed	Trial (can not save)
42	Tactic!	No	Yes	Demo
43	ToolBook Instructor	Yes	Yes	Trial (30 days, fully functional)
44	TwinPlayer 3	Yes	No (.exe)/	Evaluation (fully functional for 20 runs)

➢ Table 5

- *Effects*: No matter how high the quality, the majority of programs can work with effects.
- *Needs player*: As seen, some tools need a player and some not. Obviously, this is of no importance if an exe file can be produced.
- *Licence*: Most programs offer some kind of evaluation/demo trial period or even special licensing (e.g., academic) but, in fact, this lies on the buyer's identity (teacher, etc).

Table 6. GUI and other characteristics

	Program	WYSIWYG Design	Interactivity	Address	Notes
1	Authorware	Yes		www.macromedia.com	
2	CBTMaster (Lessons)	No	Yes (auto)	www.cbtmaster.com	
3	DazzlerMax Deluxe	No		www.maxit.com	Too many features
4	Director	Yes		www.macromedia.com	
5	EasyProf	Yes		www.easyprof.com	Requires Java Media Framework
6	eZediaMX	Yes	Yes	www.ezedia.com	Requires Java2 Runtime/QuickTime 5 or later

	Program	WYSIWYG Design	Interactivity	Address	Notes
7	Flash	Yes		www.macromedia.com	If QuickTime is installed, more import formats
8	Flying PopCorn	Yes		www.parasys.net	
9	Formula Graphics Multimedia	Yes		www.formulagraphics.com	
10	HyperMethod	Yes	Yes	www.hypermethod.com	
11	HyperStudio	Yes		www.hyperstudio.com	Requires QuickTime and DirectX
12	InfoChannel Designer	Yes	Yes	www.scala.com	Requires Internet Explorer Security Update for Windows 2000 and newer
13	iShell 3	Yes	Yes	www.tribeworks.com	Requires QuickTime 5.0 & above
14	Liquid Media	Yes	Yes	www.liquidmedia.net	QuickTime required for support, more files (shows banner)
15	Magenta II	Yes		www.magentammt.com	
16	MaxMedia	Yes		www.maxmediapro.com.br	Light edition not fully functional
17	Media Make&Go	Yes		www.mediamakeandgo.com	Requires Macromedia Director 7.0 or higher
18	Media Mixer	Not directly		www.cdromstudio.com	
19	MediaPro	Yes	Yes	www.mediapro2001.com	
20	Mediator 7 Pro	Yes		www.matchware.net	
21	MetaCard	Yes	Script	www.metacard.com	
22	Motion Studio 3	Yes		www.wisdom-soft.com	
23	MovieWorks Deluxe	Yes		www.movieworks.com	
24	MP Express	Yes	Time	www.bytesoflearning.com	Installation via internet no actions
25	Multimedia Builder	Yes	Good	www.mediachance.com	
26	Multimedia Fusion	Yes		www.clickteam.com	
27	Multimedia Scrapbook	Yes		www.alchemediainc.com	
28	MultimediaSuite	Yes/ No	Only forward (time)	www.multimediasuite.com	Only slide presentation
29	Navarasa Multimedia 4	Yes		www.navarasa.de	
30	NeoBook	Yes	Very good	www.neosoftware.com	NeoToon for animation

	Program	WYSIWYG Design	Interactivity	Address	Notes
31	ODS Players	Yes		www.playerssoftware.com	
32	Opus Pro	Yes		www.digitalworkshop.com	
33	Ovation Studio Pro	Yes		www.risoftsystems.com	
34	Platypus Multimedia Author	Yes		www.rgmt.com.au	
35	PowerPoint	Yes	Little	www.microsoft.com	Included in MS Office
36	Presentation Publisher	Yes	No	www.cmbsoftware.com	
37	Presentation Wizard	Yes		www.mindworkshop.com	
38	Revolution	Yes		www.runrev.com	
39	Shelldrake Developer	Yes		www.shelldrake.com	
40	Slim Show	Icons		www.pcww.com	
41	SuperLink	Yes	Yes	www.alchemediainc.com	
42	Tactic!	Yes		www.tacticsoftware.com	Demo publish only – (not fully functional), HTML, Has many quizzes
43	ToolBook Instructor	Yes	Yes	www.asymetrix.com	
44	TwinPlayer 3	Not directly		www.cdromstudio.com	

- Table 6
  - *WYSIWYG*: Every tool except for Media Mixer and TwinPlayer 3 can be programmed through WYSIWIG GUIs. This is the norm.
  - *Interactivity*: Data is inconclusive, as it is not so easy to determine if the failure to produce interactive applications lies on the user's lack of knowledge or in the program's inability to perform the task.
  - *Address*: Nothing more than the electronic address of the company or a simple download site.
  - *Notes*: Anything that does not apply to any of the previous categories.

This last table concludes the first stage of this analysis. However, the absence of educational data so far depicts an inconsistency with the title. The reason for this is simple: despite all efforts to find a purely educational software package (or at least a multimedia authoring tool that includes *some* educational functions), no significant relevant data was found, even though it was actually the primary leverage and the main purpose of this study.

In other words, in these 44 packages there were no distinguishable *educational* characteristics that could be mentioned in a table. A table column with data for a hypothetical variable "educational tools" would be redundant, since all cells would hold the same negative value.

Grading

Admittedly, grading all the programs above would be a hasty and subjective action in many ways. However, when looking for an appropriate multimedia authoring tool, a scale-based approach is needed. Following this concept, all the grades awarded to the programs are presented in table 7 below. Note that the grades awarded in the first place (on scale of 1 to 5) do not strictly follow a numerical scale. On the contrary, they could very easily be translated as:

- 5: Excellent
- 4: Good
- 3: Adequate
- 2: Existent, however problematic
- 1: Bad
- 0: N.A. (Not Available)

Table 7. Grades

Program	Image formats	Sound formats	Video formats	Text editor	Painting	Animation	.exe	GUI	Interactivity	Web	Total
Opus Pro	5	5	5	5	4	4	5	5	5	5	48
ToolBook Instructor	5	3	5	5	4	4	5	5	5	5	46
Director	4	4	3	5	5	5	5	4	5	5	45
Flash	5	3	5	4	5	5	4	5	4	5	45
Authorware	4	5	5	5	3	3	5	4	5	5	44
Liquid Media	5	5	5	5	1	4	4	5	5	5	44
Mediator 7 Pro	4	4	4	5	3	3	5	5	5	5	43
DazzlerMax Deluxe	5	3	3	4	4	3	4	5	4	5	40
PowerPoint 97	5	5	2	5	4	3	1	5	5	5	40
EasyProf	2	3	5	4	4	1	5	5	5	5	39
NeoBook	4	3	2	5	3	2	5	5	5	5	39
Multimedia Builder	3	5	5	5	3	2	5	4	5	1	38
Motion Studio 3	5	4	0	3	4	3	5	4	4	5	37
Flying PopCorn	5	1	3	4	4	4	1	5	5	5	37
Multimedia Fusion	4	2	3	3	2	4	5	3	5	5	36
eZediaMX	5	5	5	5	3	3	1	4	3	1	35
Tactic!	4	5	5	4	3	1	1	3	3	5	34
Formula Graphics	4	2	3	3	1	4	4	3	4	5	33
HyperMethod	3	5	4	3	2	3	1	3	4	5	33
Magenta II	5	3	4	3	1	1	5	3	3	5	33
Navarasa Multimedia 4	4	3	1	2	3	3	4	4	4	5	33
HyperStudio	5	1	2	3	3	3	4	3	3	5	32
TwinPlayer 3	3	5	3	2	2	2	5	3	2	5	32

Program	Image formats	Sound formats	Video formats	Text editor	Painting	Animation	.exe	GUI	Interactivity	Web	Total
InfoChannel Designer	4	3	3	5	0	1	1	5	4	5	31
MaxMedia	2	2	3	5	3	2	5	3	4	1	30
Platypus Multimedia Author	4	5	3	5	2	1	4	1	3	1	29
Revolution	3	2	3	4	3	3	5	2	3	1	29
Media Mixer	3	5	3	2	2	2	5	3	2	1	28
MediaPro	5	1	1	5	4	1	1	5	3	1	27
MetaCard	2	2	3	3	3	1	5	3	3	1	26
Presentation Publisher	4	4	2	2	0	0	5	2	1	5	25
MovieWorks Deluxe	3	4	2	3	4	2	1	2	2	1	24
Ovation Studio Pro	1	2	4	2	2	2	5	2	3	1	24
CBTMaster (Lessons)	3	5	4	1	0	0	1	1	1	5	21
SuperLink	3	1	3	3	2	2	1	2	3	1	21
Presentation Wizard	3	2	0	3	0	1	5	3	2	1	20
iShell 3	3	1	2	3	1	0	1	2	5	1	19
Multimedia Scrapbook	4	1	1	3	2	1	1	2	3	1	19
Media Make&Go	2	2	2	2	0	0	1	4	4	1	18
Slim Show	1	2	2	1	1	2	3	2	2	1	17
MultimediaSuite	3	2	3	2	1	1	1	1	1	1	16
ODS Players	2	3	2	2	0	0	1	3	2	1	16
Shelldrake Developer	1	1	1	3	1	2	1	2	3	1	16
MP Express	2	1	2	2	0	0	1	3	1	1	13

Table 8. Statistics

Grade	Image formats	Sound formats	Video formats	Text editor	Painting	Animation	Executive	Interface	Interactivity	Web
5	12	12	9	14	2	2	19	12	13	24
4	12	5	5	6	9	6	7	7	9	0
3	11	9	14	13	11	10	1	13	12	0

Grade	Image formats	Sound formats	Video formats	Text editor	Painting	Animation	Executive	Interface	Interactivity	Web
2	6	10	10	9	8	10	0	9	6	0
1	3	8	4	2	7	10	17	3	4	20
0	0	0	2	0	7	6	0	0	0	0

Note that in Table 7 the programs are presented in order of achievement and that 100% is equal to 50. The final achievement for each program, scaled to 10, and the corresponding price (in US dollars at the time examined) are shown in Table 9:

Table 9. Grades scaled to 10 and package prices

Program	Scale of 10	Price
Opus Pro	9.6	249.95
ToolBook Instructor	9.2	2,599
Director	9	1,199
Flash	9	499
Authorware	8.8	2,999
Liquid Media	8.8	200
Mediator 7 Pro	8.6	399
DazzlerMax Deluxe	8	1,995
PowerPoint 97	8	229
EasyProf	7.8	1,105
NeoBook	7.8	199.95
Multimedia Builder	7.6	60
Motion Studio 3	7.4	39.95
Flying Popcorn	7.4	169
Multimedia Fusion	7.2	99
eZediaMX	7	169
Tactic!	6.8	390
Formula Graphics	6.6	149
HyperMethod	6.6	29.99
Magenta II	6.6	149
Navarasa Multimedia 4	6.6	29.99
HyperStudio	6.4	199.95
TwinPlayer 3	6.4	110
Infochannel Designer	6.2	359
MaxMedia	6	120
Platypus Multimedia Author	5.8	272

Program	Scale of 10	Price
Revolution	5.8	497.5
Media Mixer	5.6	75
MediaPro	5.4	99
MetaCard	5.2	995
Presentation Publisher	5	89.95
MovieWorks Deluxe	4.8	99.95
Ovation Studio Pro	4.8	399
CBTMaster (Lessons)	4.2	49
SuperLink	4.2	129
Presentation Wizard	4	30
iShell 3	3.8	495
Multimedia Scrapbook	3.8	89
Media Make&Go	3.6	399
Slim Show	3.4	49.95
MultimediaSuite	3.2	649
ODS Players	3.2	229
Shelldrake Developer	3.2	—
MP Express	2.6	49.95

Evidently, there is more to grading than merely assigning a numerical grade, even if the presented data confirms our choice of Opus Pro as the best program. Opus Pro costs approximately $250, while the programs in second and third place cost $2,600 and $1,200, respectively. However, since program grades and prices have no connection whatsoever, purchasers must decide if the price is prohibitory or not.

Therefore, these grades are merely means of comparison among packages and do not reflect the actual performance of each multimedia tool.

Statistics

Up to this point, all the data have been presented: data based on market research and an informal grading system. The data were introduced in order to extract information from the variety of existing packages; the grading system was a way to categorize packages in a more general manner. Pie charts can also clarify the data as well as make an effort to connect the data to a possible educational use of the programs.

As shown in Figure 3, Adequacy of image formats, more than 50% of the tools examined have been categorized as more than adequate. In other words, most of the programs support a total of, on average, seven or more image formats. Of course, this can be a good thing. However, it is natural to think: “What do I need so many images for?” Is *seven* perhaps unnecessary? Does it make the authoring procedure more complex? The answer is, of course, ambiguous. Nevertheless, if one were to consider the issue from the viewpoint of a high-school teacher, one would realize that it is far simpler if a program accepts any kind of image. On the other hand, if there is a different kind of controller for every kind of image, then things get more difficult and less universal. And universality is a desirable characteristic, since it leads to simplicity.

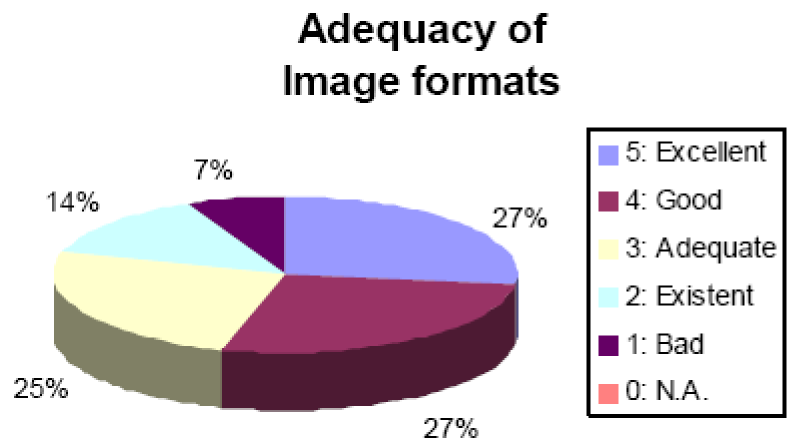


Figure 3. Adequacy of image formats (5 = Excellent, 0 = N.A.)

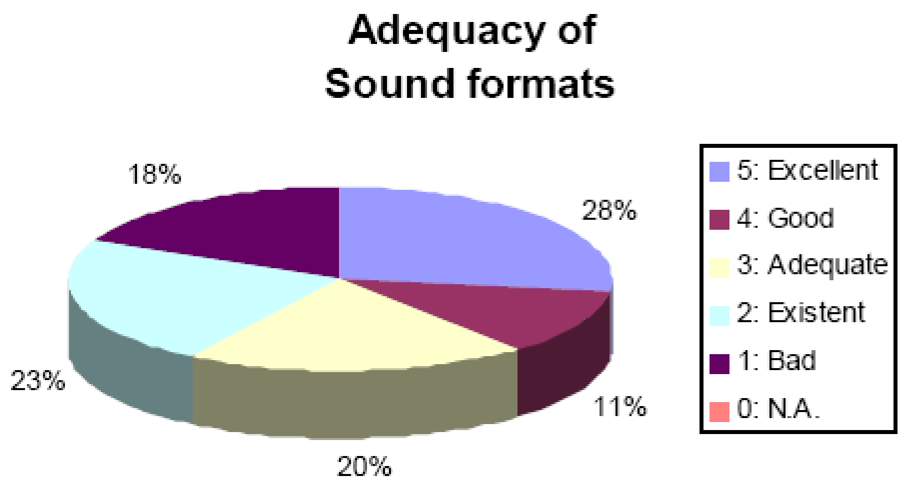


Figure 4. Adequacy of sound formats (5 = Excellent, 0 = N.A.)

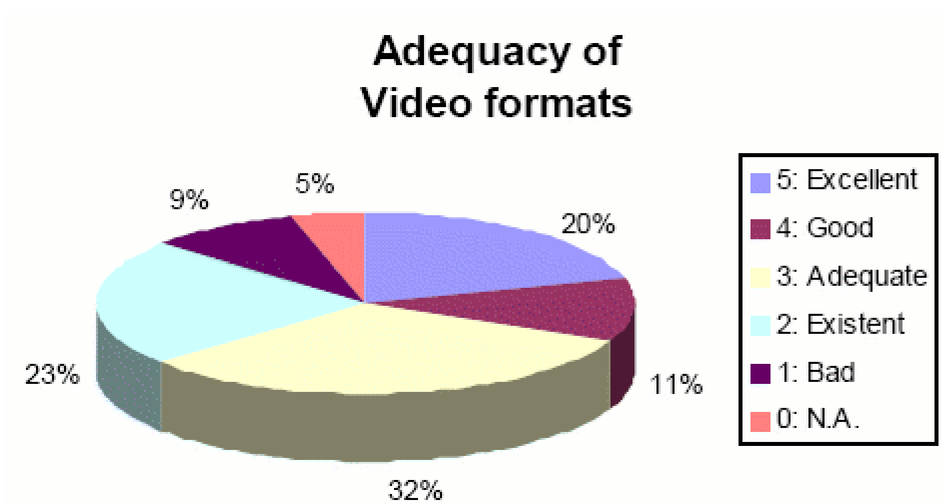


Figure 5. Adequacy of video formats (5 = Excellent, 0 = N.A.)

Approximately 27% of all packages have more than five sound formats that can be imported into the multimedia content (Figure 4). A mere 11% work with only four sound extensions. Of course, in the above, one can only suppose that the files supported are popular ones, e.g., MP3, WAV, etc., and not file types that are rarely introduced.

The percentage of 4.55% (Figure 5) corresponds to Motion Studio 3 and Presentation Wizard, which offer no video imports whatsoever. On the other hand, seven packages support between four and eight different video file types, which is more than efficient in most cases.

With regard to text editing, Figure 6 demonstrates that one in three packages offer good text opportunities. Of course, some packages don't offer such opportunities: Slim Show supports only one-line editing, while CBT Master (Lessons) contains a text editor but does not allow importing, which would prevent a teacher from importing text from one program to another.

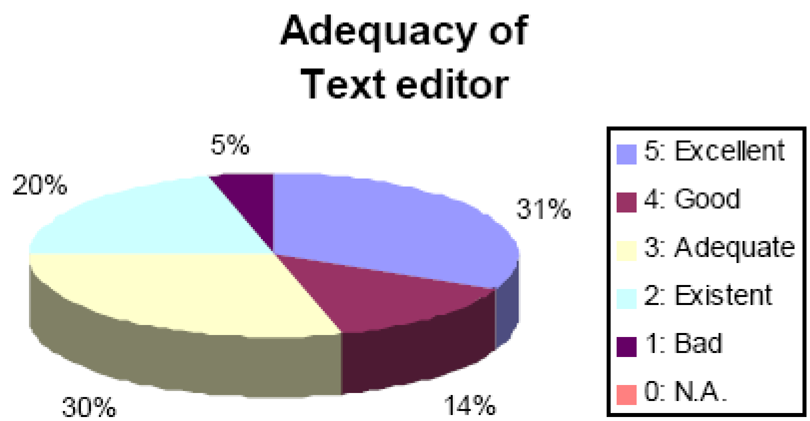


Figure 6. Adequacy of Text editor (5 = Excellent, 0 = N.A.)

As far as painting is concerned (Figure 7), statistics are a cause for pessimism: In 32% of the packages, the user is not allowed to adequately paint anything. On the other hand, Macromedia products save the day, as the only tools graded as "Excellent" were Director and Flash. But, considering it from the educator's point of view, how easy is it for one to learn how to use a Macromedia package just to make a small multimedia presentation in class?

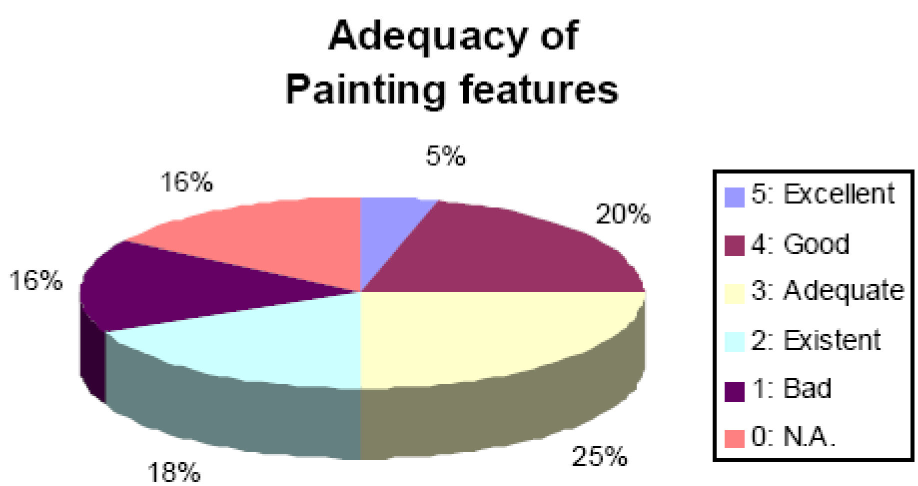


Figure 7. Adequacy of painting features (5 = Excellent, 0 = N.A.)

Animating objects, pictures, etc., is universally held as the most valuable tool when it comes to multimedia. Therefore, it is most unfortunate that only two software projects (again Director and Flash) offer good animation capabilities, while 59% are just above average (Figure 8). A true waste of computer power! Features like animation drive people to the use of PCs. If there are no animation capabilities, then most of the rest can be done with a common overhead projector and a marker.

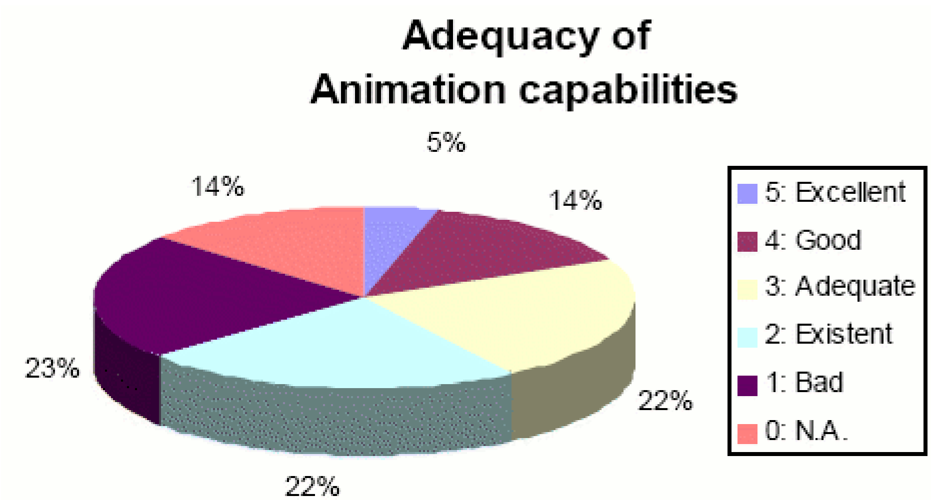


Figure 8. Adequacy of Animation capabilities (5 = Excellent, 0 = N.A.)

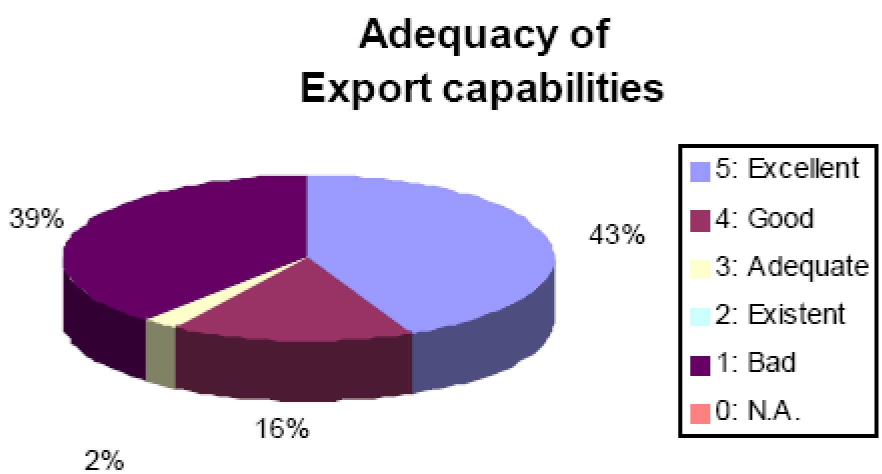


Figure 9. Adequacy of export capabilities (5 = Excellent, 0 = N.A.)

The statistics in Figure 9 speak for themselves: Only 60% can produce a file that can run independently of the whole program. In addition, only 27 out of 44 programs can produce EXE exports. A definitely pessimistic percentage, since most school computers cannot be administered by the teacher alone; it is then natural that a software package cannot really be used by the teacher (when preparing the class) if the same program has to be installed in the classroom computer or in every lab PC.

Truly, a decent interface is important to any multimedia authoring tool. Of course, what constitutes a "decent interface" is highly subjective. Nevertheless, there are unbiased factors that can be measured, such as WYSIWYG design, colors, etc. Fortunately, a proper GUI environment exists in 74% of the programs (Figure 10).

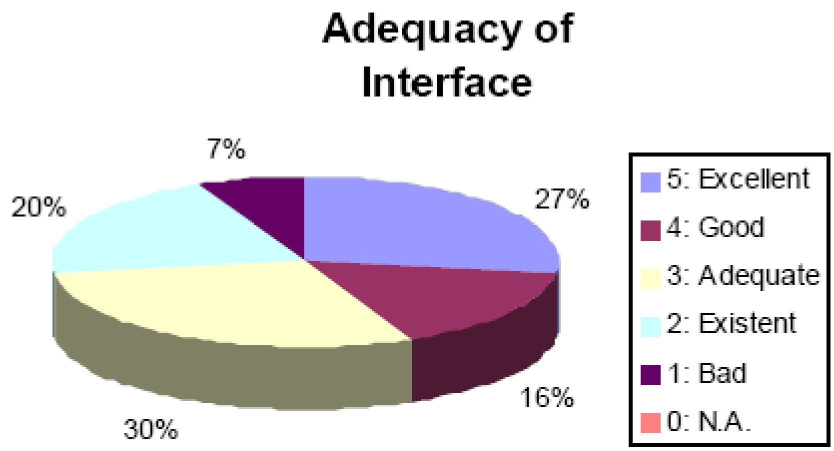


Figure 10. Adequacy of Interface (5 = Excellent, 0 = N.A.)

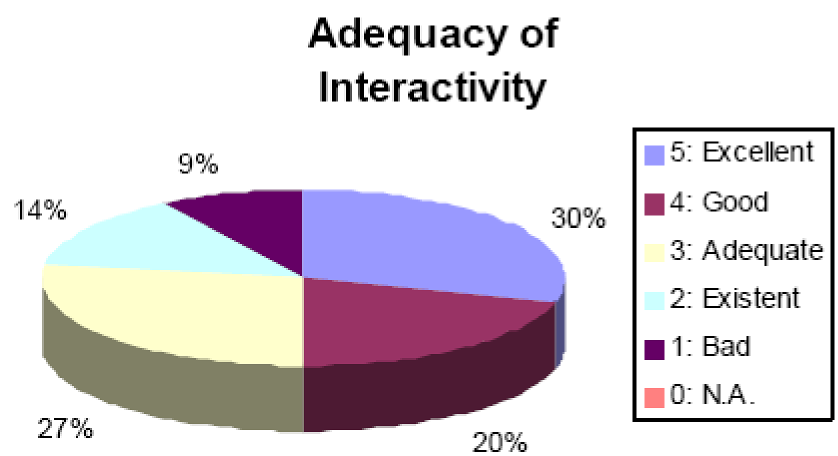


Figure 11. Adequacy of Interactivity (5 = Excellent, 0 = N.A.)

Regarding the web, parallel to the latest evolutionary tactics in the www, some programs mutated themselves in order to be able to act as network platforms that allow users to communicate. This allows file projection or exchange between the two (or more) ends. The situation in the field of multimedia can be seen in Figure 12.

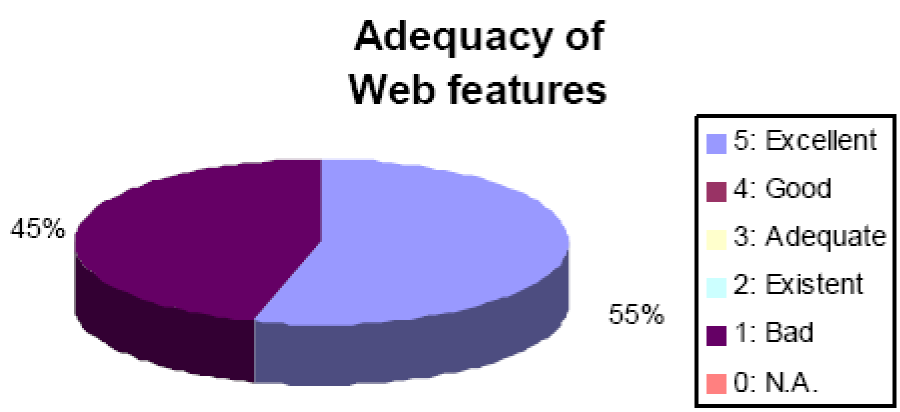


Figure 12. Adequacy of web features (5 = Excellent, 0 = N.A.)

Educational overview

Having taken many factors under consideration, a top seven list has been extracted:

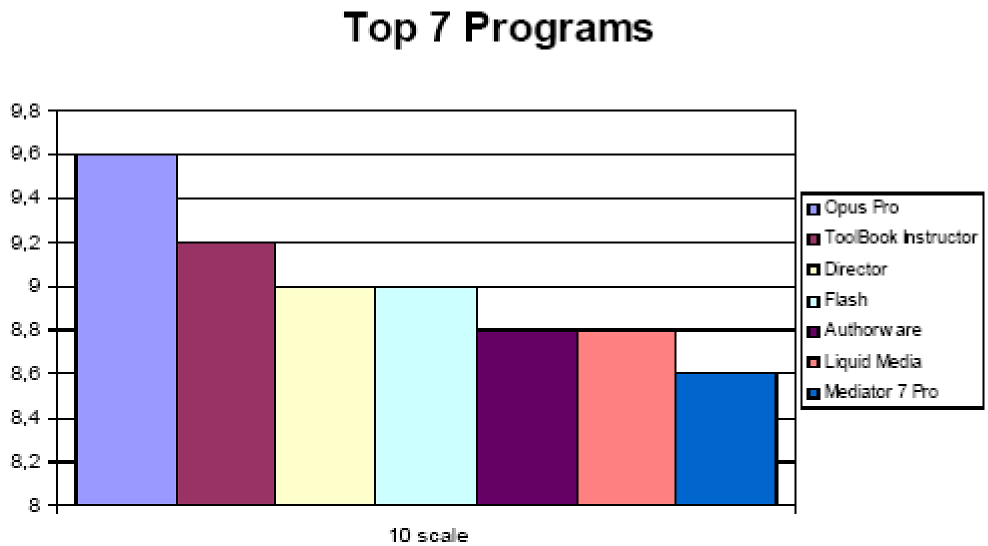


Figure 13. Best programs reviewed

It is true that the only thing clear after all this fuss about finding the best multimedia tool for the job is this question: "What job is it intended for?" Figure 13 shows the outcome of the search: the best 7 programs, according to the grades given by the authors. However, let's examine the facts about these packages a little more closely (Table 10):

Table 10. Top seven programs: data

Program	Image formats	Sound formats	Video formats	Price
Opus Pro	12	5	8	$249.95
ToolBook Instructor	17	3	5	$2,599
Director	10	5	3	$1,199
Flash	17	3	6	$499
Authorware	4	5	5	$2,999
Liquid Media	24	16	7	$200
Mediator 7 Pro	8	4	4	$399

It is easy to spot the paradox of Liquid Media: While supporting a vast number of imports of any kind, it holds only sixth place! However, what cannot be stated in this article due to limited space is that some programs present other issues that need to be resolved. For example, Liquid Media does not offer any kind of image painting, which is very crucial to the authors for without it the user cannot draw a single line; instead, everything has to be drawn using other programs and imported as an image.

Therefore, it is only natural that some facts on the grading table seem strange. In order for someone to have a perfectly clear image of what the program can or cannot do, all programs have to be installed and reviewed individually. Due to presentation limitations, in this paper two programs appear to offer scripting languages regardless of their nature and difficulty. In reality, however, a package that supports scripting in a programming language used 20 years ago is far more difficult to program than a tool that accepts visual programming and can be used by a non-IT professional.

But let's review something stated so many times previously: What about the educational side of the above programs? Shouldn't a special analysis be held for that aspect only? As has already been mentioned, none of the above programs has something specific to offer when it comes to education (except perhaps ToolBook Instructor).

In other words, there is no multimedia authoring tool specially designed to offer education professionals a chance to facilitate entire lessons with multimedia presentations. In order to be universal, an educational multimedia authoring tool has to have, in addition to the points stated above, two basic virtues:

- Low price: Keeping in mind the fact that most educational institutions cannot afford the cost of a single software package (except perhaps gigantic educational institutions), the perfect educational multimedia authoring tool has to be cheap enough for a schoolteacher, a parent, or even a student to buy.
- Ease-of-use and a friendly GUI (Preclik, 2000): No one can possibly buy a program that requires two months' full-time work to produce a single executable file. Therefore, creating multimedia presentations should be easy enough to learn in a single weekend or less, regardless of the user's skills and academic status.

The underlying problem is that all the programs examined in this review were developed with a target audience of users in a universal market. Unfortunately, that same universality works against the programs when it comes to the sensitive field of education: It would be rare for a primary-school teacher to care about all the capabilities that Macromedia Flash has to offer, no matter how fascinating these may be or how small the Shockwave export file is (Lim, 2001). All that one needs for the educational purposes that arise in a classroom is a simple program that can perform all the basic tasks in a very easy way. More complex tasks could be hidden somewhere below the superficial layer of the interface so that a teacher that needs only basic program features shouldn't be overwhelmed by them.

Summary and Conclusions

"The task of creating a multimedia presentation is multileveled and time-consuming" (Bulterman & Hardman, 2005). Despite that, all the tools available in the market offer a vast variety of work environments to choose from. However, in the eyes of a novice, this fact represents a big obstacle: "What program am I supposed to select? How can I learn how to use it and how much money must I spend learning the program?" Having all this in mind, it is only natural to feel the urge to cut back on the previously stated two factors. In other words, users should look for a program that allows better results to be produced in less time and, of course, for less money.

In this quest, the present survey began by giving a detailed analysis of the historical background of the multimedia field. From traditional programming languages and more recent authoring languages, the whole thing gradually settled on authoring systems, since they offered a more simplified presentation of the concept. In spite of the consequent cut-back on capability, universality, and power, authoring systems became very popular — especially among people with little computer knowledge and no desire to spend time learning programming languages. This fact created a large market for multimedia authoring tools, which naturally led to the creation of similar programs by many companies.

In this survey, 44 packages were identified and properly installed for a full review. For these systems to be evaluated, a group of relatively strict criteria had to be determined, since the whole examination was based on them. These factors were many, varying from package price to number of files supported.

After presenting the data collected, the next target was to impose a grading scale, which provided the basis for the final list. The outcome was scaled to 10 and was presented along with the corresponding price in order to give a more clear view of the cost-benefit relationship. This led to the extraction of a set of statistics and some thoughts regarding the total results. The results are not absolute. On the contrary, they indicate the pros and cons of every aspect so that a deduction can be made by the individual buyer.

Finally, the above data were compressed into a top-seven program list and analyzed from an educational point of view, which led to the deduction that not one tool from the ones analyzed has something special to offer in an educational environment.

In summary, the final outcome is that looking for a multimedia tool is very challenging. The interested individual must judge which feature is a “must-have” and which is mere luxury. As analyzed in the body of the paper, detailed statistics fail to reveal a suitable candidate for our interests. Packages that support numerous image, sound, or video formats, along with text editor and animation capabilities, are not oriented towards the average computer-literate educator. Furthermore, many of the examined programs do not allow the production of autonomous, self-executable, directly distributable applications.

Despite the detail of our study, only one sector has not been covered, yet: the educational sector. And that is because no serious educational features have been found in any of the programs examined in order to comment on that. This is a real pity, given the fact that education is the primary field that could benefit from the use of multimedia computing; lessons, interactive courses, multimedia tutorials, and much more. But, in order for that to be feasible, there has to be a relatively cheap and easy way to produce everyday applications for classroom use.

Therefore, it is natural to ask: Why hasn’t a purely educational multimedia authoring tool been developed yet? Why has no part of the open-source community (since purely commercial products cannot easily cover the certain need, as mentioned above) moved in that direction?

Unfortunately, there is an obvious gap in the educational field: a variety of needs can be only partially filled by existing multimedia packages (and a lot of personal sacrifice, both in time and money, is still required). This is not to say that the existing software is of low quality, merely that it is unable to serve a purely educational aim.

References

Agnew, J., & Palmer, G. (1992). The right tool for the job: A quest for the perfect authoring package. *Proceedings of the 10th Annual International conference on Systems Documentation*, New York, NY: ACM Press, 253–258.

Bailey, B. P., & Konstan, J. A. (2000). Authoring interactive media. In Webster, J. G. (Ed.) *Encyclopedia of Electrical and Electronics Engineering*, New York, NY: John Wiley & Sons.

Bulterman, D., & Hardman, L. (2005). Structured multimedia authoring. *ACM Transactions on Multimedia Computing, Communications and Applications, 1*(1), 89–109.

Dalgarno, B. (1998). Tools for authoring constructivist computer-assisted learning resources: A review. *Proceedings of the 15th Annual Conference of the Australian Society for Computers in Tertiary Education*, Wollongong: University of Wollongong, 143–153.

Henry, S. M., & Bodnar, R. P., Jr. (2000). Metrics for multimedia languages. *Proceedings of the 4th European Conference on Software Maintenance and Reengineering*, Washington, DC: IEEE Computer Society Press, 75–82.

Lim, C. G. (2001). *Development of an interactive environment for Internet based learning*, Master’s thesis, The University of Oklahoma, Graduate College, Norman, OK, USA. Retrieved June 7, 2007, from http://eml.ou.edu/paper/Research%20Paper/CHOON-GUAN%20LIM.pdf.

Preclik, J. (2000). Authoring Tools. In J. Safrankova (Ed.), *Proceedings of the 9th Annual Conference of Doctoral Students*, Prague: MATFYZ Press, 570–575.

Preclik, J. (2002). What authoring tool is the best? In J. Safrankova (Ed.), *Proceedings of the 11th Annual Conference of Doctoral Students*, Prague: MATFYZ Press, 128–133.

Shih, T. K., Chiang, D. A., Keh, H. C., & Shis, C. C. (1996). Formal specification of multimedia authoring. *Proceedings of the 1996 International Workshop on Multimedia Software Development*, Washington, DC: IEEE Computer Society Press, 128–137.

An Instrument Development: Interactivity Survey (IS)

Murat Kahveci
Center for Elementary Mathematics, and Science Education (CEMSE), University of Chicago, USA
Tel: +1 773 702-2694 // Fax: +1 773 702-4312 // mkahveci@uchicago.edu

ABSTRACT

Although there is no agreement as to what instructional interactivity and interaction mean in educational literature, researchers agree that both terms are vital for teaching and learning one way or another. This paper presents the item-development stages and validity and reliability analyses of the Interactivity Survey (IS), which attempts to uncover the perceptions of professors working at departments of education from universities around the world. To provide evidence of reliability of the instrument, a pilot study was carried out with a sample size of 262 universities. All of the statistical test results and the final version of the instrument were provided. Thus, this paper is both a theoretical paper that conceptually synthesizes the literature on instructional interactivity and a technical paper that considers the information from an instrument-development point of view.

Keywords

Instructional interactivity, Survey development, Instrument validity, Reliability, Learning

Introduction

Interactivity and interaction are two terms that have been used very often in the literature of science, science education, computer science, educational technology, distance education, curriculum and instruction, and psychology (Chim, Lau, Leong, & Si, 2003; Fahy, 2003; Juwah, 2003; Kirsh, 1997; Tobin, 1993; Wagner, 1994). While reporting a recent review of the literature about interactivity in computer-mediated college and university education, Muirhead and Juwah (2004), in an earlier issue of the Journal of Educational Technology and Society, emphasize that interactivity and interaction are critical in underpinning the learning process in face-to-face, campus-based and distance education.

Empirical and conceptual studies about interactivity and interaction are usually associated with operational definitions specific to the educational contexts investigated. Thus, while the importance of interactivity was emphasized in considerable studies in education (Anderson, 2002; Bork, 1982; Fahy, 2003; Fulford & Zhang, 1993; Hirumi, 2002; Jonassen, 1985, 1988; Juwah, 2003; Kahveci, 2006; Kirsh, 1997; Muirhead & Juwah, 2004; Rose, 1999; Simpson & Galbo, 1986; Sims, 1997, 2000; Wagner, 1989, 1990, 1994, 1997), there is no settled view of what it means for instruction (Kirsh, 1997). In fact, interactivity is essentially medium-specific (e.g., videodisks, distance education, educational software, etc.), somewhat arbitrary, and not very descriptive (Schwier & Misanchuk, 1993). Because of this, many unresolved questions about the nature of interactivity (Kirsh, 1997) remain. The operational definitions and given meanings are generally context-dependent, and fluctuate from one meaning to another as context changes. For example, Kirsh (1997) builds his argument on the concept of interactivity mostly as it applies to the design of multimedia learning environments along the lines of cognitive approach.

Also, due to the lack of theory to guide research, information available in the literature about the complex phenomena of interactivity and interaction is rather limited (Anglin & Morrison, 2003). In support of this issue, Sims (1997) indicates that interactivity is important but there appears to be no consensus of what interactivity actually represents or involves. Sims (2000) also claims that it is important to reassess not only the notion of interactivity but also its role in enhancing the learning process in its various forms. Moreover, Fulford and Zhang (1993) suggest that the model of motivational categories can provide a framework to research interactivity in education. Wagner (1990) also recommends that future considerations of interaction and interactivity should draw upon the results of research from the following domains: learning and learning theory, instructional theory, instructional design, and instructional delivery.

While having practical and technical meanings, the purpose of this study is to develop the IS survey to gather faculty members' perceptions about instructional interactivity. The faculty members are selected only from departments of education at various universities around the world. Thus, the expected output of the study illuminates educators' common perceptions about the meaning of instructional interactivity and/or interaction.

Developing the Interactivity Survey Items

With the IS, the research consists of five categories: the **functional definitions of interactivity**, the **existence of interactivity** in various instructional settings, the attributes of interactivity as a function of **motivation** and **learning theories**, and the **events of interactivity**. These categories will be evaluated with respect to eight predictors: gender, age, present status, highest degree obtained, geographic region, research interest in interactivity, personal learning preferences (revealed by the VARK Questionnaire originally developed by Neil Fleming [2001]; added to the IS with his permission), and department. In the Table 1, the IS items in all five sections and their sources were given. Note that further explanations will be provided about the survey items, such as the explanations in "grey" after presenting the pilot study analysis, in the following sections.

Table 1. The IS with item sources from related literature

<table>
<tr><th colspan="2">Functional Definitions of Interactivity</th></tr>
<tr><td colspan="2">The following are the definitions of interactivity or interaction, stemming from the literature of different fields of education.

Please rank the following definitions in terms of how comprehensive you feel the definitions are with regard to covering all of the types of interactivity you feel are important in learning, in the range of Very Comprehensive, Comprehensive, Medium Comprehensive, Somewhat Comprehensive, Not Comprehensive OR Not Applicable. If you rank any item as Not Comprehensive, please comment on it by referring to its number.</td></tr>
<tr><th>Questions</th><th>Sources for Question Design</th></tr>
<tr><td>1. Interaction is all manners of behaviour, in which individuals and groups act upon each other.</td><td>"Interaction is defined as all manners of behaviour in which individuals and groups act upon each other. The essential characteristic is reciprocity in actions and responses in an infinite variety of relationships: verbal or nonverbal, conscious or unconscious, enduring or causal. Interaction is seen as a continually emerging process, as communication in its most inclusive sense" (Simpson & Galbo, 1986, p. 38).</td></tr>
<tr><td>2. Interactions are reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another.</td><td>"Interactions are reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another" (Herring, 1987; Wagner, 1994). "Interactivity refers to the activity between two organisms" (Jonassen, 1988, p. 97).</td></tr>
<tr><td>3. Interactivity is a complex, dynamic coupling between two or more intelligent parties. The nature of interaction requires cooperation, coordination of activities, power exertions over each other, and a degree of negotiation.</td><td>"If we consider examples of interactivity in daily life, our clearest examples come from social contexts: a conversation, playing a game of tennis, dancing a waltz, dressing a child, performing as a member in a quartet, reacting to the audience in improv theatre. All these highly interactive recreations teach us something about the nature of interaction. Each requires cooperation, the involved parties must coordinate their activity or else the process collapses into chaos; all parties exercise power over each other, influencing what the other will do, and usually there is some degree of (tacit) negotiation over who will do what, when and how. In these examples, interactivity is a complex, dynamic coupling between two or more intelligent parties" (Kirsh, 1997).</td></tr>
<tr><td>4. Interactivity describes a learning process in which the student and the system (i.e., computer) alternate in addressing each other. Typically, each is capable of selecting alternative actions based on the actions of the other.</td><td>"Burke (1982) claimed that interactivity describes a learning process in which the student and the system alternate in addressing each other. Typically, each is capable of selecting alternative actions based on the actions of the other (p. 195)" (As cited in Rose, 1999).</td></tr>
<tr><td>5. Interaction is typically thought of as sustained</td><td>"Interaction is typically thought of as sustained two-way</td></tr>
</table>

two-way communication among two or more persons for purposes of explaining and challenging perspectives.	communication among two or more persons for purposes of explaining and challenging perspectives (Garrison, 1993, p. 16)" (As cited in Berge, 1999).
6. Interactivity is the extent to which the communicator and the audience respond to, or are willing to facilitate, each other's communication needs.	Interactivity is "the extent to which the communicator and the audience respond to, or are willing to facilitate, each other's communication needs" (Ha & James, 1998, p. 461).

Existence of Interactivity in Various Instructional Settings

Which of the following educational media do you think have some forms of interactivity? Please rank all that apply. Your ideas about this question are important to understand how you perceive **interactivity** in the context of teaching and learning. There will be follow-up questions to delineate the existence of **interactivity** in these contexts.

10. Classroom. *(If selected, this item has follow-up items as given below.)*	
	Which of the following classroom events do you think possess interactivity? Please rank each item in the range of Very High Interactivity, High Interactivity, Medium Interactivity, Low Interactivity, Very Low Interactivity, and No Interactivity.
	10.1. Professor lecturing only.
	10.2. Professor lecturing and encouraging students to ask content related questions: Students are able to state their opinions about the content.
	10.3. Professor lecturing and giving some pauses for small group discussions: Students in small groups have discussions about the content being lectured and share their conclusions with others in class.
	10.4. Professor lecturing and promoting discussion groups to share their conclusions.
11. Computer aided teaching/learning. *(If selected, this item has follow-up items as given below.)*	
	The following are some computer aided teaching/learning events. **Considering the use of these events for teaching and their potential for interactivity, please rank each item** in the range of Very High Interactivity, High Interactivity, Medium Interactivity, Low Interactivity, Very Low Interactivity, and No Interactivity.
	11.1. Use of computer programs (i.e., educational software) for teaching/learning.
	11.2. Use of the Internet for teaching/learning.
	11.3. Use of presentation software (e.g., PowerPoint) and simulation programs (e.g., Java).
12. Use of Multimedia for teaching/learning.	
13. Use of videodisks for teaching/learning.	
14. Textbook. *(If selected, this item has follow-up items as given below.)*	
	In what ways can a textbook be interactive? Please rank each item in the range of Very High Interactivity, High Interactivity, Medium Interactivity, Low Interactivity, Very Low Interactivity, and No Interactivity.
	14.1. By reading textbook.
	14.2. By studying visual representations in the textbook, such as charts, diagrams, and photographs.
	14.3. By solving problems or doing concept maps while reading.
15. Laboratory (i.e., hands-on inquiries).	
16. None of the items above has any degree of interactivity.	

The Attribute of Interactivity as a Function of Motivation (The ARCS Theory)

Considering the function of interactivity in the process of teaching/learning, please rank each item in the range of Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD).

Questions	Sources for Question Design
17. Interactivity is a strategy to learner motivation. **18.** Interactivity is a strategy to increase learner's participation.	"If learners are not actively engaged in the instruction, they tend to become distracted and less motivated" (Fulford & Zhang, 1993).
19. Interactivity should be perceived as a learning outcome rather than a generic teaching	"In the past, interaction has been treated as a generic teaching technique. Perhaps, instead, perceptions of interaction should

technique.	be treated as a desired learning outcome. Future studies should examine this possibility" (Fulford & Zhang, 1993).
Please rank each item in the range of Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD). **Interactivity in classroom will increase if a professor:**	
Questions	**Sources for Question Design**
Attention	
20. Captures students' attention by using unexpected approaches to teaching, such as personal experiences.	"The ARCS (Attention, Relevance, Confidence, and Satisfaction) model of motivational categories can provide a framework for designing learning strategies to increase the perception of, as well as the actual level of, interaction in the class" (Fulford & Zhang, 1993). **Perceptual Arousal:** "Create curiosity, wonderment by using novel approaches, injecting personal and/or emotional material" (Keller, 1987a).
21. Stimulates lasting curiosity with problems that invoke mystery.	**Inquiry Arousal:** "Increase curiosity by asking questions, creating paradoxes, generating inquiry, and nurturing thinking challenges" (Keller, 1987a).
22. Maintains students' attention by varying the instructional presentation.	**Variability:** "Sustain interest with variations in presentation style, concrete analogies, human interest examples, and unexpected events" (Keller, 1987a).
Relevance	
23. Emphasizes the utility of instruction by stating how instruction relates to personal goals.	**Goal Orientation:** "Provide statements or examples of the utility of the instruction, and either present goals or have learners define them" (Keller, 1987a).
24. Emphasizes the utility of instruction by having the learners determine how instruction relates to personal goals.	
25. Motivates students by providing opportunities for personal achievement (i.e., leadership responsibilities).	**Motive Matching:** "Make instruction responsive to learner motives and values by providing personal achievement opportunities, cooperative activities, leadership responsibilities, and positive role models" (Keller, 1987a).
26. Makes instruction relevant by building on learners' previous experiences.	**Familiarity:** "Make the materials and concepts familiar by providing concrete examples and analogies related to the learners' work" (Keller, 1987a).
Confidence	
27. Creates a positive expectation for success by making clear the instructional objectives.	**Learning Requirements:** "Establish trust and positive expectations by explaining the requirements for success and the evaluative criteria" (Keller, 1987a).
28. Allows learners to set their own goals.	
29. Provides opportunities for students to successfully attain challenging goals.	**Success Opportunities:** "Increase belief in competence by providing many, varied, and challenging experiences which increase learning success" (Keller, 1987a).
30. Provides learners with a reasonable degree of control over their own learning.	**Personal Control:** "Use techniques that offer personal control (whenever possible), and provide feedback that attributes success to personal effort" (Keller, 1987a). The question was designed according to Driscoll (2000, p. 331).
Satisfaction	
31. Allows learners to use newly acquired skills by providing opportunities to solve "real-world" problems.	**Natural Consequences:** "Provide problems, simulations, or work samples that allow students to see how they can now solve "real-world' problems" (Keller, 1987a).
32. Uses positive consequences such as verbal praise, real or symbolic rewards.	**Positive Consequences:** "Use verbal praise, real or symbolic rewards, and incentives, or let students present the results of their efforts ('show and tell') to reward success" (Keller, 1987a).
33. Ensures equity by providing consistent standards for all learners' tasks and	**Equity:** "Make performance requirements consistent with stated expectations, and provide consistent measurement

accomplishments.	standards for all learner's tasks and accomplishments" (Keller, 1987a).
Please rank each item in the range of Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD). **Advances in technology such as audio, text, and video increase interactivity:**	
Questions	**Sources for Question Design**
34. Between teachers and students.	"Current thinking suggests that, as a result of the technologically enabled exchange of audio, text, and video, greater interaction between teachers and students, among students, and between students and content is likely to ensue" (Wagner, 1994).
35. Among students.	
36. Between students and content.	
The Attribute of Interactivity as a Function of the Conditions of Learning (Gagné)	
The following events are the necessary conditions for learning according to the Conditions of Learning Theory (R. Gagné). **To achieve learning according to the Conditions of Learning, what degree of interactivity is required**? Please rank each item in the range of Very High Interactivity (VHI), High Interactivity (HI), Medium Interactivity (MI), Low Interactivity (LI), Very Low Interactivity (VLI), and No Interactivity (NI).	
Questions	**Sources for Question Design**
37. Gaining attention (reception).	The events that provide the necessary conditions for learning: **1.** gaining attention (reception) **2.** informing learners of the objective (expectancy) **3.** stimulating recall of prior learning (retrieval) **4.** presenting the stimulus (selective perception) **5.** providing learning guidance (semantic encoding) **6.** eliciting performance (responding) **7.** providing feedback (reinforcement) **8.** assessing performance (retrieval) **9.** enhancing retention and transfer (generalization). (Gagné, Briggs, & Wager, 1992)
38. Informing learners of the objective (expectancy).	
39. Stimulating recall of prior learning (retrieval).	
40. Presenting the stimulus (selective perception).	
41. Providing learning guidance (semantic encoding).	
42. Eliciting performance (responding).	
43. Providing feedback (reinforcement).	
44. Assessing performance (retrieval).	
45. Enhancing retention and transfer (generalization).	
The Events of Interactivity	
Please consider the following events of teaching. **Based on your experiences, knowledge, and beliefs in teaching, which "event or events" represent some degree of interactivity**. Please rank each item in the range of Very High Interactivity (VHI), High Interactivity (HI), Medium Interactivity (MI), Low Interactivity (LI), Very Low Interactivity (VLI), and No Interactivity (NI).	
Questions	**Sources for Question Design**
46. Teacher-centred instruction.	"...although interactivity eludes clear definition, those writing about it seem to find it easiest to explain what interactive instruction is by contrasting it with what it is not: not teacher-controlled but learner-controlled; not a lecture, in which the learner is a passive recipient of information, but an opportunity for students to engage in active, hands-on exploration, often via hypermedia technologies" (Rose, 1999, p. 44).
47. Learner-centred instruction.	
48. A lecture, in which the learner is a passive recipient of information.	
49. Active learning through hands-on exploration, often via laboratory or computer program.	
50. A lecture in which the student is spectator (i.e., a member of the audience).	"Thus, in discussing the value of interactive computer-based learning, Alfred Bork (1981) frequently reinforces central oppositions between students as spectators and as participants, between passive and active learning environments, and between the lecture and interactive computer programs (p. 275)" (As cited in Rose, 1999).
51. A lecture in which the student is a participant.	
52. A lecture based on instructionist principles (i.e., feeding students information).	"In extolling the benefits of computers in The Children's Machine, Seymour Papert (1993) constructs similar contrasts, such as that between 'instructionism' and 'constructionism' (p. 137) — that is, between feeding children information and letting them find it for themselves (p. 139)" (As cited in Rose, 1999).
53. A lecture based on constructionist principles (i.e. letting students find information for themselves).	
54. A lecture in which student absorbs material.	"And, in Growing Up Digital, Don Tapscott (1998) discusses

55. A lecture in which student learns how to learn.	interactive learning in terms of eight antithetical pairs, including 'linear' and 'hypermedia' learning, 'instruction' and 'construction,' and 'absorbing material' and 'learning how to learn' (pp. 142–149)" (As cited in Rose, 1999).

Functional definitions of interactivity

Six survey items ranging from **1** to **6**, as depicted in Table 1, were developed on the basis of functional definitions of interactivity, which were extracted from the literature covering various fields of education. The purpose of posing these items was to understand the commonalities of the perceptions in different meanings of instructional interactivity or interaction.

Investigating the existence of interactivity in various instructional settings

Items from **10** to **16** were meant to assess faculty members' perceptions of interactivity within various instructional settings. Some items contain follow-up items, for example, "Classroom." If "Classroom" was selected, the system prompts related items (i.e., **10.2** and **10.3**) as well in the following screen. This feature of the system is called "adaptive."

The attribute of interactivity as a function of motivation

Items from **17** to **36** investigate the faculty's perceptions of interactivity as a function of learner motivation. Fulford and Zhang (1993) suggest that since perceptions of interactions seem to be a critical predictor of satisfaction, specific strategies should be designed to increase these perceptions. They proposed that because perception and satisfaction are affective characteristics, the Attention, Relevance, Confidence, Satisfaction (ARCS) model of motivational categories can provide a framework for designing learning strategies to increase the perception of, as well as the actual level of, interaction in a class. Wagner (1994) further proposed that instructional theories such as Keller's ARCS Theory (1983) provide comprehensive frameworks to support a view of interactivity. The related items in the IS were derived from the principles of ARCS Model of motivation.

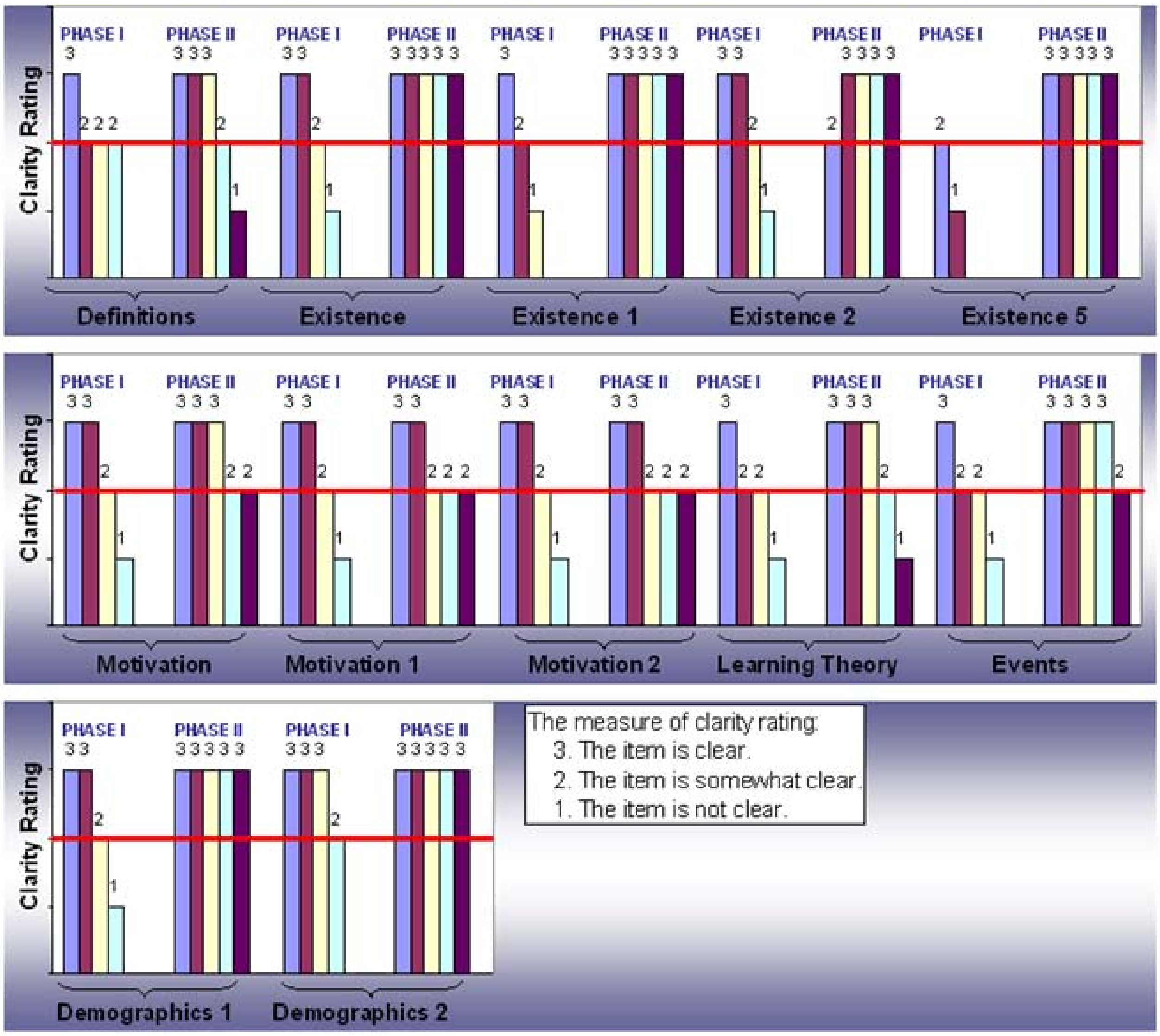
The ARCS Model describes, in four categories and their subcategories, how to understand the motivation to learn (Keller, 1987b). (See items **20** to **33** in Table 1.) The principles of the ARCS Model were presented in many early studies (Keller, 1983, 1987a, 1987b; Keller & Kopp, 1987; Keller & Suzuki, 1987).

The attribute of interactivity as a function of motivation and learning theories

In addition, Wagner (1990) suggested that future studies of interactivity should draw upon the results of research from the following domains: (1) learning and learning theory, (2) instructional theory, (3) instructional design, and (4) instructional delivery. Wagner (1994) further proposed that learning theories such as the Conditions of Learning (Gagné, 1984) — feedback, elaboration, learner control, self-regulation, and motivation — provide comprehensive frameworks to support a view of interactivity as a function of learning and instruction. That's why one of the measures of the Conditions of Learning, "the attribute of interactivity," was used to develop related items in Table 1, ranging from **37** to **45**. The Conditions of Learning was framed on the basis of cognitive psychology and information-processing conceptions. According to the information-processing model of learning and memory, learning processes follow a stage-like progression from sensory registration to long-term storage and learner performance. Events of instruction, conceived as a set of stimuli that give support to internal learning processes, accordingly follow a similar progression. These events begin with gaining attention, followed by informing the learner of the learning objective, and proceed through the stages of stimulating recall of prior learning, presenting the stimulus, providing learning guidance, eliciting performance, providing feedback, assessing the performance, and enhancing retention and transfer. These instructional events form the basis for the design of instruction as described by Gagné and Briggs (Gagné & Briggs, 1979).

The events of interactivity

Rose stated that “interactivity eludes clear definition; thus, those writings about it seem to find it easier to explain what interactive instruction is by contrasting it with what it is not as follows: not teacher-controlled but learner-controlled; not a lecture, in which the learner is a passive recipient of information, but an opportunity for students to engage in active, hands-on exploration, often via hypermedia technologies” (1999, p. 44). These are interactive events as opposed to non-interactive events. For defining interactive constructs, it is essential that these conceptualizations are examined as perceived by the education community, and compared to see if there are similarities between theory and practice. This discussion is derived the items from **46** to **55** in Table 1.



The labels under each bar denotes related items as follows: Definitions, items 1–9; Existence, 10–16; Existence 1, 10.1–6; Existence 2, 11.1–3; Existence 5, 14.1–3; Motivation: 17–19; Motivation 1, 20–33; Motivation 2, 34–36; Learning Theory, 37–45; Events, 46–55. Please note that the item numbers refer to Table 1.

Figure 1. Item clarity ratings of the experts participated in the content validity process

The content validity of the interactivity survey

Eight professors, who were the experts in the field, assisted with the content validity of the interactivity survey. Validity has been defined as referring to the appropriateness, correctness, meaningfulness, and usefulness of the specific conclusions that researchers derive from their data (Fraenkel & Wallen, 2003, p. 150). Of the eight professors, one was in the Department of Educational Leadership and had experience teaching courses via the Internet, one was working in a private company for a while and was very well known in the literature with her interactivity research focusing on the terms' conceptualization, and six were at the Department of Educational Leadership and Learning Systems of a major university in the United States. Of the six professors, one was an expert in learning and instructional theories, one was proficient in assessment and distance education, one was a survey researcher and statistics lecturer, and three were experts in instructional systems design. The experts evaluated items clarity by the following scale:

1. The item is not clear.
2. The item is somewhat clear.
3. The item is clear.

Furthermore, in the web form, a text area was provided for the reviewers to give their comments or suggestions to improve the clarity of an item. The analysis of the reviewer evaluation provided the content-related evidence of validity, which assured that the content and format of the instrument were appropriate and comprehensive. The review process was completed in two phases. In phase one, four professors gave their feedback. The instrument was revised on the basis of the comments. In phase two, the other four professors reviewed the instrument. Figure 1 illustrates their clarity ratings. Please note that the ratings in Figure 1 were grouped by the item sections in the online survey forms.

The Pilot Study

The sample of the pilot procedure consisted of one professor from each university in the database, resulting in 262 faculty members. Of the 262 invitations, 59 faculty members responded to the IS online. Due to the space limitations and the technical significance of this paper, item-based descriptive statistics are not listed here. However, the data was appropriate to conduct the necessary parametric analysis. Table 2 depicts the factor loadings of the IS data. The convention of numbering items was not changed in the following analysis. Thus, the item numbers that were removed from survey.

*Table 2***.** Item-based factor loadings of the IS

Items	C1	C2	C3
Functional Definitions of Interactivity			
1. Interaction includes all manners of behaviour, in which individuals and groups act upon each other.	-.217	.813	N/A
2. Interactions are reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another.	.229	.717	N/A
3. Interactivity is a complex, dynamic coupling between two or more intelligent parties. The nature of interaction requires cooperation, coordination of activities, power exertions over each other, and a degree of negotiation.	.713	-.234	N/A
4. Interactivity describes a learning process in which the student and the system (i.e., computer) alternate in addressing each other. Typically, each is capable of selecting alternative actions based on the actions of the other.	.685	-.225	N/A
5. Interaction is typically thought of as sustained two-way communication among two or more persons for purposes of explaining and challenging perspectives.	.676	.156	N/A
6. Interactivity is the extent to which the communicator and the audience respond to, or are willing to facilitate, each other's communication needs.	.578	.430	N/A
Cronbach's alpha	.52	.58	N/A
Existence of interactivity in various instructional settings			
10.2. Professor lecturing and encouraging students to ask content-related questions: Students are able to state their opinions about the content.	.028	-.103	.918
10.3. Professor lecturing and giving some pauses for small group discussions: Students in small groups have discussions about the content being lectured and share their conclusions with others in class.	-.085	.014	.904
11.1. Use of computer programs (i.e., educational software) for teaching/learning.	-.156	.876	-.077

Items	C1	C2	C3
11.2. Use of the Internet for teaching/learning.	-.092	.840	-.234
14.1. By reading textbook.	.871	-.126	.097
14.2. By studying visual representations in the textbook such as charts, diagrams, and photographs.	.922	.071	-.063
14.3. By solving problems or doing concept maps while reading.	.874	.003	-.090
Cronbach's alpha	.87	.82	.79
Function of interactivity			
17. Interactivity is a strategy to increase learner's motivation.	.827	N/A	N/A
18. Interactivity is a strategy to increase learner's participation.	.868	N/A	N/A
Cronbach's alpha	.71	N/A	N/A
The attribute of interactivity as a function of motivation			
20. Captures students' attention by using unexpected approaches to teaching, such as personal experiences.	.320	.679	.016
22. Maintains students' attention by varying the instructional presentation.	.264	.731	.320
23. Emphasizes the utility of instruction by stating how instruction relates to personal goals.	.070	.551	.549
24. Emphasizes the utility of instruction by having the learners determine how instruction relates to personal goals.	.436	.065	.595
25. Motivates students by providing opportunities for personal achievement.	.582	.407	.342
26. Makes instruction relevant by building on learners' previous experiences.	.729	.340	.233
27. Creates a positive expectation for success by making clear the instructional objectives.	.495	.599	.334
29. Provides opportunities for students to successfully attain challenging goals.	.701	.071	.401
30. Provides learners with a reasonable degree of control over their own learning.	.811	.113	.085
31. Allows learners to use newly acquired skills by providing opportunities to solve "real-world" problems.	.293	.418	.465
32. Uses positive consequences such as verbal praise, real or symbolic rewards.	.082	.123	.753
33. Ensures equity by providing consistent standards for all learners' tasks and accomplishments.	.190	.121	. 731
Cronbach's alpha	.83	.76	.77
The attributes increasing interactivity			
34. Between teachers and students.	.938	N/A	N/A
35. Among students.	.915	N/A	N/A
36. Between students and content.	.680	N/A	N/A
Cronbach's alpha	.81	N/A	N/A
The attribute of interactivity as a function of Conditions of Learning (Gagné)			
37. Gaining attention.	.372	.592	N/A
38. Informing learners of the objective.	.583	.574	N/A
39. Stimulating recall of prior learning.	.900	-.007	N/A
40. Presenting the stimulus.	.760	.351	N/A
41. Providing learning guidance.	.634	.370	N/A
42. Eliciting performance.	.717	.208	N/A
43. Providing feedback.	.104	.789	N/A
44. Assessing performance.	.204	.847	N/A
45. Enhancing retention and transfer.	.595	.371	N/A
Cronbach's alpha	.85	.79	N/A
The events of interactivity			
48. A lecture in which the learner is a passive recipient of information.	.821	N/A	N/A
50. A lecture in which the student is a spectator.	.907	N/A	N/A
51. A lecture in which the student is a participant.	.663	N/A	N/A
54. A lecture in which the student absorbs material.	.829	N/A	N/A
Cronbach's alpha	.80	N/A	N/A

C1: Component1, C2: Component2, C3: Component3

Discussion and conclusion

Although all of the factor loadings are given in Table 2, due to their theoretical constructs an independent factor analysis was carried out for each section of the survey (i.e., the events of interactivity, the attribute of interactivity, etc.). Factor analysis was carried out using the principal component method to uncover underlying relationships among responses. To observe the maximum variances of the factors that contribute to the model, the varimax rotation was applied to every factor solution by setting the threshold of one for the eigenvalues of each item. Naturally, the rotated solutions were possible to obtain if there was more than one component in the associated factor solutions.

The result of the factor analysis on the six variables of Functional Definitions of Interactivity showed two discrete components. These components were attributable to two sources of variation, having 56.2% cumulative variance of the eigenvalues. Although interactivity and interaction were used interchangeably, the factor analysis indicated that the faculty members perceived both terms differently, revealing two factor components: Interaction (Component 1) and Interactivity (Component 2). The interaction component accounted for 31.1% of the total 56.2% variance.

The factor structure of the seven variables of Existence of Interactivity in Various Instructional Settings showed three discrete components, named: Textbook (Component 1, having 30.6% variance), Use of Computer (Component 2, having 24.3% variance), and Classroom (Component 3, having 22.2% variance). These components were attributable to three sources of variation, having 77.1% cumulative variance.

Function of Interactivity loaded only one factor component, having 65.2% variance.

The Attribute of Interactivity as a Function of Motivation consisted of 12 items. Factor analysis with varimax rotation revealed three discrete components: Attention-Relevance (Component 1, having 21.7% variance), Confidence (Component 2, having 19.5% variance), and Satisfaction (Component 3, having 18.4% variance). These components were attributable to three sources of variation, having 59.6% cumulative variance of the eigenvalues.

The Attributes Increasing Interactivity loaded only one factor component with 72.6% total variance.

The Attribute of Interactivity as a Function of Conditions of Learning consisted of nine items. Factor structure included two components: Guidance (Component 1, having 35.4% variance) and Communication and Assessment (Component 2, having 27.3% variance). The total variation turned out to be 62.8%.

Finally, the Events of Interactivity loaded only one factor component by a total of 65.6% variance.

This study developed a 49-item instrument, the IS, to evaluate the perceptions of faculty members at departments of education at universities around the world. The instrument was originally designed for online data collection with an adaptive feature. The evidence of the instrument's content validity and its reliability is based on the pilot study, depending on both qualitative and quantitative data.

Due to the nature of the pilot study, the data presented above is too limited to speculate the faculty members' perceptions about instructional interactivity, especially by taking a comparative analysis with respect to personal characteristics such as gender, age, department, etc. However, the data was good enough to judge the instrument's internal consistency from statistical point of view.

In conclusion, this study is a theoretical paper because it conceptually synthesizes the literature about instructional interactivity and a technical paper from an instrument-development point of view. By utilizing this instrument, deeper analyses with a large sample size are needed to uncover the common perceptions among faculty members in departments of education about the nature of instructional interactivity.

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References

Anderson, T. (2002). *An updated and theoretical rationale for interaction*, Retrieved June 15, 2007, from http://it.coe.uga.edu/itforum/paper63/paper63.htm.

Anglin, G. J., & Morrison, G. R. (2003). *Evaluation and research in distance education: Implications for research*, Greenwich: Information Age Publishing.

Berge, Z. L. (1999). Interaction in post-secondary web-based learning. *Educational Technology, 39*(1), 5–11.

Bork, A. (1981). *Learning with computers*, Bedford, MA: Digital Press.

Bork, A. (1982). Interactive learning. In R. Taylor (Ed.), *The computer in the school*. New York, NY: Teachers College Press.

Burke, R. L. (1982). *Cai source book*, Englewood Cliffs, NJ: Prentice-Hall.

Chim, J., Lau, R. W. H., Leong, H. V., & Si, A. (2003). Cyberwalk: A web-based distributed virtual walkthrough environment. *IEEE Transactions on Multimedia, 5*(4), 503–515.

Driscoll, M. P. (2000). *Psychology of learning for instruction*, Needham Heights, MA: Allyn & Bacon.

Fahy, P. J. (2003). Indicators of support in online interaction. *International Review of Research in Open and Distance Learning*, Retrieved June 7, 2007, from http://www.irrodl.org/index.php/irrodl/article/view/129/209.

Fleming, N. (2001). *Teaching and learning styles*, New Zealand: Microfilm Digital Print and Copy Centre.

Fraenkel, J. R., & Wallen, N. E. (2003). *How to design and evaluate research in education* (5th Ed.), New York: NY: McGraw-Hill Companies.

Fulford, C. P., & Zhang, S. (1993). Perceptions of interaction: The critical predictor in distance education. *The American Journal of Distance Education, 7*(3), 8–21.

Gagné, R. (1984). Learning outcomes and their effects. *American Psychologist, 39*(4), 377–385.

Gagné, R., Briggs, L., & Wager, W. (1992). *Principles of instructional design* (4th Ed.), Fort Worth, TX: HBJ College Publishers.

Gagné, R. M., & Briggs, L. J. (1979). *Principles of instructional design*, New York, NY: Holt, Rinehart and Winston.

Garrison, D. R. (1993). Quality and theory in distance education: Theoretical considerations. In D. Keegan (Ed.), *Theoretical principles of distance education*. New York, NY: Routledge.

Ha, L., & James, E. L. (1998). Interactivity reexamined: A baseline analysis of early business web sites. *Journal of Broadcasting & Electronic Media, 42*(Fall), 457–474.

Herring, R. (1987). Looking at interaction. *Paper presented at the Annual Meeting of the National Society for Performance and Instruction*, San Antonio, TX.

Hirumi, A. (2002). The design and sequencing of e-learning interactions: A grounded approach. *International Journal of E-Learning, 1*, 19–27.

Jonassen, D. (1988). *Instructional designs for microcomputer courseware*, Hillsdale, NJ: Lawrence Erlbaum.

Jonassen, D. H. (1985). Interactive lesson designs: A taxonomy. *Educational Technology, 26*(6), 7–16.

Juwah, C. (2003). Using peer assessment to develop skills and capabilities. *Journal of the United States Distance Learning Association, 17*(1), Retrieved June 7, 2007, from http://www.usdla.org/html/journal/JAN03_Issue/article04.html.

Kahveci, M. (2006). Instructional interactivity endeavour and spiral dynamics. *Bogazici University Journal of Education, 20*(1), 11–24.

Keller, J. M. (1983). Motivational design of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models*, NJ: Erlbaum.

Keller, J. M. (1987a). Strategies for stimulating the motivation to learn. *Performance and Instruction, 26*(8), 1–7.

Keller, J. M. (1987b). The systematic process of motivational design. *Performance and Instruction, November/December*, 1–8.

Keller, J. M., & Kopp, T. W. (1987). Application of the arcs model of motivational design. In C. M. Reigeluth (Ed.), *Instructional theories in action: Lessons illustrating selected theories and models*. Hillsdale, NJ: Lawrance Earlbaum Associates.

Keller, J. M., & Suzuki, K. (1987). Use of the arcs model in courseware design. In D. H. Jonassen (Ed.), *Instructional designs for computer courseware*, New York, NY: Earlbaum Associates.

Kirsh, D. (1997). Interactivity and multimedia interfaces. *Instructional Science, 25*(2), 79–96.

Muirhead, B., & Juwah, C. (2004). Interactivity in the computer-mediated college and university education: A recent review of literature. *Educational Technology & Society, 7*(1), 12–20.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*, New York, NY: Basic Books.

Rose, E. (1999). Deconstructing interactivity in educational computing. *Educational Technology, 39*(1), 43–49.

Schwier, R. A., & Misanchuk, E. R. (1993). *Interactive multimedia instruction*. Englewood Cliffs, NJ: Educational Technology Publications.

Simpson, R. J., & Galbo, J. J. (1986). Interaction and learning: Theorizing on the art of teaching. *Interchange, 17*(4), 37–51.

Sims, R. (1997). Interactivity: A forgotten art? *Computers in Human Behaviour, 13*(2), 157–171.

Sims, R. (2000). An interactive conundrum: Constructs of interactivity and learning theory. *Australian Journal of Educational Technology, 16*(1), 45–57.

Tapscott, D. (1998). *Growing up digital: The rise of the net generation*, New York, NY: McGraw-Hill.

Tobin, K. (1993). Constructivism: A paradigm for the practice of science education. In K. Tobin (Ed.), *The practice of social constructivism in science education* (pp. 1–21). Hillsdale, NJ: Erlbaum.

Wagner, E. D. (1989). Interaction: An attribute of good instruction or a characteristic of instructional technology? *Paper presented at the Annual Meeting of the National University Continuing Education Association*, Salt Lake City, UT.

Wagner, E. D. (1990). Interaction in distance education: Relating practice to theory to improve practice. *Paper presented at the Annual Meeting of the National University Continuing Education Association*, New Orleans, LA.

Wagner, E. D. (1994). In support of a functional definition of interaction. *The American Journal of Distance Education, 8*(2), 6–26.

Wagner, E. D. (1997). Interactivity: From agents to outcomes. In T. E. Cyrs (Ed.), *New directions for teaching and learning* (Vol. 71), San Francisco, CA: Jossey-Bass Publishers.

Ezziane, Z. (2007). Information Technology Literacy: Implications on Teaching and Learning. *Educational Technology & Society*, 10 (3), 175-191.

Information Technology Literacy: Implications on Teaching and Learning

Zoheir Ezziane
College of Information Technology, University of Dubai, P.O. Box 14143 Dubai UAE // zezziane@ud.ac.ae

ABSTRACT

This paper aims to discuss the role and impact that information technology (IT) has on the future and existing style of learning and teaching. It highlights the importance of acquiring computer skills and being literate in IT. The focus is put on certain areas related to IT and education which include pedagogy and training to build IT literacy among both educators and learners. Particularly, it covers the current trends in IT development and how it has started to change and will further influence the way learning and teaching will take place in the future. This paper also discusses various theoretical frameworks and methodologies designed to cope with progress in IT. In summary, this paper delivers a message that IT literacy is the key to today's empowerment and that education is the best foundation for it.

Keywords

IT literacy, Computer literacy, Teaching and learning, Workforce development

Introduction

The demand for qualified IT workers rose steadily over the last decade and is likely to become strong again as the global economy recovers from the current recession. Two specific areas where demand for talent has been consistently growing are those of networking/telecommunications and e-commerce (Minch & Tabor, 2003). This demand is a worldwide phenomenon, with technology-based regions such as Southeast Asia banding together from a National Information Infrastructure plan (Bui, 1997). Organizations of all sizes are increasing their dependency on technology and electronic transactions, moving toward what Straub & Watson (2001) call the network-enabled organization (NEO).

The infrastructure that supports this trend requires technical talent to fill positions such as network managers, web administrators, e-commerce developers, and security specialists. Universities, on the other hand, face important challenges in educating the IT workers of tomorrow in these highly technical fields. Even with increasing enrollments, the number of graduates in computer science and information systems has been inadequate to meet worldwide industry demand (West & Bogumil, 2001), and our teaching methods have not evolved to meet the needs of students and employers in these rapidly changing technical fields (Laurillard, 2002). We face additional challenges in curriculum design with the changing student population. Stein and Craig (2000) note that the "dot.com generation" enters university with an intensive education in technology. Stein and Craig's experiences in Australian universities reveal that incoming students exhibit increased computer knowledge, have more confidence in their skills, and use IT applications more extensively than prior generations.

People acquire their technology literacy in two ways: formally through school programs or in the workplace, and informally, whether at home, from friends, or by themselves. Hoffman and Blake (2003) showed that students learn formally how to create and maintain presentation files as part of a course requirement, and participate in a threaded discussion or possibly create and maintain web pages. Informally, however, students use technology to share what interests them. Online computer help sites at many universities (UMD, 2002; QU, 2002) offer students the ability to informally increase their knowledge about new technology. The presumption appears to be that students already know most of what is considered traditional computer literacy, and they are willing to learn what they do not know about the operation of this technology.

Instructors are feeling increasing pressure to use IT, but they commonly face several obstacles when attempting to use technological teaching techniques. Institutions of higher education must strategically develop IT integration plans that help overcome these obstacles, addressing the needs of diverse pedagogical agendas and multiple levels of comfort with technology. Barriers can make technology use frustrating for the technologically perceptive, let alone the many teachers who may be somewhat techno-phobic (Whitaker & Coste, 2002).

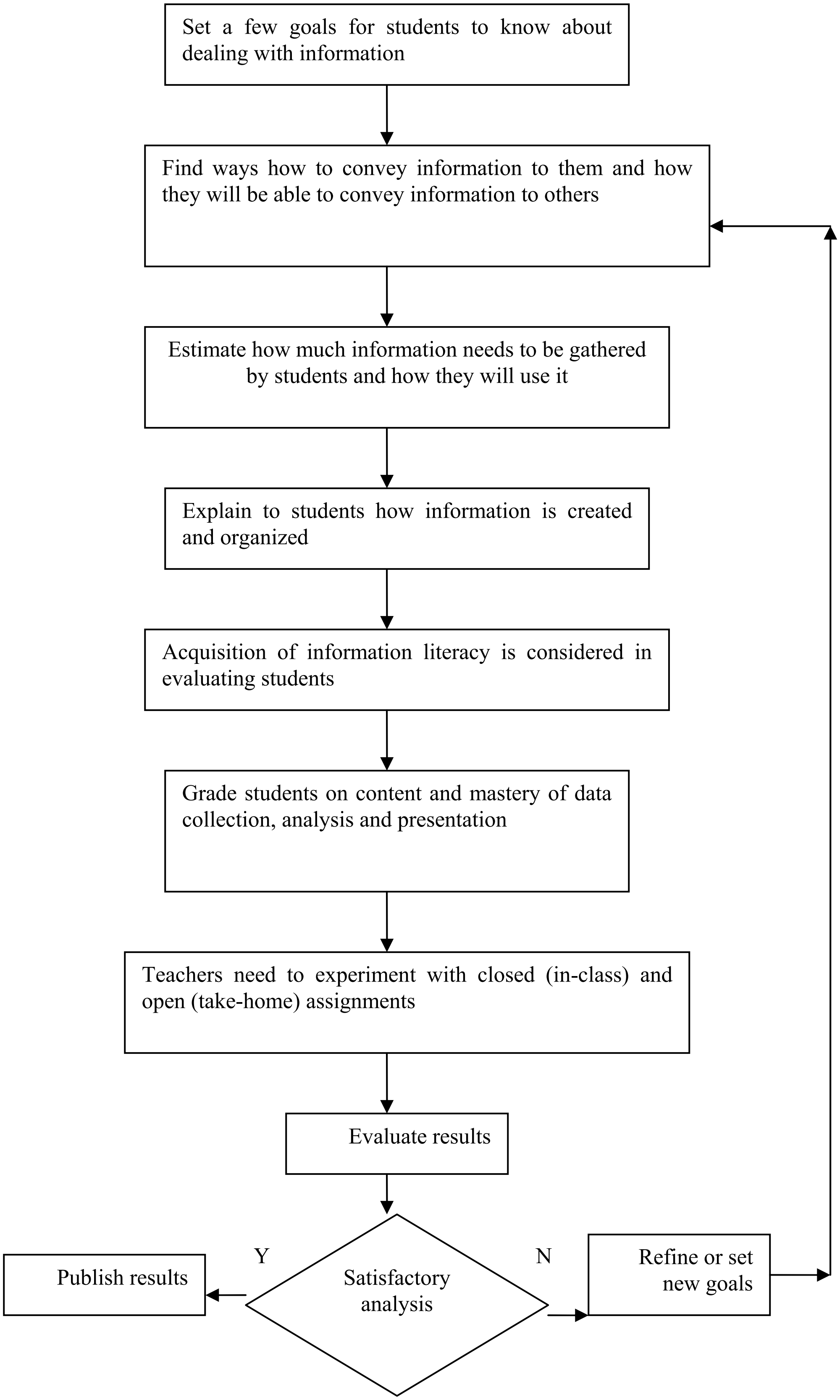

Figure 1. Setting-up and evaluating goals for students' learning

Each instructor uses his or her own approach to teaching and instructing, which he or she believes is the best for the students. Unfortunately, many educators seem unaware of the abundance of the research literature in the teaching and learning sciences to support and question their teaching approaches (Collis, 1998). Key principles for university didactics, as comprehensively reviewed and summarized are:

- Learning arises from the active engagement of the learner; cognitively active roles of both instructor and learner are necessary (Moonen, 1994).
- Communication-oriented pedagogy is turned towards the learner; assessment of competence depends on listening, observing, and responding to learners.
- Good learning is not instructor-transmission oriented but rather process-based and learner-oriented.
- A well-designed instructional environment requires instructor preparation, yet it is aimed at learner self-responsibility (Luft & Tiene, 1997).
- "We must do more with less," students want to move efficiently through their studies, instructors have to move efficiently through their budget (McAvinia & Oliver, 2002).

A common compass reading behind the mentioned principals can be recognized: some sort of strategic orientation in knowledge and skills that the educational system has to provide to a student. Though, not by *pushing,* but rather by preparing the learners to *pull* knowledge and by endowing them with skills that will enable and ease their further education (Trkman & Baloh, 2003). Candy (2004) argues that since organizations are becoming more knowledge based, academics as knowledge workers are ideally equipped to help students become lifelong learners in the information society. Figure 1 depicts a method of how teachers set up goals for students in order to help them learn and acquire knowledge.

Understanding and learning, whether about science or science education, technology integration issues, or teaching in general, requires and follows active involvement. This is true for students learning science, for pre-service teachers learning to teach, or in-service teachers and educators implementing education reform programs in schools (Stevens & Dexter, 2003).

IT Literacy

Over the past 25 years, models and approaches of computer and information literacy have started to merge. This process has been fueled by the rapid growth of technology and its increasing impact on society. Technology is becoming the vehicle for information, and the evaluation of information is becoming one of the main applications of technology.

Looking back chronologically (over the literature), it is obvious that technology paradigm shifts changed not only the way of computing but also how the technology itself is perceived by society. More important, these shifts advance the integration of computing with our environment. Minicomputers allowed a relatively small number of people direct access with a comparatively small cost over earlier mainframes. Universities and even smaller departments within organizations found themselves able to afford dedicated computing power. Computer literacy emerged then as a means of making people aware of this technology.

Computer Literacy

Computer literacy is finding greater common ground with other literacies. It has been described as literacy with digital texts (William, 2002). As digital texts and their unique characteristics become a significant means of communication and information distribution, literacy with digital texts will be included as a component of literacy. Focus is shifting away from the computer toward its integration into a broader understanding of literacy. A brief look at the number of articles indexed under the heading "Computers — Study and Teaching," the subject heading most closely related to computer literacy in the *Reader's Guide to Periodical Literature*, shows a dramatic increase in the mid-1980s, as depicted in figure 2.

There is no agreement among scholars on the definition and measurement of computer literacy (Alshare, Grandon, & Miller, 2004). While some researchers define and measure computer literacy in terms of the number of computer courses completed, the amount of time spent on the computer, and having a computer at home, others consider the familiarity with computer terms, experiences, and ability. Computer literacy is also defined as understanding computer characteristics, capabilities, and applications as well as the ability to implement this knowledge in the skillful, productive use of computer applications to individual roles in society. Accordingly, one of the important tasks the school system has to fulfill is to train students for effective use of technological tools in their future and present daily work.

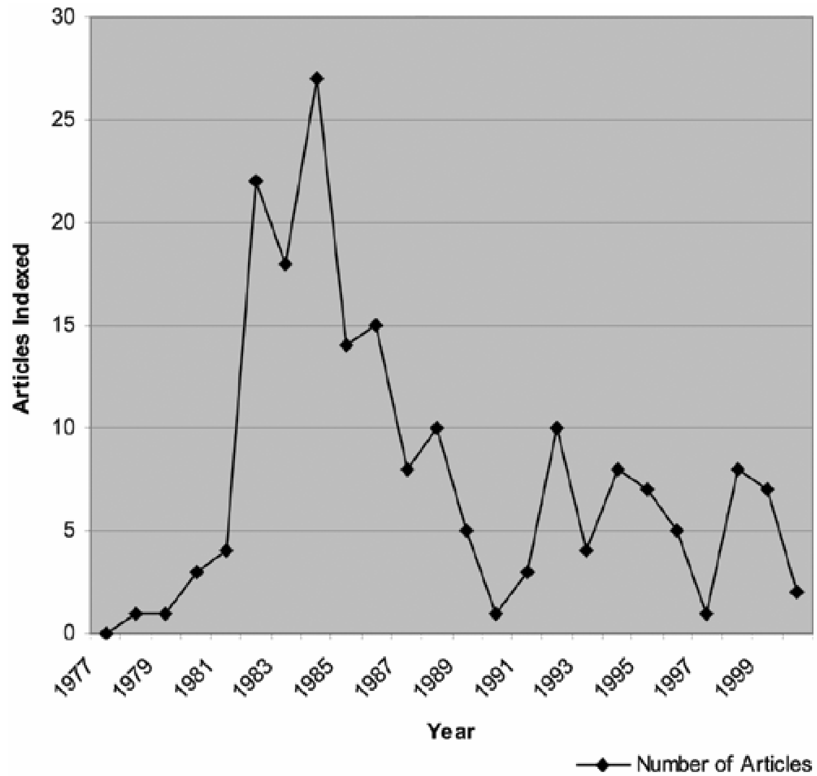

Figure 2. Number of articles indexed under the heading "Computers — Study and Teaching,"

Computer literacy is one of the most important skills a person can have in today's competitive environment. One of the most important changes was the transformation of blue-collar workers into white-collar workers (Hughes, Ginnett, & Curphy, 1999). The pervasive use of IT makes knowledge of and the ability to use IT essential requirements, no matter what kind of work is being done. Whether in a government agency or a multinational corporation, inadequate IT skills of employees are sure to undermine the day-to-day functioning of any organization (Mahapatra & Lai, 2005). Employees today must contribute value by what they know and by the information they can provide. Following that, it is harder and harder to imagine a successful professional career without decent knowledge of (IT) and its effectual use. The degree of computer literacy of new employees is a key element that may dictate the number of resources a company should allocate in training for a successful deployment of computer and IT skills.

IT Skills

It has been noted that high schools play an important role in providing students with computer literacy and preparing them for the global IT workforce (Csapo, 2002). Imparting basic IT skills to students is essential in order for them to function in academia, in the workforce, and in everyday activities. With today's technological society, basic computer literacy is emphasized in every institution's requirements, and is many times offered as a stand-alone core competency, in addition to being integrated into all other core curriculum content areas.

Skills such as managing a personal computer (Radi, 2002; Bartholomew, 2004; Burger & Blignaut, 2004; Hoffman & Vance, 2005), using word processing, network browsers, mail, and spreadsheet software, or understanding an operating system are what are most usually subsumed under the label of computer literacy. Because IT skills are closely tied to today's applications, the set of necessary skills can be expected to change at about the same rate that commercial IT changes, i.e., quite rapidly. Note, for example, that a list of skills developed 10 years ago would not have mentioned the web or the Internet. Changes in the specific interests and needs of the individual involved also have a significant effect on what skills are essential. Over the course of a lifetime, individuals who use IT must regularly evaluate their skills and determine which new skills they need for their workplace or personal success.

Another hurdle in coping with computer literacy is the constant state of flux of IT today. For example, students with a basic awareness of HTML no longer require any knowledge of any encoding system in order to author web pages. In fact, web-authoring programs nowadays such as Dreamweaver or FrontPage not only facilitate the creation of static web pages, they also enable the creation of interactive web pages using a pull-down menu to insert JavaScript "behaviors" or snippets of code. Even learning about website navigation can become an issue. In many academic institutions, teachers use a web course authoring program such as WebCT or Blackboard to create a course website, where each course website presents a familiar and comfortable user interface to students.

The following list of topics is usually taught in many computer literacy courses. Acquiring these skills includes understanding what similarities and differences to expect between different products for the same task (Committee on Information Technology Literacy, 1999). The set of skills might include the following:

- Setting up a personal computer
- Using basic operating system features
- Using a word processor to create a text document
- Using a graphics and/or artwork package to create illustrations, slides, or other image-based expressions of ideas
- Connecting a computer to a network
- Using the Internet and the web to find information and resources
- Using a computer to communicate with others
- Using a spreadsheet to model simple processes or financial tables
- Using a database system to set up and access useful information
- Using instructional materials to learn how to use new applications or features

Skills, concepts, and capabilities represent the three major IT literacy components, which might be approached differently. Students can learn word processing through the need to prepare and submit essays, spreadsheets or databases through the need to manipulate data in science courses, and so on. Many students will develop some of these skills prior to college, but even those who do not will have considerable motivation to learn them. College students have many non-curricular opportunities to develop current IT skills, such as reading self-instruction books, learning from friends, or taking college or university workshops and non-credit courses taught by non-faculty professionals such as computing center professionals and librarians.

The fundamental concepts are somewhat harder to integrate into standard curricula. However, as instructors develop and structure their courses to use IT for enhanced pedagogical effectiveness, it will be increasingly possible to take advantage of the opportunities provided for discussing the fundamental concepts and the application of these concepts in terms that are relevant to the disciplinary content of those courses. For example, art students study images, and often these images are images on a computer screen. But understanding the fidelity of these images to the originals requires an understanding of how images can be digitally represented. A business course might use computer simulations to demonstrate business processes. But understanding the limitations of a simulation requires understanding how processes can be modeled and the nature and scope of their limitations.

The capabilities also warrant being taught as part of disciplinary or departmental instructional programs. Indeed, these capabilities contribute both to IT literacy and to developing analytical skills that are necessary for success in multiple disciplines. The mode of instruction is primarily through projects that serve the purposes of the domain yet offer students the opportunity to interact effectively with IT and to learn and/or exercise all capabilities.

Effective interaction with IT

Information literacy provides students with the opportunity to explore how information and knowledge shapes their lives, their community, and the world. Students become critical users of information, learning how to situate information and knowledge in a diverse global environment. One of the purposes of IT Literacy course of action is to provide a framework for the integration of IT to achieve the vision of IT as a foundation skill area. Effective integration of IT into all curricula assists students in developing the abilities necessary to use, manage, and understand IT. The development of these abilities guides students on their journey toward IT literacy.

Careful consideration of the role of IT will lead to new ways of teaching, learning, and assessing (http://www.edu.gov.mb.ca/ks4/docs/support/tfs/developing.html) (Province of Manitoba, 1998). However, the presence of IT alone will not produce this transformation. Effective interaction with IT provides students with opportunities to:

- utilize the rich, interactive capabilities of IT, providing experiences traditionally unavailable within the school (i.e., computers used only for drill and practice or remedial work will not help reshape education)
- ask questions, identify problems, and seek multiple solutions to problems
- progress at their own rate and gain access to necessary learning resources
- work together, where the emphasis is on teamwork and critical and creative thinking
- act as peer tutors, helping classmates work through problems and challenges
- take responsibility for their own learning and strive to reach high expectations

In here, students focus on the role of technology as an integration tool and how it can be utilized to solve real-world problems, such as how to improve the way a company keeps its customers satisfied, the way decisions are made, how raw materials become finished products, or how products are distributed. Sophisticated IT interactions will be handled during specific training programs provided by the employer.

Targeted IT Training

The critical role of end-user training is regularly noted by corporate managers, as evidenced by the fact that U.S. companies planned to spend approximately $57 billion on employee training in 2001 and that more than one-third (37%) of such programs were targeted at improving the computer skills of employees (Galvin, 2001. While the training of technical employees is not a new challenge, measuring that training for effectiveness and efficiency remains a daunting task. Today, the training function must focus on sustainable competitive advantage by strategically aligning itself with overall corporate business goals (Devaraj & Babu, 2004).

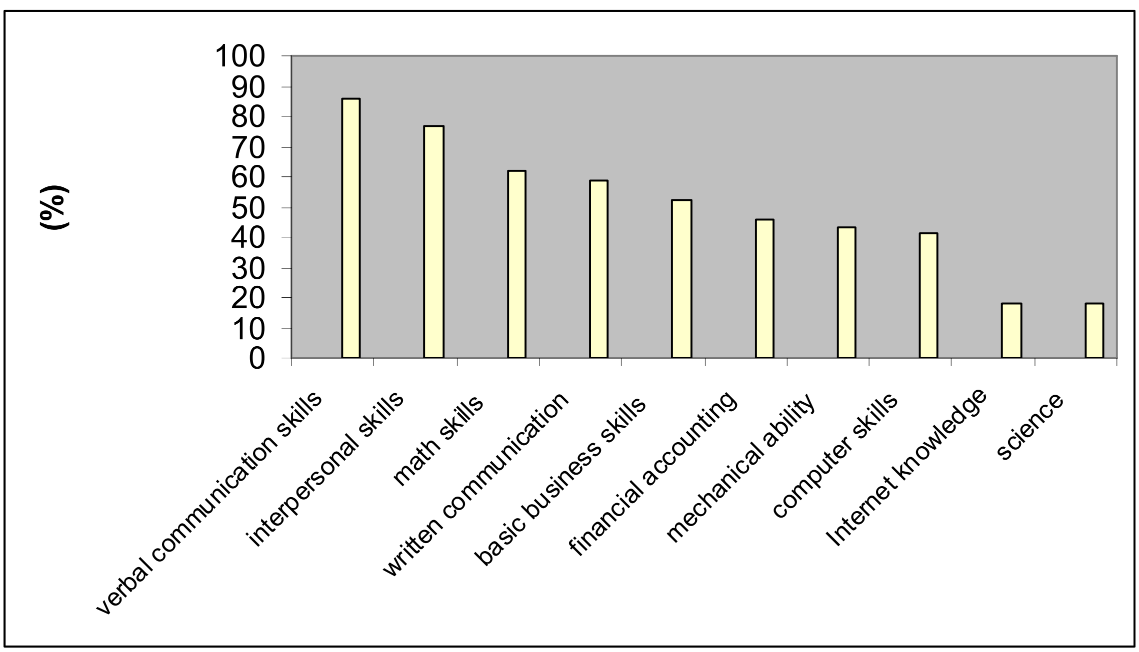

Figure 3. Voices from Main Street: Assessing the state of small business workforce skills

In the U.S., the education and training requirements of the 2000–2010 projected total job openings (Hecker, 2001) due to growth and net replacement are:

- 69.8% of jobs will require work-related training:
- 42.7% short-term on-the-job training
- 15.1% moderate on-the-job training
- 6.5% long-term on-the-job training
- 5.55% work experience in a related occupation.
- 20.9% will require a bachelor's degree or higher
- 9.3% will require an associate's degree or postsecondary vocational award.
-

Voices from Main Street is a program launched by American Express Small Business Services to engage small business owners in a national dialogue about the issues that matter most to them. This report presents the results of the American Express Voices from Main Street Survey, June 2000, which was the second in a series of U.S. small business opinion polls that reached nearly 800 small businesses (American Express, 2000). Computer skills and Internet knowledge represent 42% and 18% respectively. Other skills reported to be important are depicted in figure 3.

Two years later, the National Association of Manufacturers 2001 members' survey found computer skills and specific skills for a particular job were the most important skills representing 54.3% and 64.2% respectively (National Association of Manufacturers, 2002). Table 1 shows the rest of the skills and their corresponding percentages.

Table 1. National Association of Manufacturers 2001 members' survey

7.0%	of employers offered advanced math education opportunities
8.6%	basic reading and writing
9.3%	GED
13.3%	diversity awareness
14.5%	ESL
15.8%	basic math
19.0%	verbal communication
19.7%	formal apprenticeship programs
22.9%	interpersonal skills
25.1%	problem solving
28.7%	customer service
33.5%	teamwork/leadership
37.1%	certification training for various technical degrees/licences
39.6%	continuing education for technical/professional personnel
54.3%	computer skills
60.6%	tuition reimbursement for undergraduate or graduate programs
64.2%	specific skills for a particular job

A strategic business challenge facing all software companies is how to train their employees to keep pace with the software industry's ever-changing knowledge and development requirements. Organizations increasingly recognize that formal training is critical not only for the success of their software professionals but to the organizations' competitive position in the marketplace. One result is growing pressure on training departments to deliver high-quality training and education (Devaraj & Babu, 2004).

Current trends indicate that most computing skills will be learned informally. Skills inventories may be used to identify where student skill and experience is deficient due to lack of training or because a skill was not included in their informal education. Increasingly, the skills that are of value will be mastered informally. In place of formal education, missing skills will be usually acquired by targeted training such as help desks (Hoffman & Blake, 2003).

In principle, educators are not well prepared to use IT effectively (Wright & Marsh, 2000). Proper training requires that faculty gain familiarity with a tool, observe someone experienced in its use implementing it successfully, use the tool themselves, and then gauge its potential to help them meet their pedagogical goals (Barrette, 2000). The learning outcomes of technology use are the result of the activities in which the technology is used. Technology use in and of itself does not provide results (Ehrmann, 2000). Rather than having technology drive teaching practice, teaching goals should drive how technology is implemented (Frayer, 1999), and the training engaged must be prioritized in support of educational content (Sanford, 2000).

Despite the fact that some faculty members have overcome fears of an environment of depersonalized information delivery, training should not minimize the fact that technological advances present faculty with a lot of challenges, or that higher education as a whole has a lot to learn about how technology can enhance student learning. In fact, IT innovation may be occurring faster than our understanding of its use in practice (Merisotis & Phipps, 1999). To respond to the impact of this phenomenon, IT implementation must be approached more as an ongoing organizational learning process than as a technology-acquisition process (Levinson, 2000). Effective IT use involves a continual process of: 1) identifying pedagogical goals; 2) determining what activities will serve this goal; and 3) selecting the appropriate IT tools to implement the activity (Ehrmann, 2000). The fundamental question driving IT adoption must ask what the best methods to teach our students are at any given point in time.

Theoretical Framework for IT Literacy

Jurema and O'Rourke (1997) identified four theoretical IT constructs: tutorial, machine-as-human, tool kit, and catalyst. Their research claims that pervading these constructs is the understanding that IT can be used as an ideological agent, which is vital if there is a need to connect theoretical foundations with practice. The outcome of this investigation underpinned the importance to address both practical levels and theoretical perspectives of IT literacy in the educative process. The practical includes technical, socio-historical, and political-ideological levels, while theoretical perspectives help us to identify which conceptions emphasize the way IT is used.

A theoretical framework for IT literacy could be drawn from various research approaches: 1) organizational knowledge creation theory (Von Krogh et al., 2000; Nonaka, 2003); 2) relational information literacy theory and practice (Bruce, 1997a; Bundy, 2004); and 3) systems thinking methodology (Checkland, 1999; Checkland, 2000; Somerville et al., 2006).

Bruce (2000) argued that research driven by critical theory is intended to be empowering and participatory, and is likely to be of substantial concern to practitioners. Like other research approaches, critical research is recognizable through the philosophies and views supporting it. Relational research, specifically phenomenography, searches to expose important differences or variations in people's ways of seeing aspects of the world. This is achieved through attending to variation in what is called the "relation" between people and the phenomenon of interest. Systems thinking methodology (Somerville et al., 2006) offers a holistic systems thinking framework comprised of rich pictures, root definitions, and conceptual models. This methodology provides common language and shared tools for discussion and analysis of the complexities and interdependencies of situated issues in order to facilitate participants' efforts to make tacit professional knowledge explicit.

Somerville et al. (2006) employed a theoretical framework for IT literacy that blends Eastern and Western approaches to knowledge creation through making implied information explicit and codifying it, while also enhancing implied knowledge flow through better human interaction to generate new ideas.

Numerous studies use a well expressed theoretical framework and provide the research and practitioner community with new methods of thinking about significant aspects of information literacy. For example: 1) Cheuk (1998) used the sensemaking approach to investigate the experience of IT literacy in the workplace; 2) Limberg (1999) studied the use of phenomenography to determine varying ways of experiencing the information-seeking and -use process; 3) Bruce (1997b) conducted phenomenographic exploration of people's varying experience of information literacy; and 4) Todd (2000) examined a cognitive analysis of adolescent girls' use of heroin information to get a better picture on the impact of the drug and hence increase learning capability.

Colins (1995) investigated a number of theoretical and empirical studies on various aspects of literacies. Recently, various new literacies have been identified and conceptualized, and new categorizations of literacies have been proposed (Leu et al. 2004; Lonsdale & McCurry, 2004). However, as Lonsdale and McCurry (2004) argue, not all new theories have added much value to existing conceptualizations of literacies. Their research review suggests that the most explicit and comprehensive theoretical framework for the investigation of literacies includes two taxonomies. The first taxonomy separates the motive of the literacy according to who benefits from literacy: the individual or society. The second taxonomy positions various conceptual and practical aspects of literacy enhancement into two models: autonomous and ideological.

Various taxonomies classify theoretical and practical perspectives according to different criteria. For example, Ba et al. (2002) classify the definitions of digital literacy according to their conceptual and operational features. They identify four major groups of definitions: technical, generic, generic with information technology, and problem-based. Corbel and Gruba (2004) classify perspectives of computer literacy according to their conceptual origin. They identify four categories of perspectives: skills, textual practices, sociopolitical, and information.

The basic IT skills perspective has a more empirical, rather than philosophical, conceptual base (Martin 2000) and a strong wide-ranging practical presence in day-to-day IT literacy teaching and assessment practices (ECDL 2004). This perspective focuses on the basic practical skills needed to use computer hardware, software, and networks.

The cognitive perspective focuses on IT literacy outcomes from a generic skills angle. This view integrates IT knowledge and skills with problem-solving and information handling capabilities (Markauskaite, 2006). Therefore, theoretical works and practical implementations emerge in different disciplinary domains such as information literacy (Eisenberg & Johnson, 2002) and interdisciplinary domains (Candy, 2004). Ba et al. (2002) described two structural approaches: problem-based and generic with information technology. The difference between these two approaches is that problem-based approaches structure IT outcomes based on the key steps of the problem-solving, whereas the generic approach does not link knowledge or skills to specific problem-solving.

Challenges in IT Education and Integration Efforts

Generally, students are expected to support and nurture the learning experiences of their classmates as well as their own (Whitaker & Coste, 2002). This sense of responsibility for one's own learning and the learning of others is extremely empowering and not something to be tampered with. However, it has been observed that fears that technology would dilute this culture were largely groundless. In fact, it may be that IT's greatest contribution to education will be that students take more responsibility for their own learning experiences. Although the inhibiting effect of computer phobia/apprehension was an early concern in the classroom adoption of IT, these fears have faded. The most important factor in reducing apprehension appears to be overall experience with technology (Scott & Rockwell, 1997). In addition, the socially and culturally neutral IT environment (Do & Lee, 1997) seems to mediate the effects of power dynamics present in oral communication and may further reduce apprehension in articulating ideas. As students' exposure to technology increases, IT emerges as an excellent venue for all to share in the learning experience.

Throughout the world, information and communication technology (ICT) is changing the face of education. In addition, ICT is changing the nature of work and the workplace. The knowledge revolution combined with economic globalization has created conditions in which countries that have focused on knowledge-based industries have been able to harvest significant rewards. Knowledge-based industries require an educated labor force of computer-literate individuals who themselves understand and can harness the power of ICT. In response to the demands for producing such a labor force, many countries have changed the objectives of their education system and have directed much of their attention to the development of ICT skills in schools.

Furthermore, ICT offers tremendous possibilities in enhancing students' learning, developing teachers' professional capability, and strengthening institutional capacity. Such possibilities include: 1) computer-aided applications which could be used to individualize learning while giving immediate reinforcement and feedback; 2) combination of computers and multimedia tools and then integrating graphic, audio, and video into appealing computer-based instructional units; and 3) computer-mediated communication technologies such as instant messaging, bulletin boards, and computer conferencing to facilitate communication among students and teachers.

The introduction and sustainability of ICT in the education system is also expensive. The capital cost of the entire infrastructure needed to initiate the process is quite obvious. A little less obvious is the high level of recurrent costs associated with the effective use of ICT. An attempt must therefore be made to optimize the benefits of such large investments and to develop cost-effective maintenance procedures.

Administrative Barriers

Keen vendors, hoping to corner the educational market, provide cut-rate products and services. Legislators pass budgets with large sums for educational technology, because they fear that students will be unprepared for the future unless they use technology every day in school. As a result, well-meaning administrators often seize upon technology as a solution to their budgetary problems. No doubt, some administrators also see technological initiatives as a path to their personal success, a way to make their mark on an institution and advance their own careers (Neal, 1998).

Linked to uncertainty about administrative motives for promoting IT is the necessity for administrative support of the pedagogical rationales for using educational technology tools (Whitaker & Coste, 2002). Administration must acknowledge and address institutional barriers to technology selection and implementation for IT to thrive in the classroom. Usually, administration (or management) provides the original momentum to create an IT committee and will be responsible for charging the group with its mission. Throughout the evolution of the IT environment, administration should monitor how the group is reacting to the challenges encountered during the continual attempts to upgrade and maintain the IT resources.

One of the most popular methods of support for faculty is one in which the complete responsibility for incorporating technology is placed on IT services. The role of the faculty member is to provide the idea. It is then the responsibility of IT services to take the idea and make it work with the technology available on campus. It is also IT services' duty to maintain the tools and technologies and update them when necessary. Accordingly, IT services should design services that are stable and easy to maintain because they know that, in the end, they will be the ones looking after it (Wainwright & Arnold, 2004). High-quality IT literacy teaching requires the administration to provide support for faculty by adequately funding the staffing of IT services personnel to levels that can accommodate the demands placed upon them.

IT Support Structure

IT literacy education focuses on how to effectively enhance teaching and learning, involving all the structures and processes used by an institution to support effective student learning including, for example, support through independent learning, e-learning, and distance learning. It places great importance on the role of "support" services in supporting effective learning, for example, in the provision of libraries and information services and the institution's IT infrastructure. It considers that students are active partners with shared responsibilities for their own learning and achievement, and that one of the defining characteristics of education is the extent to which it relies on this active participation in, and student ownership of, the learning process.

Hampel & Keil-Slawik (2001) argue that mainstream discussions on the role of technology in teaching and learning are based on two basic paradigms. Hypermedia systems aim to support individual learning processes, with special emphasis on new educational qualities, which are attributed to the interactive combination of various media types such as text, graphics, audio, video, etc. The second paradigm embodies the notion of delivering education through networking technology to distribute and access study materials as well as establish communication channels between students and teachers. Students are able to learn individually at their own pace and at their own selected location.

At an institutional level, an area of faculty concern is the support available to them when technology tools fail. Similar to the experiences described by faculty at different institutions, those of us who have used various technologies in our classrooms encountered related problems. Most commonly, problems developed when a new technique was being implemented without sufficient debugging or when software was upgraded without sufficient warning or documentation. Moreover, having faculty and technology staff in constant communication about practices that result in less-than-desirable experiences has greatly improved the likelihood of having adequate lead-time to effectively adapt to new technological tools (Whitaker & Coste, 2002).

Over time, we have learned that the most effective applications of IT tools are those that encourage a more active student involvement in the learning experience, facilitate a greater depth of understanding of course content, and promote richer communication between faculty and students (Whitaker & Coste, 2002). In keeping with our foundational belief in the importance of continually evaluating the pedagogical impact of the methods, this longitudinal process ignores traditional student/faculty boundaries and facilitates the practice of a discipline much like what is achieved with the apprentice system. To the extent that the learning community's members are dependent upon their modes of communication and dissemination of knowledge, a sustained environment is established that determines the tenor of interaction (Brown & Dugid, 2000). However, for this environment to be beneficial for all, a number of critical factors must be attended to: 1) the varying technological opportunities and challenges of different disciplines; 2) the faculty's concerns about the impact of technology on their students' learning, classroom environments, and the make-up of the institution; 3) the training needs of users at a variety of levels of technological expertise; and 4) the unique support demands of each technological tool being adopted.

Future Trends in Computer Literacy and Learning

Computing technology profoundly shapes the definition of computer literacy. Understanding the trends of today will help us make an educated guess about the future. Portable and mobile computing technologies are the defining technologies of this decade. The Internet has connected PCs around the globe, but PCs for the most part have remained stationary appliances. Wireless technology truly frees laptops to be mobile, providing an application from a particular platform at a particular location. In essence, portability and mobility imply access to information and the ability to communicate from any place and at any time.

Pedagogy concerned with critical literacy and new technologies began a long way back. Many teachers, and many teacher educators, are simply not conversant with operational and cultural aspects of new technologies and their associated social practices and literacies. The development of new interactive technologies inevitably has an impact on all aspects of teaching and learning. This is more evident in the case of novel interactive technologies that fascinate the broad public, such as Virtual Reality (VR) and computer and video games.

VR, the three-dimensional, multisensory, immersive, and interactive digital environment, has triggered public imagination as the technology that will dominate the way our work, education, and leisure are delivered in the future. VR is a technology that was traditionally associated mainly with gaming and entertainment. During the last decade VR has gained recognition also for its great educational potential. For educational purposes, VR has been proposed as a technological breakthrough that holds the power to facilitate learning. VR can work for educators as a tool in assisting students to become immersed in a learning environment where they can participate in their own learning in a technology-based environment. Recent research has identified several capabilities of the VR technology that are expected to facilitate learning (Youngblut, 1998; Halvorsrud & Hagen, 2004). The visual nature of VR and the intuitive manner in which users (students) can control and manipulate virtual objects are thought to be the two main ingredients that support learning in virtual environments (Win & Jackson, 1999). Research in VR and education is a relatively young field, but in recent years it has shown considerable growth (Roussou, 2000; Roussou, 2004; Connolly, 2005).

Video games for learning are important and can be used at different academic levels (Aguilera & Mendez, 2003). In addition to simulating motivation, video games are considered very useful in acquiring practical skills, as well as increasing perception and stimulation, and developing skills in problem-solving, strategy assessment, media, and tools organization. Of all the games available, simulators stand out for their enormous educational potential.

Playing games to learn basic life skills has been an important learning strategy from the earliest times and remains so today, especially for early instruction at home. However, when games are mooted as strategies for formal instruction, opinion quickly polarizes around two very different positions: on the one hand, some educators will point out that apart from their undeniable power to motivate, games are capable of fostering the development of valuable skills in areas such as strategic thinking, communication and collaboration, group decision-making and negotiation, and literacy and numeracy. On the other hand, others (perhaps less willing to accept the role of fun in education) see games as wasting valuable time, irrelevant to set curricula, and incapable of helping students to achieve mandated high-stakes outcomes. The advent of digital games has tended to add more fuel to the controversy, being popularly portrayed as even more time-consuming, motivational to the point of addiction, and fostering a range of antisocial values that may translate into sexist, racist, or criminal behavior.

It is repeatedly pointed out, for example, that young people choose to spend many hours playing complex computer games outside school. Games seem to have a way of engaging and interesting young people. The desire to harness this motivational power to encourage young people to want to learn is the main driver behind an interest in computer games for learning.

Summary

The growth and use of IT and the resulting demand for workers with specialized skills have placed a considerable demand on the traditional educational system to provide a qualified and sustainable IT workforce (Randall & Zirkle, 2005). According to the US Department of Labor statistics (2004), IT is the fastest growing sector in the economy, with a projected 68% increase in growth rate between 2002 and 2012. In response to advances in computer technology, rapidly deprecating skills sets, and the slow response of traditional education, the IT industry uses extensive training programs as a way to accredit its own (Clarke, 2001).

The goal of integrating and implementing IT as a foundation skill area within all curricula is to help students on their journey toward IT literacy through the use, management, and understanding of IT. Curriculum developers, teachers, and administrators play a significant role in working toward achievement of this goal. Strategies for the integration and implementation of IT, developed with an understanding of the use and historical impact of IT, will help facilitate positive change in the classroom and lead to IT-literate students.

Many, if not most, colleges and universities understand that IT will play an increasingly large role on their campuses (Burg & Thomas, 1998). Indeed, some colleges and universities are requiring that all matriculating students have a personal computer for use throughout their college careers. Courses are being restructured and new curricula are being developed to take advantage of new pedagogical opportunities offered by IT.

Students who are successful in these courses must have skills adequate to support their use of the technology. Most institutions and courses provide some opportunities, whether in for-credit courses or not, for students to learn these skills. But the fundamental concepts and intellectual capabilities do not seem to be essential in these courses in any meaningful way. The challenge for colleges and universities is then how to build on the existing infrastructure of hardware, support services, and technology-adapted curricula and courses to support IT literacy.

IT-literate people who are equipped with a set of IT skills, understand the basic concepts on which IT is founded, and those who have engaged in the higher-level thinking embodied in the intellectual capabilities should use IT confidently. They should come to work ready to learn new business systems quickly and use them effectively, and they should be able to apply IT to personally relevant problems. They should be able to adapt to the inevitable change as IT evolves in their lifetime.

In summary, education is a process, and as such can be constantly improved (Funk, 2005). Improving education involves internal and external resources and influences. Just one or more of these factors can cause a learner to drop out. If this happens, then we as educators have failed to help individuals achieve their full potential. However, if we intervene in some manner by creating a sense of community, facilitating financial aid, validating their shared ideas, and being sensitive to problems of adult life; then we are empowering students to learn, live, and serve.

References

Aguilera, M., & Mendez, A. (2003). Video games and education: Education in the face of a "parallel school." *ACM Computers in Entertainment, 1*(1), 10–24.

Alshare, K., Grandon, E., & Miller, D. (2004). Antecedents of computer technology usage: Considerations of the technology acceptance model in the academic environment. *Journal of Computing Sciences in Colleges, 20*(1), 323–331.

American Express (2000). Small Business Services, Voices from Main Street: Assessing the State of Small Business Workforce Skills, New York, NY: American Express.

Ba, H., Tally, W., & Tsikalas, K. (2002). *Investigating children's emerging digital literacies*. Retrieved June 7, 2007, from http://escholarship.bc.edu/jtla/vol1/4/.

Barrette, C. (2000). Preparing teachers for IT: Process, timeline, and outcomes. *Compute-Ed*, *5*, Retrieved June 7, 2007, from http://pandora.nla.gov.au/pan/10253/20010613-0000/computed.coe.wayne.edu/Vol5/Barrette.html.

Bartholomew, K. W. (2004). Computer literacy: Is the emperor still exposed after all these years? *Journal of Computing Sciences in Colleges 20*(1), 323–331.

Brown, J. S., & Duguid, P. (2000). *The social life of information*, Boston, MA: Harvard Business School Press.

Bruce, C. (1997a). *Seven faces of information literacy in higher education*. Retrieved June 7, 2007, from http://sky.fit.qut.edu.au/~bruce/inflit/faces/faces1.php.

Bruce, C. (1997b). *The Seven Faces of Information Literacy*, Adelaide, South Australia: AUSLIB Press.

Bruce, C. (2000). *Information literacy research: Dimensions of the emerging collective consciousness*. Retrieved June 7, 2007, from http://www.anziil.org/resources/papers/archive/bruce/1_multipart_xF8FF_2_AARLsub.pdf.

Bui, T. X. (1997). PRIISM workshop on information technology policy and national information infrastructure in pacific Asia. *Database, 28*(1), 10–13.

Bundy, A. (2004). *Australian and New Zealand information literacy framework: Principles, standards, and practice*, Retrieved June 7, 2007, from http://www.anziil.org/resources/Info%20lit%202nd%20edition.pdf.

Burg, J. J., & Thomas, S. J. (1998). Computers across campus. *Communications of the ACM, 41*(1), 22–25.

Burger, A., & Blignaut, P. (2004). Computer literacy course may initially be detrimental to students' attitudes towards computers. *Paper presented at the 2004 annual research conference of the South African institute of computer scientists and information technologists on IT research in developing countries*, October 4-6, 2004, Stellenbosch, South Africa.

Candy, P.C. (2004). Linking thinking: Self-directed learning in the digital age. Canberra: Australian Government, Department of Education, Science and Training. Retrieved June 7, 2007, from http://www.dest.gov.au/sectors/training_skills/publications_resources/other_publications/linking_thinking.htm.

Cantor, J. (2002). Skills certification and workforce development: Partnering with industry and ourselves. *Leadership Abstracts, 15* (1).

Checkland, P. B. (1999). Systems thinking, systems practice: Includes a 30-year Retrospective, Chichester, England: John Wiley & Sons.

Checkland, P. B. (2000). Soft systems methodology: A thirty year retrospective. *Systems Research and Behavioral Science, 17*(S1), S11–S58.

Cheuk, B. (1998). An information seeking and using process model in the workplace: A constructivist approach. *Asian Libraries, 7*(12), 375–390.

Clarke, B. (2001). Corporate curricula in schools: Issues and implementation. *Paper presented at the Seventh World Conference on Computers in Education*, July 29 – August 3, 2001, Copenhagen, Denmark.

Collins, J. (1995). Literacy and literacies. *Annual Review of Anthropology, 24*, 75–93.

Collis, B. (1998). New didactics for university instruction: Why and how? *Computers & Education, 31*, 373–393.

Committee on Information Technology Literacy (1999). *Being fluent with information technology*, Washington D.C., USA: National Academies Press.

Connolly, P. E., (2005). Virtual reality & immersive technology in education. *International Journal of Information and Communication Technology Education, 1*(1), 12–18.

Corbel, C., & Gruba, P. (2004). *Teaching computer literacy*, Sydney: Macquarie University, AMEP Research Centre.

Csapo, N. (2002). Certification of computer literacy: The international computer driving license provides standards that let individuals participate in a global digital society. *T.H.E Journal, 30*(8), 46–51.

Devaraj, S. S., & Babu, R. (2004). How to measure the relationship between training and job performance. *Communications of the ACM, 47*(5), 62–67.

Do, J., & Lee, I. (1997). World Wide Web in the virtual classroom. *Compute-Ed, 3*, Retrieved June 2, 2007, from http://pandora.nla.gov.au/nph-arch/O1998-Dec-3/http://www.education.uts.edu.au/projects/comped/Vol3/do.html.

ECDL (2004). *ECDL foundation*, Retrieved June 2, 2007, from http://www.ecdl.com/products/index.jsp.

Eisenberg, M. B., & Johnson, D. (2002). *Learning and teaching information technology: Computer skills in context*, Syracuse, NY: Syracuse University, ERIC Clearinghouse on Information &Technology (ERIC Document Reproduction Service No. ED465377).

Frayer, D. A. (1999). Creating a campus culture to support a teaching and learning revolution. *Cause/Effect Journal, 22*(2), Retrieved June 7, 2007, from http://www.educause.edu/ir/library/html/cem/cem99/cem9923.html.

Funk, J. T. (2005). Best practices: At-risk online Learners: Reducing barriers to success. *eLearn, 8*, 30–46.

Ehrmann, S. (2000). Computer intensive academic programs. *AAHE Bulletin, 53*(3), 7–11.

Galvin, T. (2001). Birds of a feather. *Training, 38*, 58-68.

Halvorsrud, R., & Hagen, S. (2004). Designing a collaborative virtual environment for introducing pupils to complex subject matter. *Proceedings of the third Nordic conference on Human-computer interaction,* Tampere, Finland, pp. 121–130.

Hampel, T., & Keil-Slawik, R. (2001). sTeam: structuring information in team-distributed knowledge management in cooperative learning environments. *Journal on Educational Resources in Computing, 1*(2), article 3.

Hecker, D. E. (2001). Occupational Employment Projections to 2010*, Monthly Labor Review, November 2001*, Washington, DC: US Department of Labor, Bureau of Labor Statistics.

Himanen, P. (2001). *The Hacker Ethic*, New York: Random House.

Hoffman, M. E., & Blake, J. (2003). Computer literacy: Today and tomorrow. *Journal of Computing Sciences in Colleges, 18*(5), 221–233.

Hoffman, M. E., & Vance, D. R. (2005). Computer literacy: What students know and from whom they learned it. *Proceedings of the 36th SIGCSE Technical Symposium on Computer Science Education.* St. Louis, Missouri, USA, pp. 356–360.

Hughes, L. R., Ginnet, C. R., & Curphy, J. G. (1999). *Leadership: Enhancing the lessons of experience* (3rd International Ed.), New York: Irwin/McGraw-Hill.

Jurema, A., & O'Rourke, M. (1997). An international approach to developing information technology (IT) literacy in schools based on critical consciousness. *Proceedings of Computer Support for Collaborative Learning*, December 10–14, Toronto, Canada, pp. 129–135.

Laurillard, D. (2002). Rethinking teaching for the knowledge society. *Educause Review, 37*(1), 16–25.

Leu, D. J., Kinzer, C. K., Coiro, J. L., & Cammack, D. W. (2004). Toward a theory of new literacies emerging from the Internet and other information and communication technologies. In R. B. Ruddell & N. Unrau (Eds.), *Theoretical models and processes of reading*, Newark, DE: International Reading Association, Retrieved June 7, 2007, from http://www.readingonline.org/newliteracies/leu/.

Levinson, E. (2000). Technology and accountability: A chicken and egg question. *Converge, 3*(11), 46–47.

Limberg, L. (1999). Experiencing information seeking and learning: A study of the interaction between two phenomena. *Information Research, 5* (1), Retrieved June 7, 2007, from http://informationr.net/ir/5-1/paper68.html.

Lonsdale, M., & McCurry, D. (2004). *Literacy in the new millennium*, Adelaide, Australia: National Centre for Vocational Education Research Ltd., Retrieved June 7, 2007, from http://www.ncver.edu.au/publications/1490.html.

Luft, P., & Tiene, D. (1997). Using instructional design principles to develop Web-based teaching units. *Paper presented at TELED '97*, November 1997, Austin, TX.

Mahapatra, R., & Lai, V. S. (2005). Evaluating end-user training programs. *Communications of the ACM, 48*(1), 66–70.

Markauskaite, L. (2006). Towards an integrated analytical framework of information and communications technology literacy: From intended to implemented and achieved dimensions. *Information Research, 11*(3), Retrieved June 7, 2007, from http://informationr.net/ir/11-3/paper252.html.

Martin, A. (2000). *Concepts of ICT literacy in higher education*, University of Glasgow, Retrieved June 1, 2007, from http://www.citscapes.ac.uk/citscapes/products/backgroundreports/files/concepts_ict_HE.pdf.

McAvinia, C., & Oliver M. (2002). "But my subject's different": A web-based approach to supporting disciplinary lifelong learning skills. *Computers & Education, 38,* 209–220.

Merisotis, J., & Phipps, R. (1999). What's the difference? Outcomes of distance vs. traditional classroom-based learning. *Change, 31*(3), 13–17.

Minch, R. P., & Tabor, S. W. (2003). Networking education for the new economy. *Journal of Information Technology Education, 2*(1), 51–60.

Moonen, J. (1994). How to do more with less? In K. Beattie, C. McNaught, & S. Wills (Eds.), *Interactive multimedia in university education: Designing for change in teaching and learning*, North Holland: Elsevier, 155–163.

Murphy, T., & Hirai, M. (2003). Teaching with technology: Setting an example. *Proceedings of the 31st annual ACM SIGUCCS conference on user services*, San Antonio, TX, USA, pp. 208–212.

National Association of Manufacturers (2002). *The skills gap 2001: Manufacturers confront persistent skills shortages in an uncertain Economy*, Washington, DC: National Association of Manufacturers.

Neal, E. (1998). Using technology in teaching: We need to exercise healthy skepticism. *The Chronicle of Higher Education, 19 June*, B4–5.

Nonaka, I, & Toyama, R. (2003). The knowledge creating theory revisited: Knowledge creation as a synthesizing process. *Knowledge Management Research & Practice, 1*, 2–10.

Patterson, D. (2004). Encouraging and assisting faculty incorporation of innovative classroom technologies. *Proceedings of the 31st annual ACM SIGUCCS conference on user services*. Baltimore, MD. pp. 79–81.

QU (2002). *Academics*, Retrieved June 6, 2007, from http://www.quinnipiac.edu/x148.xml.

Radi, O. (2002). The impact of computer use on literacy in reading comprehension and vocabulary skills. *ACM international conference proceeding series*, Vol. 26: *Proceedings of the seventh world conference on computers in education: Australian topics*,Vol. 8, Copenhagen, Denmark, pp. 93–97.

Randall, M. H., & Zirkle, C. J. (2005). Information technology student-based certification in formal education settings: Who benefits and what is needed. *Journal of Information Technology Education, 4*(1), 287–306.

Roblyer, M. D. (2000). The national educational technology standards (NETS): A review of definitions, implications, and strategies for integrating NETS into K-12 curriculum. *International Journal on Instructional Media, 27*(2), 133–146.

Roussou, M. (2000). *Immersive interactive virtual reality and informal education*, Retrieved June 12, 2007, from http://ui4all.ics.forth.gr/i3SD2000/Roussou.PDF.

Roussou, M. (2004). Learning by doing and learning through play: An exploration of interactivity in virtual environments for children. *Computers in Entertainment, 2*(1), article 1.

Sanford, S. (2000). The evolution of ThinkPad education at UMC. *Converge, 3*(12), 67–70.

Scott, C. R., & Rockwell, S. C. (1997). The effect of communication, writing, and technology apprehension on likelihood to use new communication technologies. *Communication Education, 46*(1), 44–62.

Somerville, M. M., Mirijamdotter, A., & Collins, L. (2006). Systems thinking and information literacy: Elements of a knowledge enabling workplace environment. *Proceedings of the 39th Hawaii International Conference on System Sciences*, Retrieved June 7, 2007, from http://csdl2.computer.org/comp/proceedings/hicss/2006/2507/07/250770150.pdf.

Stein, A., & Craig, A. (2000). The dot.com generation: IT practices and skills of transition students. *Proceedings of the on Australian Computing Education Conference*, December, Melbourne, Australia, pp. 220–227.

Stevens, R., & Dexter, S. (2003). *Developing teachers' decision-making strategies for effective technology integration: A simulation design framework*, Retrieved June 1, 2007, from http://immex.ucla.edu/docs/publications/pdf/aera2003final.pdf.

Province of Manitoba (1998). *Technology as a Foundation Skill Area*, Retrieved June 23, 2007, from http://www.edu.gov.mb.ca/k12/docs/support/tfs/developing.html.

Todd, R. (1999). Utilization of heroin information by adolescent girls in Australia: A cognitive analysis. *Journal of the American Society of Information Science, 50*(1), 10–23.

Trkman, P., & Baloh, P. (2003). Use of a model for information technology education. *Journal of Information Technology Education, 2*(1), 379–392.

UMD (2002). *Computer literacy homepage*, Retrieved June 6, 2007, from http://www.d.umn.edu/student/loon/acad/ComputLit.html.

Von Krogh, G., Ichijo, K., & Nonaka, I. (2000). *Enabling knowledge creation: How to unlock the mystery of tacit knowledge and release the power of innovation*, New York, NY: Oxford University Press.

Wainwright, K., & Arnold, B. (2004). Walking the tightrope of faculty support. *Proceedings of the 36th SIGCSE technical symposium on computer science education*, Baltimore, MD, pp. 332–335.

West, L., & Bogumil, W. (2001). Immigration and the global IT work force. *Communications of the ACM, 44*(7), 34–38.

Whitaker, B., & Coste, T. G. (2002). Developing an effective IT integration and support system. *Journal of Information Technology Education, 1*(1), 53–63.

William, K. (2002). *Literacy and Computer Literacy*, Michigan: University of Michigan.

Winn, W., & Jackson, R. (1999). Fourteen propositions about educational uses of virtual reality. *Educational Technology, 39*, 5–14.

Wright, V., & Marsh, G. (2000). Technology and teaching: A turning point. *Compute-Ed, 5*, Retrieved June 1, 2007, from http://pandora.nla.gov.au/nph-arch/2000/Z2000-Jun-5/http://computed.coe.wayne.edu/Vol5/Wright&Marsh.html.

Youngblut, C. (1998). *Educational uses of virtual reality technology*, Retrieved June 7, 2007, from http://handle.dtic.mil/100.2/ADA339438.

Yearwood, J., & Stranieri, A. (2007). Narrative-based Interactive Learning Environments from Modelling Reasoning. *Educational Technology & Society*, 10 (3), 192-208.

Narrative-based Interactive Learning Environments from Modelling Reasoning

John Yearwood and Andrew Stranieri
School of Information Technology and Mathematical Sciences, University of Ballarat, Victoria, Australia
j.yearwood@ballarat.edu.au

ABSTRACT

Narrative and story telling has a long history of use in structuring, organising and communicating human experience. This paper describes a narrative based interactive intelligent learning environment which aims to elucidate practical reasoning using interactive emergent narratives that can be used in training novices in decision making. Its design is based on an approach to generating narrative from knowledge that has been modelled in specific decision/reasoning domains. The approach uses a narrative model that is guided partially by inference and contextual information contained in the particular knowledge representation used, the Generic/Actual argument model of structured reasoning. The approach is described with examples in the area of critical care nursing training and positive learning outcomes are reported.

Keywords

Narrative, interactive learning, case-based learning, decision making, emergent narrative, transformationalism

Introduction

There are two main approaches that people use to organize and make sense of their experiences: logical thinking and narrative thinking. Both of these approaches have a long history of providing useful structures for organizing experiences. Narrative reasoning can provide a valuable approach to complex reasoning involved in problem solving and decision-making. Often, clear practical reasoning towards decisions is required in an area, though the area may be poorly understood and not amenable to learning by some form of logical analysis and representation.

Setting out the reasoning involved in certain situations may improve transparency but does not in itself add to the understanding or absorption by the practitioner. Presenting this reasoning as narrative scenarios provides a means for practitioners to assimilate the reasoning above abstract rules and has the potential to connect with human understanding at the story level. Stories have been shown to be useful for clarifying uncertainties and problem solving (Hernandez-Serrano & Jonassen, 2003). This resonates with the notion that Schank had about human reasoning described in Schank (1990), that people do not naturally reason deductively, but rather use a form of thinking that might be called "story-based reasoning". We can draw on our own experience to notice that most communication between people could be characterised as having a story form. These “mini-stories” correspond in workplaces and technical contexts to scenarios. In the legal context, Pennington & Hastie (1981) have demonstrated that jurors display narrative and not just logical reasoning to make sense of evidence.

Pennington and Hastie's story model is based on the hypothesis that jurors impose a narrative story organization on trial information, in which causal and intentional relations between events are central (Pennington & Hastie, 1981). Meaning is assigned to trial evidence through the incorporation of that evidence in one or more stories describing what happened. Pennington and Hastie demonstrated the influence of story order on verdicts in criminal trials. They found that if a party's story was told to the juror in story order instead of in a random order, such as the witness order, the juror more easily followed that party's story in the verdict. If the prosecution's case was told in story order, while the defendant's case was told in a random order, the accused was convicted in 78% of the cases. If, on the other hand, the prosecution's case was relayed in random order and the defendant's in story order, the accused was convicted in 31% of the cases. This work strongly suggests that narrative organization of material can have a significant impact on the way it is understood and used to come to conclusions.

As we move towards a knowledge-based society and knowledge is increasingly represented for use within computational systems it is important to be able to develop efficient ways of using that knowledge effectively for training. An environment that allows the interactive construction and manipulation of narratives that correspond to practical reasoning instances would provide a useful platform for interaction and learning. Furthermore if the narratives are underpinned by the desired reasoning model then the environment can have the capacity to flexibly involve participants in their learning.

In this paper we describe a narrative-based Intelligent Interactive Learning Environment (IILE). Through interaction with the IILE, learners are allowed to engage with the tasks that they may be called upon to perform and the decisions that they will need to make. Presenting this knowledge as a set of graphs and argument trees is not very useful to a learner, although it does have value in its visual representation. Group discussion of these graphs has also proven to be useful in reinforcing tradition methods of communicating the knowledge. There are three important aspects to the narrative based-IILE:

- Its intelligence is based on the expert knowledge modelled in a knowledge acquisition exercise;
- the knowledge is used to generate narrative that express practical reasoning situations;
- user interaction is based on the learner interrogating or acting in the environment and the system providing response through narrative description and advice that is constructed for dramatic effect.

In the next section, we describe the motivation for this work and then survey literature on narrative in order to motivate the story framework deployed in the IILE. Following that, the Generic Actual Argument Model (GAAM), the model of reasoning that is used in the IILE to infer whether the actions taken by the protagonist are correct, and if not, which events should occur to heighten the consequence of the error, is described. In section five, a detailed example is provided before concluding remarks.

Motivation for a Narrative-based IILE

In our work with a range of decision makers involved with complex decisions it has been found that there is an expressed need for a representation of reasoning in the form of scenarios or small stories. Whilst there have been advantages of presenting reasoning as *structured reasoning* (Yearwood & Stranieri, 2006), there seem to be further advantages in annotating reasoning structures within a domain with narrative in the form of scenarios. Geoffrey (2005), in research on clinical reasoning and expertise points out that the nature of expertise lies in the availability of multiple representations of knowledge and that in terms of learning reasoning "…the critical element may be deliberate practice with multiple examples which, on the one hand, facilitates the availability of concepts and conceptual knowledge (i.e. transfer) and, on the other hand, adds to a storehouse of already solved problems."

Case-based learning has been employed in law schools since the 1800's. In general, students are presented with a story or narrative of events and this is either read or `acted' by students, leading them to a `correct' response or to understand the effects of their decisions. Cases have been prominent in teaching about roles in which decisions have to be made and are less likely to be used in school situations (Merseth, 1991). Amongst some of the features of a `good' case, Herreid (1998) mentioned that a good case:

- *tells a story* - have an interesting plot that relates to the experiences of the audience and have a beginning, a middle, and an end.
- *focuses on an interest-arousing issue* - there should be drama and a case must have an issue.
- *should create empathy with the central characters.*
- *should have pedagogic utility.*
- *is conflict provoking.*
- *is decision forcing.*
- *has generality*.

Jarz et al. (1997), in developing multimedia-based case studies in education point out the need for didactic design, the need to collect, reduce and structure data for the construction of the case.

An IILE that allows a user (learner) to interact in constructing narratives that correspond to the use of domain reasoning to solve problems contains elements of Schank's goal-based scenarios (Schank, 1996) and anchored instruction (Cognition and Technology Group at Vanderbilt, 1990). The benefits of using cases and stories for instruction have been demonstrated in many studies (Bransford & Vye, 1989; Bransford, Sherwood, Hesselbring, Kinzer & Williams, 1990). Hung, Tan, Cheung and Hu (2004) discussed possible frameworks and design principles of good case stories and narratives. Narrative is a fundamental structure of human meaning making (Bruner 1986; Polkinghorne 1988). Stories are effective as educational tools because they are believable, easily rememberable, and entertaining (Neuhauser 1993). The believability derives from their dealing with human experience that is perceived as authentic. They aid remembering because they involve an audience in the actions and intentions of the characters. As audience, we are engaged with the story on both an action level and a consciousness level and it is through this dual engagement that we become involved with the minds of the characters and understand the story.

When narratives are underpinned with sound domain knowledge, they can provide a way of assimilating and realizing practical reasoning in an effective way. In specialised fields like health (e.g. intensive care nursing), learners already have significant basic knowledge and training. The pedagogy that is appropriate in these circumstances tends not to be that for understanding basic knowledge in the discipline, or that for studying clinical problems in the abstract but needs to be appropriate for the gaining of expert knowledge. Evidence indicates that this is achieved through induction from cases. Frize & Frasson (2000) distinguish three levels of cognitive learning styles that are evident in medical schools. Figure 1 indicates the different pedagogies that are appropriate for different learning contexts.

Problem based learning has been widely adopted in both medicine and law. According to Mayo, Donnelly, Nash, & Schwartz (1993)`problem-based learning is a strategy for posing significant, contextualized, real world situations, and providing resources, guidance, and instruction to learners as they develop content knowledge and problem-solving skills'. The amount of direct instruction is reduced in problem based learning, so students assume greater responsibility for their own learning. The instructor's role becomes one of subject matter expert, resource guide, and task group consultant. Many medical schools use a problem based learning methodology to teach students about clinical cases, either real or hypothetical (Vernon & Blake, 1993).

At the beginning of their curriculum, students learn basic knowledge to build a base of fundamental knowledge. During this period this knowledge is stored and not yet linked to real cases. This is the first level shown in Figure 1. The student is only able to identify basic problems, and generate basic solutions. In progressing to clinical problems, the second level shown in Figure 1, students acquire some procedural and contextual knowledge, a step in which elements of knowledge are linked through examples of situations. They make hypotheses and start to establish strategies for selection and rejection of these. Problem-based learning is appropriate and often used to support this activity.

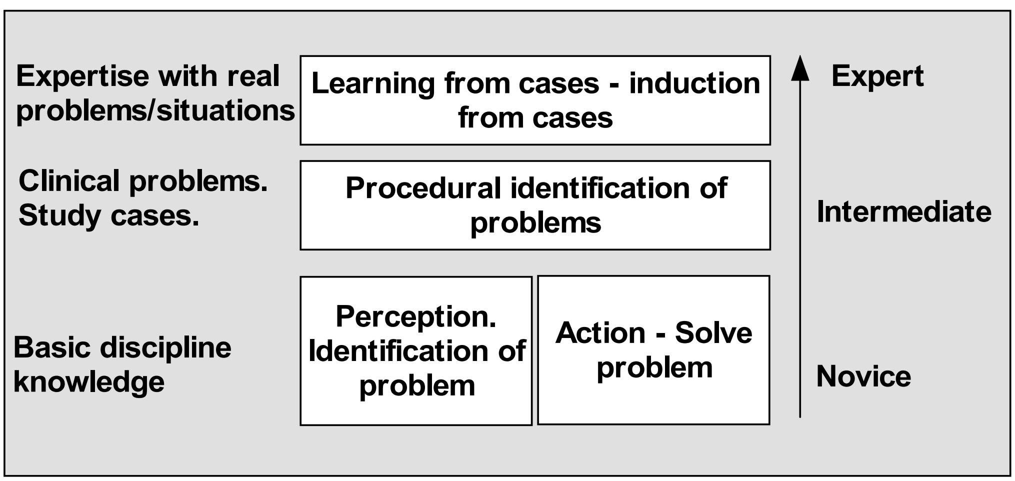

Figure 1: Frize & Frasson's pedagogical approaches for different learning levels

The top layer of Figure 1 is concerned with acquiring knowledge through exposure and interaction with real situations or cases. The learner can accumulate experience with a more complete base of cases and may reach expert status by being able to induce new rules or new cases from a set of cases. The cognitive model operating here being case-based reasoning. Becoming an expert is usually associated with active exposure to many real cases. The transformation from the second level to the upper, expert level is achieved through experience with complex real cases. This fits within the framework of transformationalism (Mezirow, 2000) and in most situations the transformation from novice to expert will be incremental. Mezirow also suggests that transformation can be triggered by narrative that relates to the learner's own experience.

Problem based learning is a strategy that motivated the design of the intelligent learning environment (IILE) described in this paper. Exposure to real-life problems in an interactive simulation of the real situation is targeted at facilitating the transition from novice to expert. However, given that narrative plays such an important role in human learning, an IILE based on narrative structures is likely to enhance the learning. Narrative based interactive learning environments have been advanced by Peinado, Gervais and Moreno-Ger (2005), Iuppa et al. (2004), Riedl and Young (2004) and Cavazza, Charles and Mead (2002). Narrative based environments deploy similar ideas to those described by Schank (1996) and anchored instruction (Cognition and Technology Group at Vanderbilt, 1990).

In the majority of narrative based interactive learning environments multiple storylines are stored in the environment in one way or another. For example, the branching decision tree structure used by Iuppa et al. (2004) encodes multiple pre-authored plans into a single decision tree. A learner interacts with the system by selecting events that branch the storyline in different ways. The control a learner has to shape the direction of the story enhances his or her engagement with the situation and leads to a deeper engagement with the material to be learnt.

According to Peinado, Gervais and Moreno-Ger (2005), IILE architecture based on pre-authored cases conflicts directly with the learner's desire to exercise free will. A learner exercises no free will in the construction of a case study presented in a text or classroom situation, and only slightly more free will in selecting branches from a tree of storylines. In order to enable learners to exercise more free will and therefore engage more fully with the learning environment, Peinado, Gervais and Moreno-Ger (2005) have devised an IILE that allow the learner to perform actions at will. Their IILE matches a learner's actions against set storylines. If the learner deviates from a set storyline, the system generates a new storyline that will, as far as possible, realise the objectives of the original learning plan. This is achieved with the case based reasoning paradigm. Cases are encoded as story plots and case adaptation is used to generate new storylines.

In this paper we describe an IILE that similarly allows the learner substantial freedom. The IILE presented here is underpinned by two pillars:

- a strong model of expert reasoning in the subject matter domain. A strong model of expert reasoning is provided by a knowledge representation model called the Generic Actual Argument model advanced by Yearwood and Stranieri (2006) deployed in numerous knowledge based systems to date including *Nurse*, a system that depicts steps of best practice for critical care nurses to take when responding to a low oxygen alarm in a ventilated patient.
- a connection of the reasoning model to a narrative structure in a way that allows emergent narrative from learner interaction. The narrative structure is based on the model described by Bennett and Feldman (1981). The IILE reflects the emergent narrative as a 'story so far' feature that acts as the voice of a third person narrator articulating the emergent narrative as feedback to the learner.

The approach advanced here is most appropriate in disciplines where reasoning is intricate and usually not set out as rules. It may be set out as guidelines, have a large tacit component or learned through on-the-job training. In these areas, simply acquiring a model of the reasoning and presenting it as rules or instructions does not seem to add to the understanding of the area to elevate a novice to expert.

Rather than hard coding multiple storylines in a memory, the IILE presented here begins a narrative and then enables a learner to perform actions on the patient. The IILE uses a strong domain model to infer whether the actions are appropriate and if not, to identify the consequences of the error. Consequences are used by the IILE to set events that will propel the emergent narrative towards critical outcomes such as patient death. The IILE does not present fixed narratives crafted from a real or hypothetical case but instead allows the learner to take a large role in constructing the narrative. The story that emerges from the interaction of the learner and the IILE is responsive to the learner's actions.

Narrative Reasoning

Much of our attempt to understand our world has taken the form of stories and narrative myths. These myths and stories have often passed on, in a compressed form reasoning that has been important practically as well as in a literary sense. McCloskey (1990) described stories and metaphors as the two ways of understanding things and suggests that they can work together to provide answers. Narrative reasoning addresses situations that find difficulty in being addressed with the sequential form of logical reasoning. The situations often involve multiple causes and multiple effects. Many social phenomena are like this and it would be fair to say that the great body of our accumulated social wisdom is expressed as narrative. Narrative reasoning could be viewed as an efficient way of dealing with complexity.

In both formal logical reasoning and narrative reasoning, cause and effect relations are established (Warren et al, 1979) between factors and used in sequential patterns. Both aim to organize and make sense of human experience in a way that can guide problem solving and decision-making. Whilst we recognize the product of logical or analytical reasoning as laws or rules which are largely context free and testable, the product of narrative reasoning is a story which is highly contextual and testable mainly through personal and interpersonal experience.

We view narrative as comprising two fundamental parts: story and discourse (Chatman 1990, Emmot 1999). From a narratological perspective, a story consists of a complete conceptualization of the world in which it is set and so includes all the characters, locations, actions and events that take place during the story. Two fundamental components of a narrative are its plot and its characters and these are defined within the story itself. The discourse contains those elements responsible for the telling of the story. The most important of these is the particular selection of the story elements that the narrator will use and the medium.

Most stories have a predictable structure or pattern of events that create the properties of a story and include *basic elements* and *abstract story structures*. Most narrative theorists agree that the basic elements of stories include *objects, events, causality* and *time.* A *character* is a type of object that has attributes, motivations and a spatial relationship with other objects. According to Black and Wilensky (1979) such a cluster of objects is usually called a *scene*. *Structures for characters* in stories depend on their role in the story. There are five basic roles (although other sets have been used): protagonist, antagonist, helper, hinderer and neutral. The protagonist is the main character and the antagonist is the main opponent of the main character.

Structures for events are classified in terms of their influence on objects and on the episode in which they occur. The influence that an event has is related to the number of objects that the event affects. An event which affects objects in many scenes is called a *global* event. The *episode* in which events occur refers to the sequence of events that occur in a particular scene. Structures for causality have generally been disregarded in non-computational models. In Schank's influential script model, causality has four types: result causation, enable causation, initiation causation and reason causation. Three *structures for time* are identified: story-time, discourse-time and iconographic-time. Story time is monotonically related to normal time whilst discourse time is the order in which events are presented to the audience. Iconographic time refers to the period in which the story is set.

While the basic elements are generally agreed upon, it is the abstract story structures that have provided the greatest area of debate. *Abstract story structures* refer to those structures that can be abstracted from stories but are not explicitly represented within stories. Many abstract structures have been proposed such as plots and episodes. *Top-down* approaches provide a framework that is filled in progressively as the story unfolds. *Bottom-up* approaches provide a number of units that are matched to elements of a story and are connected together to provide a representation of the story. *Event-scene* structures are those which relate the objects of a scene and can be classified as to whether events are dependent or independent of the scene. *Event-character* structures are those that relate to the interactions between events and characters. These can be classified as those which affect every character or those which affect the main character. Event character structures link specific events to characters' goals which in turn cause other events and outcomes for those events.

An *event-character* goal hierarchy structure views stories from the point of view of characters dealing with various types of conflict. Rumelhart (1975) exemplifies this approach in formalizing the work of Propp (1968). Episode schemas describe various events in every story in relation to a character's goals. Many event-character structures are variations of story grammars. Black and Wilensky (1979) criticize story grammars due to their inability to distinguish between stories and non-stories (e.g. procedural exposition). Criticism has also been levelled at the limited way in which these grammars represent stories as little more than a set of coherent sentences although Mandler and Johnson (1977) and Mandler (1984) have used a grammar that captures quite complex story structure.

Wilensky (1982) claimed that understanding a story is more about understanding the point of what the text is about rather than understanding the structure of a text. The notion of a story *point* competes with the idea of story grammars as a way to characterize story texts. In the *points* structure used in the story understanding program PAM (Wilensky, 1982) a story has three levels: the story itself; the important content of the story; and the points. The *points* are a template for the important content of the story in terms of the goals of the characters. A story grammar defines a story as having a certain form, whereas a story point model defines a story as having certain content. The form of a story is viewed as being a function of the content of the story.

The narrative theory of Bennett and Feldman (1981) describes the structure of a story as consisting generally of a *setting, concern, resolution* sequence. The setting usually includes the time, place and some of the characters. The concern is an action that given the setting creates a climactic (eventful, ironical, suspenseful) situation. For example, if someone is rock-climbing and slips and falls, slipping and falling are the concern. If the story ended at this point, the audience would be left wondering: what happened to the climber? Was he hurt or killed? A complete story will provide an answer to these questions. This stage is the resolution. The central action is the structural element that creates the central question the story must resolve. The resolution normally resolves both the predicament created by the problem and the questions listeners might have had about the outcome. In the rock-climbing story the resolution consisted of telling the audience that the climber was taken to the hospital for treatment.

Bennett and Feldman (1981) argue that it is not the weighting of the individual elements of the story, each in terms of the evidence for that element, which renders a case persuasive or not, but rather the plausibility of the story structure taken as a whole. In a good story all elements are connected to a central action and nothing is left standing on its own. The context provides a full and compelling account of why the central action should have developed in the way that it has. If this is not the case then the story contains ambiguities.

Wagenaar et al. (1993) proposed the theory of anchored narratives moving on from the work of Bennett and Feldman (1981) where the task of the judge was seen as determining the *plausability* of the stories presented by the prosecution and the defence. This narrative theory has its basis in cognitive psychology and contends that evidence derives its meaning from a story context. The plausibility of the story is related to its *narrative coherence*. Various schema-based approaches have been used in the study of story understanding. Story grammars try to capture and define the internal structure of stories as grammars. Many story grammars have been proposed and studied (Mandler & Johnson, 1977; Rumelhart, 1975; Simmons & Correira 1979; Thorndyke, 1977). Frames could be used to represent stories with slots for setting, protagonist, main event, moral or point, characters. However, progression through the story may need modification. The main way in which frames have been used in story modelling is as scripts. A script is a predetermined, stereotyped sequence of actions that defines a well known situation (Schank & Abelson 1977). They do not have the capacity to deal with unfamiliar and novel situations which is important in stories. SAM (Script Applier Mechanism) is a program that `understands' stories that are heavily based on scripts. Plans (Schank & Abelson 1977) can be used to tackle the problem of dealing with tasks for which there is no script. PAM is a program that understands plan-based stories.

The *setting, concern, resolution* sequence of Bennett and Feldman (1981) is well suited to the IILE in this work. The rich domain model deployed in the IILE is sufficiently expressive to obviate the need to embed structures to represent causal relations between elements found in more complex story grammars. A relatively simple story grammar is sufficient because the domain model is so expressive. The domain model deployed is based on argument structures and is described in the next section.

Representation of Domain Reasoning

An approach for representing knowledge called the Generic Actual/Argument Model (GAAM) has been advanced by Yearwood and Stranieri (2006). The GAAM model has been applied to the development of numerous decision support systems in law including; *Split Up,* predicting the percentage split of assets a Family Court judge awards divorcees (Stranieri et al., 1999), *Embrace*, assessing the strength of claims for refugee status (Yearwood and Stranieri, 1999), *GetAid,* determining eligibility for legal aid in Victoria (Stranieri et al., 2001) and witness selection in Scotland (Bromby and Hall, 2002). A web-based engine developed to implement the GAAM (*justReason* http://www.justsys.com.au) automatically generates a web based decision support system accessible with any web browser, using the knowledge.

The GAAM represents reasoning to a decision at two levels of abstraction, the generic argument level and the actual argument level. A generic tree that captures reasoning regarding risks associated with roof light design is illustrated in Figure 2. The 'root' of the tree is the OHS risk rating associated with a particular roof light element in a building. The linguistic variables "extreme", "high", "moderate" and "low" represent acceptable terminology for denoting the magnitude of risk in that field.

Every variable in a generic argument tree has a reason depicting its relevance. The factors *likelihood that an injury or illness will occur*; and the *likely severity of the consequence of that injury or illness should it occur* are relevant because risk management theory and Australian legislation dictates these two factors are relevant for determining risk. Argument trees are intended to capture a shared understanding of relevant factors in the determination of a value (in this case the level of OHS risk). Irrelevant factors are not included in an argument tree. Thus, the roof light colour is not considered relevant by designers or safety experts, so is not represented as a node in the tree - though one can imagine circumstances where a colour is indeed relevant to OHS, such as in the specification of emergency lighting or signage.

An actual argument is an instantiation of variables in the generic tree by setting leaf node values and inferring up the tree. A linguistic variable value on a parent node is inferred from values on children nodes with the use of inference procedures. An inference procedure is essentially a mapping of child variable values to parent variable values. In Figure 2, the inference procedures are denoted by A, B, C, D and R. Thus, for example the inference procedure R could take the form of a commonly used risk matrix where assessments of likelihood and consequence combine to determine the level of risk presented by a hazard. Thus a hazard for which the likelihood of occurrence is rated moderate but the consequence is major would be considered "Extreme."

For example, the risk rating is inferred using an inference procedure, R from values instantiated on two factors: In Australia, the inference derives from a risk matrix formula set by a government based standards organisation. The height and location of a roof light are factors that lead to an inference describing the consequence of a fall (i.e. the severity of the injury). The trolley system and protection for external work are used to infer an overall level of protection, and therefore the likelihood that a fall will occur. The existing protection is also coupled with the frequency with which the roof light will be maintained to infer the likelihood of a fall.

In argumentation-based KBSs different inference mechanisms can be used according to the nature of knowledge being modelled. For example, in the 'Split Up'system (described in Stranieri et al., 1999), neural networks trained on data drawn from divorce property judgements were used to infer about half of the 35 nodes. In a different system, known as 'Embrace,' which supported the determination of someone's refugee status, inferences were always left to the discretion of the decision-maker (Yearwood and Stranieri, 1999). In another system called GetAid, Stranieri et al. (2001) assigned weights to each linguistic variable and then summed these weights before and compared the result with a pre-determined threshold to infer eligibility for legal aid.

Argument trees, such as that depicted in Figure 2, represent a template for reasoning in complex situations. Thus, in a discussion about the level of risk posed by a particular roof light, two designers might disagree at the root node level in that one designer perceives the risk to be high while the other perceives it to be moderate. This difference in perception may derive from the different values assigned by each designer to subordinate nodes in the argument tree. For example, when one designer believes that existing protection is certainly adequate, whereas the other does not. The difference may also derive from alternate inference procedures; one uses inference A, the other uses a different mapping mechanism. However, although the two designers disagree, they can both reasonably accept the argument tree structure as a valid template for the expression of their beliefs.

The generic argument level is very useful in determining the mapping to the narrative model because it is rich in contextual information as well as providing information on reasons for relevance of premises (which ensures coherence) and reasons for inference procedures which captures values and principles behind the reasoning as well as sequencing information for events when their order is critical to the reasoning.

Table 1 illustrates the elements of the GAAM and the corresponding story elements that comprise the structured reasoning to narrative mapping central to the IILE.

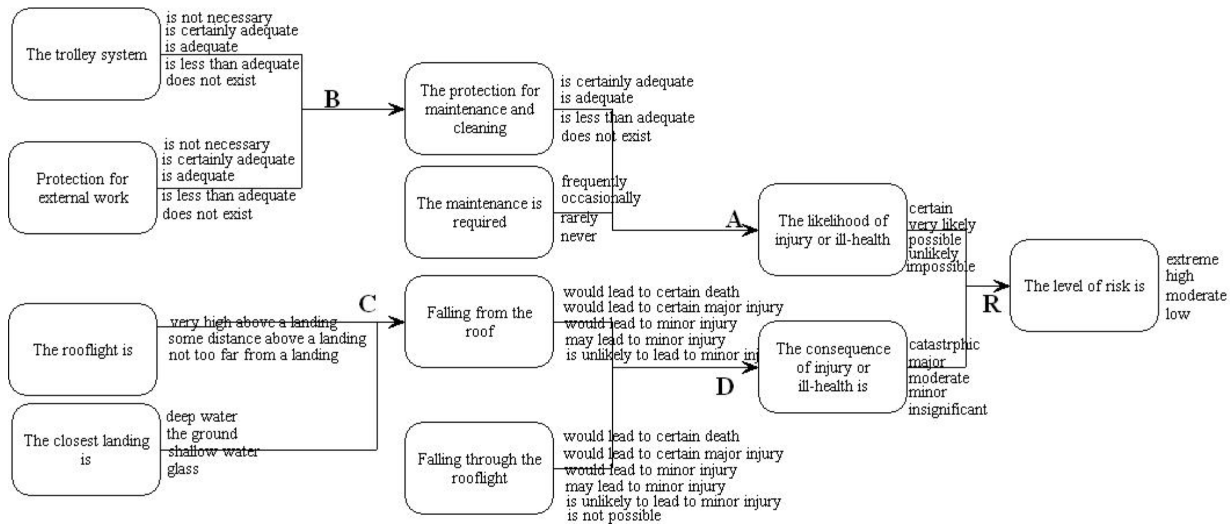

Figure 2: The structure of an argument tree in occupational health and safety

The mapping of the GAAM to story elements provides the framework for the IILE. In the next section an example from the domain of critical care nursing is provided that illustrates the mechanisms in some detail.

Table 1: Mapping of GAAM to Story elements

Reasoning: GAAM Element	**Story Element**
Context variable values	**Setting**
Not represented	Character
Set of child factor values, e. g. The likelihood of injury is *certain.* The consequence of injury *is catastrophic.*	**Concern**. Our protagonist will be exposed to certain catastrophic injury
Inference procedure reason, e. g. The risk matrix, R in Figure 2	Point. Protagonists exposed to certain catastrophic injury is at extreme risk
Parent factor value, e. g. The level of risk is *low*	**Resolution**
Not represented	Narrative voice
Reason for relevance of child factors	Coherence

Extended Example

Advances in critical care technologies and practices over recent decades have led to decision making settings that are complex and demand extensive nursing training. Monitoring and responding to ventilated patients' gaseous exchange is a central role for ICU nurses. (Van Horn, 1986) argued that there are too many factors or possible solutions for a human to remember at once, even when the problem is broken down into smaller pieces. Decisions must be made under pressure, and missing even a single factor could be disastrous.

The decision making involved in determining the actions a nurse should perform when a low oxygen alarm sounds with a mechanically ventilated patient is typically taught informally 'on the job' in conjunction with some classroom exercises. In practice, nurse educators aim to instil knowledge of three aspects of practical reasoning to novices:

- *Action* - What action to perform next. For example an action an ICU nurse has to learn to perform is to check the shape of the pleth wave. This is a wave displayed on a monitor that is derived from an infrared finger probe detecting the level of oxygen in the blood stream.
- *Incorrect Action Consequence* – This is the consequence of performing the incorrect action. For example, changing the finger probe is the correct action when the oxygen alarm is sounding and the pleth wave is noisy. A noisy pleth wave often indicates the probe is not reading accurately. Checking the blood pressure at this time has a consequence that is relatively minor in that it diverts the nurse's attention from effective troubleshooting.

Other situations have more serious consequences. The severity of each consequence is captured on a scale from 1-10 illustrated in brackets in Figure 3.

- *Omission consequence* – This is the immediate consequence of failing to perform the action when it is should be performed. Failing to administer pure oxygen to the patient when the alarm has sounded and the pleth wave is accurate results in a possible state of insufficient oxygen.

Reasoning involving the action and consequences following a low oxygen alarm in an Australian hospital has been modelled using decision trees described in Stranieri et al. (2004). In that study, reasoning was modelled using a decision tree in order to implement a decision support system that represented best practice in critical care nursing. The decision tree structure has been converted to an argument tree representation shown in Figure 3 for the IILE.

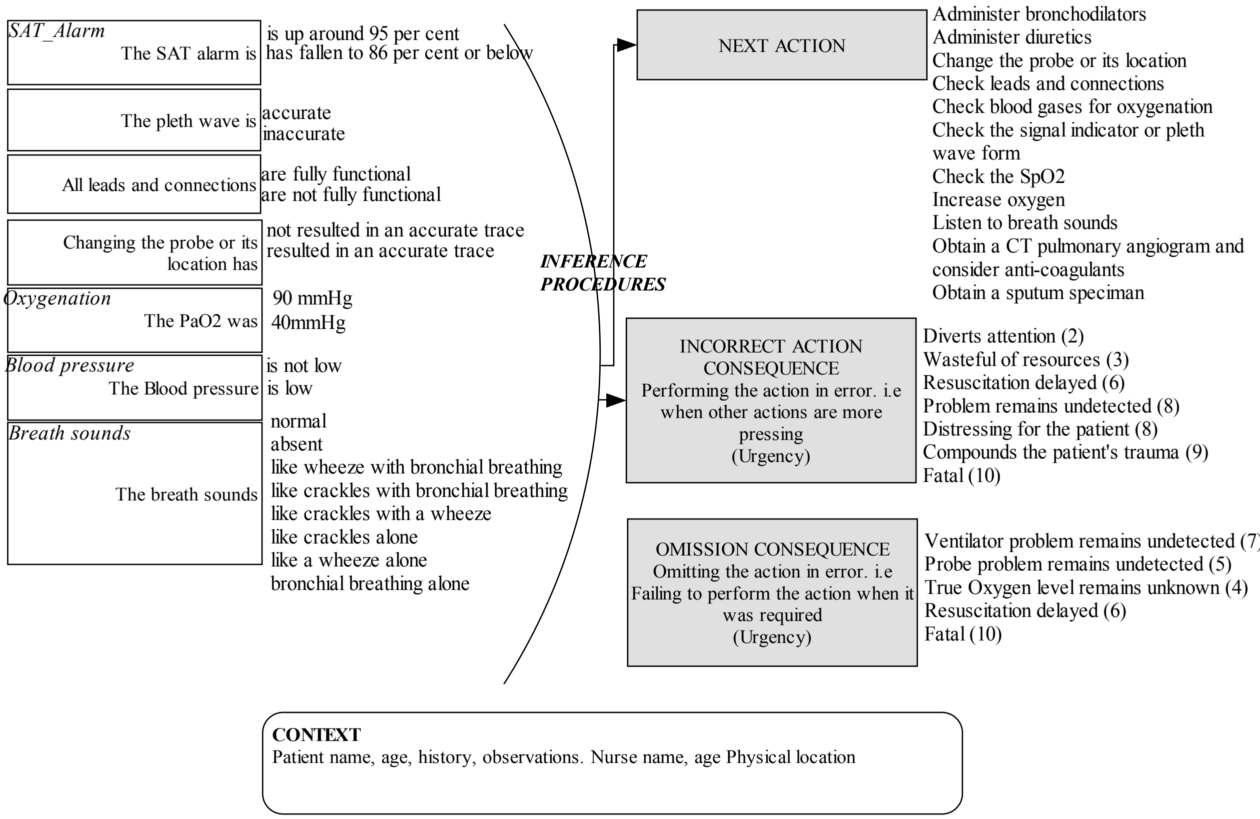

Figure 3: ICU Argument tree

The data items (extreme left) represent possible events or causal factors in ICU situations. There are three claim variables (extreme right): 1) the actions an ICU nurse may take at a point in time in a given situation, 2) the consequence that follows if the action is not correct and, 3) the consequence of failing to perform the correct action for the situation. Arrows represent inference procedures that will be invoked to infer a value on each claim variable for any set of input data items.

After initialisation, the IILE functions using a SET-INFER-NARRATE- cycle illustrated in Figure 4.

A prototype IILE with partial functionality has been implemented and evaluated to date. The prototype permits a restricted set of context variables and does not infer the severity of incorrect actions or omission consequences but more simply, presents canned text about the errors to the learner during the narrative phase. The learner has initial input into the story by setting context variable values such as the name and gender of the patient and nurse. *Figure* 5 illustrates the main screen for the prototype. On the left is a list of all actions available to the nurse. The top pane on the right provides the narration to date. Beneath that the learner is prompted to set data item values for the 'Check the signal indicator or pleth wave" action that was selected prior to the display of the screen in the SET phase. Once an action is selected and a data item value set, the system invokes the inference procedure in the argument tree to determine what the correct next action should be (INFER). If the next action the learner selects is not correct two segments of text are generated for the NARRATE phase; a segment explaining why the action was incorrect and another explaining the consequences associated with the non-performance of the correct action.

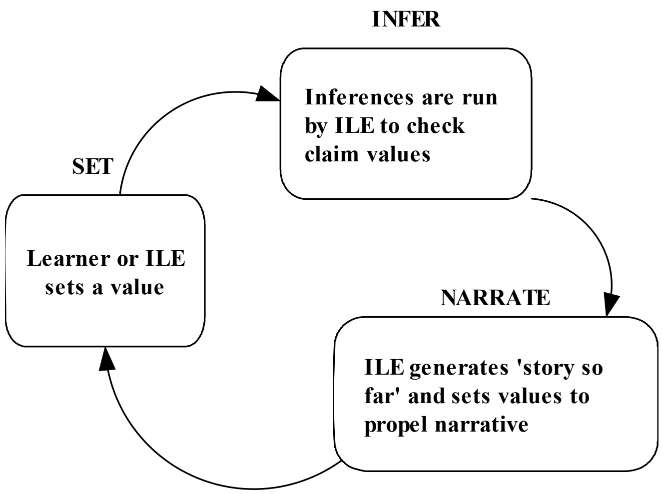

Figure 4: Narrate, Set, Infer cycle

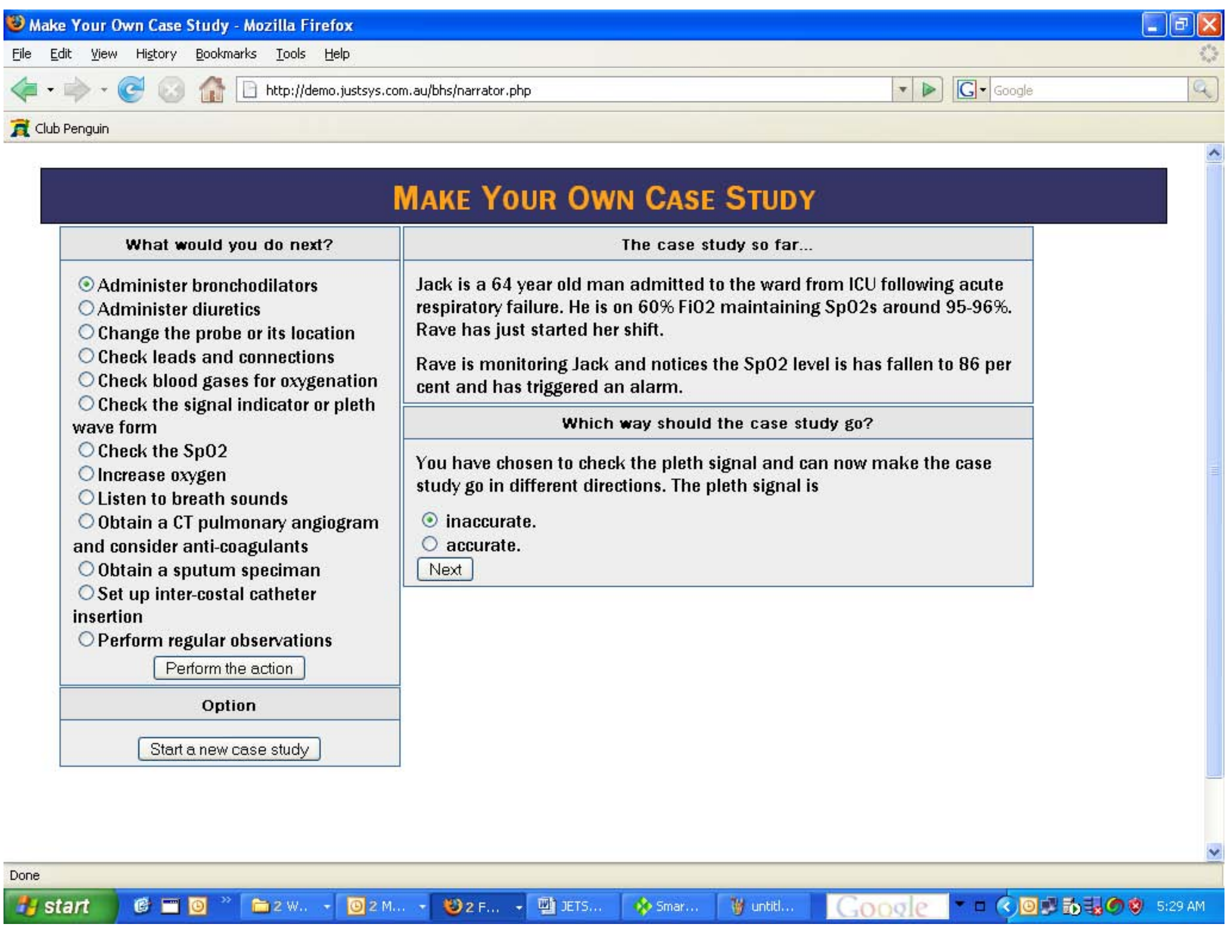

Figure 5. SET phase screen prompting the learner to set Pleth data item values

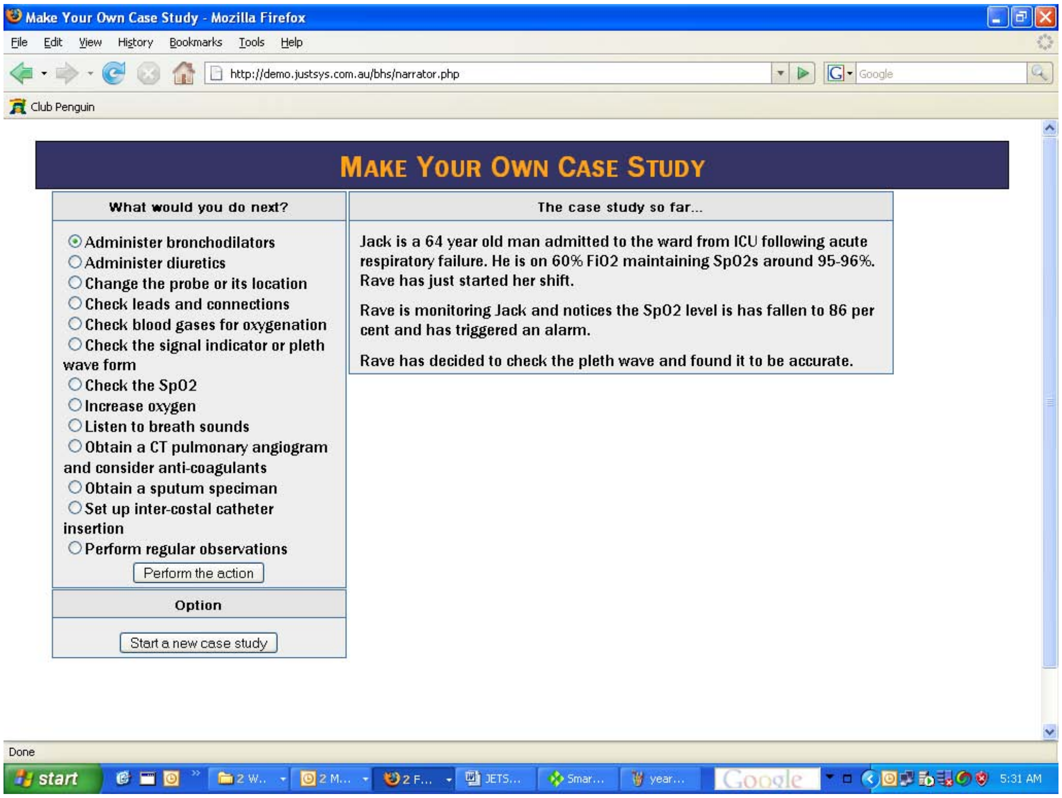

Figure 6. NARRATE phase screen after pleth set to accurate

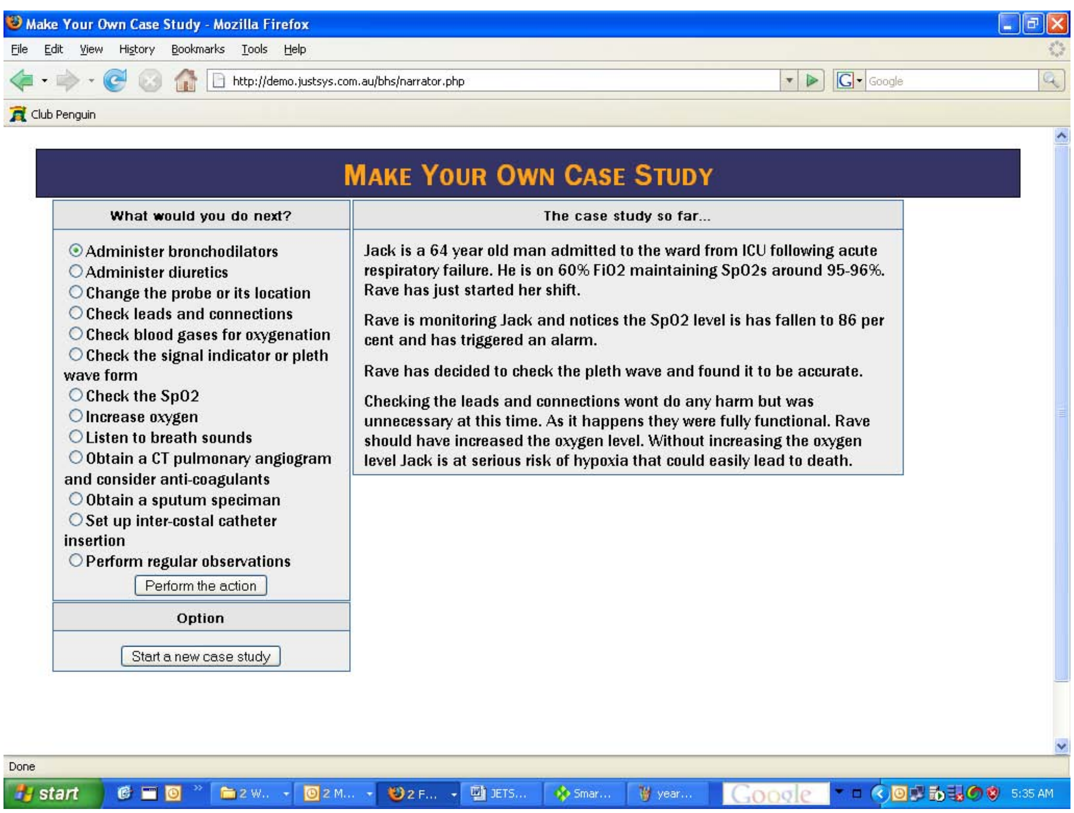

Figure 7. NARRATE phase screen after an incorrect action

Figure 6 illustrates a screen that presents narrators voice back to the learner following the setting of the pleth wave to accurate. The learner is about to select the next action to infer is to check the leads. However, behind the scenes, the INFER phase has determined that the correct action to perform next is to Increase oxygen. **Error! Not a valid bookmark self-reference.**7 depicts the NARRATE phase screen that displays the incorrect action text explaining why checking the leads was not appropriate and the omission text explaining why increasing the oxygen was more important. The NARRATE, SET, INFER cycle continues until a pre-defined end state is reached. These end states depict recovery or escalation of the concern to a point where a doctor is called.

Table 2 illustrates a similar example though differs from the prototype sample above in that the IILE exerts control of events to dramatise the impact of an error and produce a more dramatic story. Initially, at Steps 1 to 7, the learner propels the narrative on sufficiently so the IILE does not intervene but acts only as a narrator providing the learner with an alternate description of the learner's experiences.

At Step 8, the learner erroneously elects to check the breath sounds instead of checking the leads. The noisy pleth wave typically indicates that the finger probe is not accurately picking up a signal so checking the breath sounds is unnecessary. The IILE infers the next action given the situation (i.e "alarm", "noisy pleth wave" and "wheezing breath sounds") is still that leads should be checked. The consequence of not doing this (omission consequence) is that the true oxygen level is not known. The severity of this is rated at 4.

Table 2: Emergent narrative example

PHASE	Step	EVENTS
NAR	1	patient_name(jim), patient_age(jim,60), patient_cxr(jim, bilateral patchy infiltrates), patient_fio2(jim,60%) patient_spo2(jim, 95-96%), nurse(flo).
SET	2	Set(ILE,*SAT_Alarm*,sounding)
INF	3	infer(*Check pleth*)
NAR	4	nurse(observes,*SAT_Alarm*, sounding)
SET	5	Set(learner, *Pleth*, noisy)
INF	6	infer(*Check leads*)
NAR	7	nurse(observes, *Pleth*, noisy)
SET	8	set(learner, *Check breath*, like a wheeze) set(ILE, *Oxygenation*, inadequate)
INF	9	infer(Increase oxygen to 100% and suction)
NAR	10	nurse(observes, *Breath,* wheeze), narrator(tells, *Incorrect action consequence*, Diverts attention), narrator(tells, *Omission consequence*, True oxygen level unknown), narrator(tells, *Oxygenation*, inadequate)
SET	11	Set(learner, *Check ETT function* , functional)
INF	12	infer(Increase oxygen to 100% and suction)
NAR	13	narrator(resolution,*Patient dies*), narrator(tells, *Oxygenation*, inadequate), narrator(tells, *Check breath* instead of *Check lead,*), narrator(tells, *Incorrect omission consequence*, Unknown oxygen level)

In order to make a dramatic impact of the learner's error, the IILE commences to direct the narrative by attempting to set events that would extend the current situation and lead to the maximum omission consequence (i.e death rated at 10) or the maximum incorrect action consequence (i.e. death rated at 10).

The IILE performs a search, essentially by scanning inference procedures backwards, from claim to data-item values, in a goal-driven search. The search aims to find a set of data items that subsumes those currently set (alarm, noisy pleth wave, wheezy breath) and an omission consequence equal to the target (death). The search ends with the addition of the value *is inadequate* set for the data item *Oxygenation* to the currently set items. That is, the forward inference on the set (alarm, noisy pleth wave, wheezy breath and oxygenation inadequate) results in the next action being to increase oxygen to 100% (Step 9) and a consequence that failing to do this would be fatal. The IILE therefore sets the data item *Oxygenation* to - *is inadequate.*

The narration at Step 10 informs the learner of the consequence of performing the last action erroneously. Further, the narrator also informs the learner and that the story has taken a twist in that the patient now has insufficient oxygenation.

> *..when the SAT alarm begins sounding. Flo checks the pleth wave and notices it is noisy. She immediately checks the breath sounds and hears a wheeze. However, this is not the best thing for her to do because it has diverted her attention from the real problem and she doesn't know the true oxygen level. As it happens Jim has taken a turn and has a very low oxygen level.*

At Step 11, the learner again errs by checking the endotracheal tube without increasing the oxygen level to pure oxygen and suctioning. The IILE detects that this is the second error with a fatal consequence and triggers a resolution sequence that will leave the patient dead. Finally, the narrator describes the resolution by informing the learner of the mistakes made and actions that should have occurred.

> *..As it happens Jim has taken a turn and has a very low oxygen level. Flo checks the endrotracheal tube but has not increased the oxygen intake to 100% O2. Jim has entered seizure due to the low oxygen and has died.*
>
> *Early on, as soon as Flo noticed a noisy pleth wave she should have checked the leads instead of the breath sounds. Failing to do this meant that she didn't know the true oxygenation which as it happens was critically low. She will do better next time.*

In order to make a dramatic impact of the learner's error, the IILE commences to direct the narrative by attempting to set events that would extend the current situation and lead to the maximum omission consequence (i.e. death rated at 10) or the maximum incorrect action consequence (i.e. death rated at 10). This functionality has not been included in the current ILE prototype illustrated in the screens above.

In the next example, a short scenario is generated from a session driven entirely by the IILE. This simulates the presentation of case studies of best practice central to second tier learning illustrated in Figure 1.

Table 3: Automated generation of plausible case example

PHASE	Step	EVENTS
NAR	1	patient_name(jim), patient_age(jim,60), patient_cxr(jim, bilateral patchy infiltrates), patient_fio2(jim,60%) patient_spo2(jim, 95-96%), nurse(flo).
SET	2	Set(ILE,*SAT_Alarm*,sounding)
INF	3	infer(*Check pleth*)
NAR	4	nurse(observes,*SAT_Alarm*, sounding)
SET	5	Set(IILE, *Pleth*, noisy)
INF	6	infer(*Check leads*)
NAR	7	nurse(observes, *Pleth*, noisy)
SET	8	Set(IILE, *Leads*, fully functional)
INF	9	infer(*Change probe*)
NAR	10	nurse(observes, *Leads ,* fully functional)
SET	11	Set(IILE, *Change probe*, not resulted in an accurate trace)
INF	12	infer(*Check oxygenation*)
NAR	13	nurse(observes, *Change probe,* not resulted in an accurate trace)
SET	14	Set(IILE, *Oxygenation*, adequate)
INF	15	infer(Continue to monitor)
NAR	16	nurse(observes, oxygenation, adequate), narrator(resolution,Continue to monitor)

Automated case study generation

In problem based learning and learning through cases considerable resources go into the construction of problems/cases and related resources for supporting learners in enabling users to learn through understanding and solving the problems. The construction of cases depicting past or hypothetical scenarios in a non-interactive format is important for the early stages of the transformation from novice to expert, as illustrated in Figure 1. The automated generation of case narratives from a strong domain model is a useful function of the IILE in a non-interactive mode of control.

In the automatic generation of plausible case studies, the IILE first establishes the setting of the narrative by executing the initialisation phase of the cycle. Following that, the IILE selects actions based on inferences drawn from best practice. The cycles are illustrated in Table 3. The events, depicted as predicate-like clauses in Table 3 are feasibly converted to natural language below with relatively standard natural language generation techniques (from the rich resources stored in the GAAM).

> *Jim is a 60 year old man admitted to the intensive care unit with acute respiratory failure. He has been intubated for the last 3 days. His CXR shows bilateral patchy infiltrates and he is on 60% FiO2 maintaining SpO2s around 95-96%. You are caring for this patient when the SAT alarm begins sounding. You notice that the pleth wave does not appear accurate but is noisy. You check leads and connections and see that they are fully functional. Changing the probes or their position has not resulted in an accurate trace. You take blood gas samples to check saturation and find that these values are adequate.*
>
> *You conclude that oxygenation is adequate despite the probe readings, but proceed to apply the OxyMax procedure. OxyMax is necessary to accurately detect oxygen levels in some patients. You continue to monitor Jim closely.*

Results and Discussion

The basis of the system and its functionality has been illustrated using two examples. The IILE allows the user to interactively interrogate or select actions within a setting and receive feedback in the form of a narrative. The learner is engaged in the respiratory treatment of the patient and tries to act in the way that is best for the patient. To this end they select actions to perform and the IILE responds through the narrator to receive feedback and commentary to improve the user's understanding. The system uses knowledge to recognize incorrect actions or omitted actions by the learner and makes subsequent events occur for dramatic impact on the learner through the narrative. As the narrative emerges from the interaction between the learner and the IILE it provides supportive commentary as the learner reasons correctly but causes increased concern for the learner as reasoning mistakes or omissions are made. The IILE is capable of automatically generating a narrative based on knowledge that has been captured on reasoning to complex practical decisions.

A Web-based version of this design has been built and used as an instructional aid. There are some differences from this design in that the system does not propel the story to a dramatic end but simply narrates what has happened with the narration including advice about the consequences of incorrect actions, omissions as well as consequences of these actions.

The impact of the ILE on learning outcomes amongst student nurses was evaluated in a trial involving three groups of third year nursing students at the University of Ballarat described in Yearwood et al. (2007). Briefly, the study involved the use of three groups of student nurses. One group used the IILE in a tutorial, another used decision tree flowcharts and the third, a control group used a conventional tutorial format. Results from a test common to all groups was used as an objective measure of learning outcomes and subjective ratings of student interactions in the classroom were used as a measure of engagement. T-tests revealed that students who used the flowcharts and those that used the IILE performed significantly better on the common test than the control group. Further, the measures of student engagement clearly favoured the IILE.

Conclusion

We have described the design of a narrative based interactive intelligent learning environment which aims to elucidate practical reasoning about the critical care of acute respiratory patients by generating scenarios that capture the actions of the learner and their reasoning, as a narrative. The approach relies on a strong domain model of reasoning. It is expected that, as knowledge-based systems become more prevalent, models will be more readily accessible though their existence alone will not enhance the transformation from novice to expert. An interactive learning environment that embeds domain knowledge into a narrative scenario in a manner that allows the learner a very large degree of free-will has the potential to aid the transformation. One of the key features of this approach is the mapping from the reasoning represented using the Generic/Actual Argument Model to a narrative model that is illustrated here.

The increasing prevalence of knowledge-based systems will also allow for the rapid development of interactive learning systems that are able to connect naturally to the appeal of narrative in understanding and assimilating knowledge for human users. The approach has been found to be effective for learners over the traditional case-study approach. Further work is proceeding in two directions. An empirical study of the benefit of using this approach in a 3D environment over traditional approaches and refinement of the narratives by incorporating the emotional state of the user in interactive mode.

Acknowledgements

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References

Aleven, A., (2003). Using background knowledge in case-based legal reasoning: a computational model and an intelligent learning environment. *Artificial Intelligence, 150*(1-2), 183-237.

Aleven, V., & Ashley, K. D. (1996). How Different Is Different? Arguing About the Significance of Similarities and Differences. *Lecture Notes in Artificial Intelligence, 1168*, 1-15.

Bennett, W. L., & Feldman, M. S. (1981). *Reconstructing Reality in the Courtroom: Justice and Judgment in American Culture*, Piscataway, NJ: Rutgers University Press, USA.

Black, J., & Wilensky, R. (1979). An evaluation of story grammars. *Cognitive Science, 3*, 213-230.

Bransford, J. D., & Vye, N. J. (1989). Cognitive research and its implications for instruction. In L. B. Resnick and L. E. Klopfer (Eds.), *Toward the thinking curriculum: Current Cognitive Research,* Alexandria, VA: ASCD, 173-205.

Bransford, J. D., Sherwood, R. S., Hesselbring, T.S., Kinzer, C. K., & Williams, S. M. (1990). Anchored Instruction: Why we need it and how technology can help. In D. Nix and R. Spiro (Eds.), *Cognition, education, and multi-media: Exploration ideas in high technology*, Hillsdale, NJ: Lawrence Erlbaum, 115-141.

Bromby, M., & Hall, J. (2002). The development and rapid evaluation of the knowledge model of ADVOKATE: an Advisory System to Assess the Credibility of Eyewitness Testimony. *Paper presented at the 15th Annual International Conference on Legal Knowledge and Information Systems, December 16-17, 2002, London, UK*.

Bruner, J. (1986). *Actual Minds, Possible Worlds*, Cambridge, MA: Harvard University Press.

Chatman, S. (1990). *Story and Discourse: Narrative Structure in Fiction and Film*, Ithaca, NY: Cornell University Press.

Cognition and Technology Group at Vanderbilt (1990). Anchored Instruction and Its Relationship to Situated Cognition. *Educational Researcher, 19*(6), 2-10.

Denning, S. (2001). *The Springboard: How Storytelling Ignites Action in Knowledge-Era Organizations*, Boston: Butterworth Heinemann.

Emmot, K. (1999). *Narrative comprehension: A Discourse Perspective*, Oxford: Oxford University Press.

Frize, M., & Frasson, C. (2000). Decision Support and Intelligent Tutoring Systems in Medical Education. *Clinical and Investigative Medicine, 23*(4), 266-269.

Geoffrey, N. (2005). Research in clinical reasoning: past history and current trends. *Medical Education, 39*(4), 418-427.

Graesser, A. C., & Franklin, S. P. (1990). Quest: A cognitive model of question answering. *Discourse Processes, 13*, 279-303.

Hernandez-Serrano, J., & Jonassen, D. (2003). The effects of case libraries on problem solving. *Journal of Computer Assisted Learning. 19*(1), 103-114.

Herreid, C. F. (1998). What Makes a Good Case? Some Basic Rules of Good Storytelling Help Teachers Generate Student Excitement in the Classroom. *Journal of College Science Teaching, 27*, 163-165.

Hung, D., Tan, S. C, W. S., & Hu, C. (2004). Supporting Problem Solving with Case-Stories Learning Scenario and Video-based Collaborative Learning Technology. *Educational Technology and Society, 7*(2), 120-128.

Iuppa, N., Weltman, G., & Gordon, A. (2004) Bringing Hollywood Storytelling Techniques to Branching Storylines for Training Applications. *Paper presented at the Narrative and Interactive Learning Environments (NILE 2004),* August 10-13, 2004, Edinburgh, UK.

Jarz, E. M., Kainz, G. A., & Walpoth, G. (1997). Multimedia-based case studies in education: Design, development, and evaluation of multimedia based case studies. *Journal of Educational Multimedia and Hypermedia, 6*(1), 23-46.

Kirkwood, W. G. (1983). Storytelling and Self-Confrontation. *Quarterly Journal of Speech, 69*, 58-74.

Mandler, J. M., & Johnson, N. S. (1977). Remembrance of Things Parsed: Story Structure and Recall. *Cognitive Psychology, 9*, 111-151.

Mandler, J. M. (1984). *Stories, scripts and scenes: aspects of schema theory*, Hillsdale NJ: Lawrence Erlbaum.

Merseth, K. (1991). The early history of case-based instruction: Insights for teacher education today. *Journal of Teacher Education, 42*(4), 243-249.

Mayo, P., Donnelly, M. B., Nash, P. P., & Schwartz, R. W. (1993). Student perceptions of tutor effectiveness in problem based surgery clerkship. *Teaching and Learning in Medicine, 5*(4), 227-233.

Mezirow, J. (2000). Learning to think like an adult: core concepts of transformation theory. In Mezirow, J. (Ed.), *Learning as Transformation*, San Francisco: Jossey-Bass, 3-34.

McCloskey, D. N. (1990). Storytelling in economics. In C. Nash (Ed.), *Narrative in Culture: The Uses of Storytelling in the Sciences, Philosophy and Literature*, London: Routledge, 5-22.

Neuhauser, P. C. (1993). *Corporate legends and lore: The power of storytelling as a management tool*, New York: McGraw-Hill.

Peinado, F., Gervás, P., & Moreno-Ger, P. (2005). Interactive Storytelling in Educational Environments. *Paper presented at the 3rd International Conference on Multimedia and ICT in Education*, June 15-18, Cáceres, Spain.

Pennington, N., & Hastie, R. (1981). Juror decision-making models: The generalization gap. *Psychological Bulletin, 89*, 246-287.

Pennington, N., & Hastie, R. (1986). Evidence evaluation in complex decision making. *Journal of Personality and Social Psychology, 51*, 242-258.

Propp, V. (1968). *Morphology of the Folktale*, Austin, TX: University of Texas Press.

Rumelhart, D. E. (1975). Notes on a schema for stories. In Bobrow, D.G. and Collins, A. (Eds.), *Representation and Understanding: Studies in Cognitive Science*, New York: Academic Press, 185-210.

Schank, R. C. (1990). *Tell me a story: A new look at real and artificial memory*, New York, NY: Charles Scribner.

Schank, R. C. (1996). Goal-based scenarios: case-based reasoning meets learning by doing. In Leake, D. (Ed.), *Case-Based Reasoning: Experiences, Lessons & Future Directions*, Menlo Park, CA: AAAI Press, 295-347.

Schank R. C., & Abelson, R. P. (1977). *Scripts, Plans, Goals and Understanding: an Inquiry into Human Knowledge Structures*, Hillsdale, NJ: Lawrence Erlbaum.

Simmons, R. F., & Correira, A. (1979). Rule forms for verse, sentences and story trees. In Findler, N. (Ed.), *Association Networks - Representation and Use of Knowledge by Computers*, New York: Academic Press.

Thorndyke, P. W. (1977). Cognitive structures in comprehension and memory of narrative discourse. *Cognitive Psychology, 9*, 77-110.

Stranieri, A., Zeleznikow, J., Gawler, M., & Lewis, B. (1999). A hybrid rule-neural approach for the automation of legal reasoning in the discretionary domain of family law in Australia. *Artificial Intelligence and Law, 7*(2-3), 153-183.

Stranieri, A., Zeleznikow, J., & Yearwood, J. (2001). Argumentation structures that integrate dialectical and non-dialectical reasoning. *The Knowledge Engineering Review, 16*(4), 331-358.

Stranieri, A., Yearwood, J., Gervasoni, S., Garner, S., Deans, C., & Johnstone, A. (2004). Web-based decision support for structured reasoning in health. *Paper presented at the 12th National Health Informatics Conference (HIC 2004*), July 25-27, 2004, Brisbane, Australia.

Stranieri, A., & Yearwood, J. (2007). *Enhancing Learning Outcomes with an Interactive Knowledge-based Learning Environment providing Narrative Feedback*, Technical Report, University of Ballarat, Australia.

Van Horn, M. (1986). *A guide to expert systems*, New York: Bantam Books.

Vernon, D. T., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*(7), 550-563.

Wagenaar, W. A., van Koppen P. J., & Crombag, H. F. M. (1993). *Anchored narratives: the psychology of criminal evidence*, Hempstead: Harvester Wheatsheaf.

Warren, W. H., Nicholas, D. W., & Trabasso, T. (1979). Event Chain and Inferences in Understanding Narratives. In R. O. Freedle (Ed.), *New Directions in Discourse Processing*, Hillsdale, NJ: Lawrence Erlbaum, 5-27.

Wilensky, R. (1982). Points: a theory of the structure of stories in memory. In Lehnert W. G. and Ringle M. H. (Eds.), *Strategies for Natural Language Processing*, Hillsdale, NJ: Lawrence Erlbaum, 459-473.

Yearwood, J., & Stranieri, A. (2006). The Generic Actual Argument Model of Practical Reasoning. *Decision Support Systems, 41*(2), 358-379.

Yearwood, J., & Stranieri, A. (1999). The integration of retrieval, reasoning and drafting for refugee law: a third generation legal knowledge based system. *Paper presented at the 7th International Conference on Artificial Intelligence and Law*, 14-17 June 1999, Oslo, Norway.

Yearwood, J., Stranieri, A., & Avery, J. (2006). Interactive Narrative by Thematic Connection of Dramatic Situations. *Paper presented at the Narrative and Interactive Learning Environments (NILE 2004),* August 10-13, 2004, Edinburgh, UK.

Lam, W., Williams, J. B., & Chua, A. Y. K. (2007). E-xams: harnessing the power of ICTs to enhance authenticity. *Educational Technology & Society*, 10 (3), 209-221.

E-xams: harnessing the power of ICTs to enhance authenticity

Wing Lam[1], Jeremy B. Williams[1] and Alton Y.K. Chua[2]
[1]School of Business, Universitas 21 Global, Singapore // Tel: +65 6410 1300 // Fax +65 6410 1358 // wing.lam@u21global.edu.sg // jeremy.williams@u21global.edu.sg
[2]School of Communication and Information, Nanyang Technological University, Singapore // Tel: +65 6790 5810 // Fax +65 6790 5214 // altonchua@ntu.edu.sg

ABSTRACT

Within an authentic assessment regime, a student is evaluated in terms of their ability to demonstrate application of a body of knowledge to a scenario situated in an actual, or a near replica of a real-world context. At Universitas 21 Global (U21Global), a completely online graduate school backed by 16 universities from around the world, the entire pedagogical model is founded on such an approach. One unique feature of the U21Global model is its interactive examination instrument which harnesses the power of the various information and communication technologies (ICTs). This instrument, referred to as the Open-Book Open-Web (OBOW) exam, presents students with a description of a simulated business problem using multimedia. They are then asked to assume a particular role and make recommendations about how to go about solving the problem. Feedback to date indicates that students are generally very positive about OBOW exams. On the minus side, the construction of OBOW exams presents a number of challenges. Not least of these is the steep learning curve it presents for exam authors unaccustomed to working within this paradigm.

Keywords

Authentic assessment, Examinations, Constructivism, ELearning

Introduction

In recent years, there has been a growing interest in authentic assessment (see, for example, Svinicki 2005; Laurillard 2002; Hanna 2002). This is largely fuelled by the realisation that traditional assessment, which relies on indirect, simplistic or proxy items to make inferences about a student's performance, no longer provides (if it ever did!) an adequate and realistic measure of knowledge (and its application) in a fast-changing world. In an authentic assessment setting, a student is evaluated in terms of their ability to demonstrate application of a body of knowledge to a scenario situated in an actual, or a near replica of a real-world context.

Wiggins (1998) notes that authentic assessment often involves 'ill-structured' challenges and roles that help students rehearse for the complex ambiguities of real life. Authentic assessment focuses on students' analytical skills, the ability to integrate new learning, and gives equal weight to the *process* as much as the finished product. Arguing in a similar vein, Mueller (2005) identifies several benefits of authentic assessment. First, authentic assessments are direct measures of a student's ability to apply knowledge and skills. Second, authentic assessment encourages a constructivist approach to learning, where students learn through application. Third, authentic assessment gives students considerable freedom to demonstrate what they have learnt without being limited to a particular set answer. Authentic assessment is particularly relevant to applied disciplines such as business, where a student may be assessed on their ability, for example, to develop a marketing strategy for a company rather than critique a theory of market segmentation.

The use of business cases and problem-based learning found in many graduate schools can be construed as a form of authentic assessment (Savery and Duffy l995). However, by and large, these paper-based cases are very static, and fail to harness the liveliness that can potentially be brought about by the inclusion of multi-media elements. Indeed, given the advent of the information age and the Internet, it is surprising that cases are still presented in a traditional format. Furthermore, because of the time needed for publication, cases tend to be at least one year old and often do not capture important topical issues emerging in the subject area. Importantly though, once published, the 'answer' to a case readily surfaces in the public domain, so calling into question the use of those cases as an instrument for a student's final examination.

The School of Business at Universitas 21 Global (U21Global), one of the new breed of online academic institutions, has been using authentic assessment in its MBA program since it commenced operations in mid-2003. This paper reports on the overall experiences of U21Global with authentic assessment, specifically with a unique final examination instrument it has developed, known as the Open-Book Open-Web (OBOW) exam. While there may be individual professors working in other institutions, such as in the Wharton School of Business (Cole 2006), who are giving their students real-life cases to analyse as part of their final examination, these appear to be less well developed as an authentic assessment instrument as OBOW exams. Furthermore, U21Global is distinctive in that OBOW exams are an institution-wide approach to final examinations that is mandatory to all subjects, not just a select few.

The paper begins with a brief overview of U21Global. This is followed by a description of the assessment regime at U21Global and how OBOW exams are constructed and delivered. The lessons learnt from experience with OBOW exams and their implications are then discussed. The paper concludes that authentic assessment in the form of OBOW exams is a positive step from a pedagogical standpoint but the acceptance and successful implementation of such a model is contingent upon some form of training/ professional development for exam authors.

The Context: Universitas 21 Global

Organisational overview

U21Global is a joint venture between Thomson Learning, one of the world's largest publishers, and Universitas 21 (U21), a network of research-oriented universities spanning four continents. Nineteen of the U21 universities have an equity stake in U21Global including McGill University, University of British Columbia, University of Virginia, Tecnológico de Monterrey, University of Birmingham, University of Edinburgh, University of Glasgow, University of Nottingham, Lund University, University College Dublin, University of Melbourne, University of New South Wales, University of Queensland, University of Auckland, National University of Singapore, Korea University, University of Hong Kong, Shanghai Jiao Tong University, and Fudan University. U21Global is head-quartered in Singapore, with regional offices throughout the Asia-Pacific.

U21Global commenced, first of all, with the MBA program, and offered its first classes in July 2003. This program (including students enrolled in associated diploma, certificate and single subject programs) has since attracted nearly 2000 students. The typical profile of a U21Global MBA student is a working adult in a middle management position. The average age of students is 35 years old, average work experience is 11 years, and the majority are married (72%). No fewer than 83% travel to other countries in the course of their jobs. Singapore, India and the Middle East countries supply more than half of the students, but there are more than 50 different nationalities on the program in total.

Overall learning design

Programs offered by U21Global are delivered entirely online; i.e. there is no face-to-face classroom study. Subjects last for 12 weeks and there is an expectation that, on average, students will spend 10 to 12 hours studying per week per subject. Since students are geographically dispersed among many different time-zones, interaction is largely asynchronous through discussion forums and email housed within U21Global's learning management system (LMS). However, students may also use synchronous tools such as online chat and audio conferencing.

The online courseware integrates with a prescribed textbook (although subjects are not textbook-driven) and exploits the power of the Internet to deliver text, graphics, interactive exercises, animations, downloadable resources, and hyperlinks to web sites. There are no lectures as there are in the conventional classroom. Indeed, this is a pedagogy that is quite at odds with the constructivist approach favoured by U21Global. While each class is led by a professor who maintains a presence throughout the duration of the class, he or she is the 'guide on the side' rather than the 'sage on the stage'. Students exercise considerable control over the direction of their learning and navigate their way through the web-based materials, accessing the electronic library when necessary, and only drawing on the expertise of the professor in an advisory capacity.

Importantly, there is a strong emphasis on peer learning, not least because the student demographic is such that they clearly have a lot to learn from one another given the diversity of professional experience, nationalities and cultures. Aside from the extensive interaction on discussion boards, there is considerable opportunity for students to collaborate through team assignments and projects (all individual contributions being subject to peer assessment), which help to contribute to the development of a robust online learning community.

The assessment regime at U21Global

All U21Global MBA subjects feature four assessment instruments; namely, written case study assignments, discussion board contributions, a final project and a final examination. The description of these instruments and their relative weights are shown in Table 1.

Table 1: Assessment instruments

Assessment Instrument	Description	Weighting (% of overall mark)
Case analyses	Students complete up to 4 business case analyses (at least one as a member of a team, and at least one on an individual basis).	30
Discussion boards	Students are assessed on the quality of their contributions to discussion boards (according to 4 ‘categories of interaction’ (MacKinnon 2000)	30
Final project	Students complete a major business case analysis, usually as a member of a team.	15
Final examination	Students are given an OBOW examination. This exam must be passed in order to pass the subject overall.	25

From the outset, U21Global committed itself to a case-oriented, problem-based learning approach where student learning would be firmly grounded in reality. Assignments and discussion topics are incorporated extensively into the courseware at logical junctures to help students reinforce learning. Assignments primarily take the form of business cases drawn from Harvard, the Ivey School of Business or the European Case Clearing House (ECCH) while discussion topics usually take the form of contentious or open-ended issues that seek to solicit a multiplicity of views from students. Typically, half of the assignments require students to work in teams of three to five. The final project, submitted at Week 12, may also a team assignment. In Week 14, two weeks after the class ends, students are required to sit the final exam.

After a year of experience with this assessment regime, it became clear that there were inherent structural problems. It was U21Global’s intention to model the final exam format and conditions as closely as possible after those found in traditional universities. The final exam was originally designed as a 3-hour exam which comprised multiple-choice questions and short-answer questions, and it was administered in a proctored environment by Prometric, a Thomson-owned company, which operates test centres throughout the major cities in the world.

However, it became increasingly evident that the existing examination instrument had serious operational and pedagogical shortcomings. Scheduling final exams for a rapidly growing pool of students from all over the world became a logistical challenge. More significantly, the final exam format was not consistent with U21Global’s preferred pedagogy; that is, there was a lack of what Biggs (1999) refers to as ‘constructive alignment’. First of all, an objective of the U21Global MBA program is to develop strategic problem-solvers in the workplace. The approach used in the existing final examination was considered inappropriate to further this goal. Second, the conditions under which the existing examination was conducted were far too remote from those in the real-world. The 3-hour exam gave students little time to ponder, investigate and reflect on realistic business problems. Rather, the short time fostered ‘quick-fixes’ and memorisation rather than encouraging deep-thinking and integration of learning. For these reasons, U21Global turned instead to an approach founded on the principles of authentic assessment introducing what it calls OBOW exams.

Authentic assessment and OBOW exams

Defining characteristics of the OBOW examination instrument

The OBOW exams used at U21Global represents a significant departure from the conventional, closed book, invigilated model for examinations in that they not only leverage the rich media resources available through the World Wide Web, they are also situated in an authentic context. In keeping with the constructivist tradition, the OBOW exam comprises a case-story that invites students to draw upon all they have learned throughout the subject, and in assembling this knowledge, they demonstrate what they know rather than what they do not know. There is no call for individuals to memorise and regurgitate facts and concepts in a controlled setting. Such case-stories are recognised as powerful learning instruments as well as assessment instruments (Hung et al. 2004).

Students can complete the OBOW exam at any physical location of their choosing within a 75-hour window over a designated weekend (usually the end of week 14). Once the OBOW exam paper has been downloaded from the U21Global LMS, the students have 24 hours to submit their response (via the LMS). A wide range of resources such as the text books, electronic library and the World Wide Web are at the students' disposal throughout the duration of the examination.

The construction of the OBOW exam at U21Global follows a six-step process (Williams, 2004). The first step is to generate some preliminary ideas for the examination. Rich sources of ideas include local newspaper, current affairs publications or professional journals. Compared to text books and academic papers in general, news items or articles written for the general reader have the capacity to engage the student more readily. Since interesting ideas usually take time to incubate, it is wise to maintain vigilance in amassing relevant materials and shaping the theme rather than hastily developing the questions just before the examination time.

The second step involves creating a context which holds a story in a non-academic manner. The context could be situated in a government department, a company, or one that faces an individual. As the subject matter expert, the author of an OBOW exam has the capacity to read a newspaper article or watch a television news report through the lens of their academic discipline. In constructing an authentic assessment item such as this, the objective is to create an opportunity for students to tackle an issue quite differently than if they had not had the benefit of formal learning in the discipline in question.

The third is to enrich the story with various media such as photographs, audio clips and streaming video that add a human dimension to the task and effectively bring the case to life (Herrington & Herrington 1998). Hyperlinks to company web sites and news portals can also be provided to attest to the genuineness of the case. The text and media are selected on the basis of their relevance in describing a situation that currently confronts the central character in the case.

The fourth step is to define the assessment task. Presenting students with the task in context and then setting them up as key decision maker, the expert advisor, or the auditor is an effective mechanism for validating their learning. It is important to note that assessment tasks are crafted in conjunction with the stated learning outcomes for the subject. The purpose of the assessment tasks is therefore to afford students maximum opportunity to demonstrate that they have achieved these learning outcomes.

The fifth step is to provide a task guide that offers some broad plan as to how the students might approach the task without being overly prescriptive. The objective here is to maintain students' focus on the tackling the assessment task in a way that is aligned to the learning outcomes.

The sixth and final step in the process is essentially administrative, but quite critical in terms of the overall design of the examination instrument. There are statements about the importance of critical analysis and the rejection of exam scripts for late submission, but also advice specifically designed to combat plagiarism and cheating. In particular, that it is a *requirement* that students to draw on the concepts and analytical tools referred to in the U21Global subject they have studied and that they demonstrate this through direct reference to course materials. This condition, together with the fact the assessment task is heavily contextualised, make it extremely difficult for students to cheat.

Table 2 summarises the six steps in the construction of an OBOW examination.

Table 2: Process in constructing an OBOW exam

Step	Process	Description
1	Generate the idea	Generate the idea from a variety of sources such as newspaper, current affairs publications or professional journals.
2	Set the context	Set the context of the case in a government department, a company, or one facing an individual.
3	Enrich the story	Bring together various media such as photographs, audio clips and streaming video to enrich the story.
4	Define the task	Place students in the role of an expert witness and define the assessment task in conjunction with the stated learning outcomes for the subject.
5	Provide a guide	Offer broad guidelines on how the task could be approached.
6	Issue administrative instructions	Specify the necessary administrative instructions to maintain rigour and integrity in the examination system.

An example OBOW exam

An example of an OBOW exam used in the subject 'IT Systems for Business', an introductory course in IT, is given in the Appendix. It is quite unique and will not be used again for examination purposes. The length of an OBOW exam paper is deliberately kept relatively short and succinct, and typically, the exam comprises three components; namely, 'The Context', 'The Task' and the 'Guide to the Task'. The Context introduces the case and provides some background information. The Task specifies what students are required to do while the Guide to the Task outlines the approaches students may take in response to The Task. Table 3 summarises the main components of the OBOW exam.

Table 3: The components of an OBOW exam

	Description	Concise example
The Context	Describes a real-world problem	"Company XYZ wants to improve the efficiency of its logistics operation…"
The Task	Describes the role the student is playing and what needs to be done	"You are a consultant in a major consulting firm who has been asked to develop recommendations…"
Guide to the Task	Provides suggestions about how the student might go about addressing the problem without being overly prescriptive	"Your colleagues suggest that you examine the logistic processes used at Company XYZ…

Although the template for the OBOW exam (The Context, The Task and the Guide to the Task) remains unchanged, the content within this template is deliberately quite varied and unstructured. The reason for this, quite simply, is that in the real world, information about a business problem is rarely straightforward and neatly structured. Thus the content provided in The Context section of an OBOW exam is incomplete and loose, so as to simulate a real-world setting. Similarly, in the Guide to the Task, it is important to avoid being too prescriptive as to how the student might go about solving the problem. The idea here is to provide no more information than a consultant would ordinarily receive in a brief from a prospective client. The onus is on the students to manage the fuzziness, make realistic assumptions where needed, interpret the core issues in a problem, and piece together a convincing and cogent solution to the problem.

According to Wiggins (1990), for assessment to be authentic it will display the following characteristics:

i. The assessment is realistic and reflects the way the information or skills would be used in the real world;
ii. The assessment requires judgment and innovation and is based on solving unstructured problems that could easily have more than one right answer and, as such, requires the learner to make an informed choice;

iii. The assessment asks the student to do the subject; that is, to go through the procedures that are typical to the discipline under study;

iv. The assessment is done under situations as similar to the contexts in which the related skills are performed as possible;

v. The assessment requires the student to demonstrate a wide range of skills that are related to the complex problem, including some that involve judgment; and

vi. The assessment allows for feedback, practice, and second chances to solve the problem being addressed.

The OBOW examination instrument would appear to exhibit the first five of these characteristics, the summative nature of the final examination precluding any 'second chances'. However, students are quite at liberty to seek feedback on their performance from their professors, and while there might not be an opportunity to 'practice' solving a similar problem within the confines of the subject they have just completed, the knowledge acquired – specifically the generic skills of sound critical analysis and synthesis – are transferable to other subjects and, indeed, in the course of their professional lives.

Evaluating the effectiveness of OBOW exams

Researching the effectiveness of the OBOW exam instrument,is a complex task, and a definitive analysis is still some way off. To date, a major source of quantitative data has been the surveys (mandatory for all students completing a subject) collected from students at the end of every class. Other sources of data include the qualitative feedback obtained from the full-time faculty at U21Global who are largely responsible for the implementation of the OBOW exam approach at U21Global, and the adjunct faculty who supervise the online classes and author the OBOW exam papers. A synthesis of this research data is presented below, together with preliminary analysis of the findings to date. Such a research strategy can be justified for an exploratory investigation aimed at evaluating the general utility of the OBOW approach. A major longitudinal study is currently in process that compares learning outcomes from the OBOW instrument with those derived from more traditional examination instruments.

Preliminary Findings and Lessons Learnt

Student approval

In late 2004, a survey of students completing both the original and OBOW formats of examination showed the student body to be extremely happy with the OBOW model. Questions focused on the relative depth of learning, real world relevance, the consistency of the examinations with the pedagogy, the time allowed for the examinations, the opportunities for plagiarism and cheating, and overall preferences regarding examination format. The questionnaires were submitted voluntarily and there was a response rate of 45% from a population of 120. The most significant statistic was that *all* students either agreed (27%) or strongly agreed (73%) that, overall, OBOW examinations were preferable to a closed book, invigilated examination format. Other similarly resounding results were that 96% either agreed or strongly agreed that a 24 hour period for the OBOW examination was about right; 98% either agreed or strongly agreed that it was more convenient; and a similar proportion believed the format to have greater relevance to their business education. From an educational perspective, 96% either agreed or strongly agreed that the OBOW examination format was more closely aligned with the U21Global pedagogy than the closed book, invigilated format; 88% either agreed or strongly agreed that, by comparison, it produced higher quality outcomes; 84% either agreed or strongly agreed that the OBOW format was more intellectually challenging; with a similar number finding the interactive nature of the examination more engaging (Williams 2006).

Combating plagiarism and cheating

As an assessment instrument, the OBOW exam is supposed to be completed solely as an individual piece of work. Students are at liberty to discuss various approaches to a problem beforehand in the same way as they would discuss a problem with colleagues in the workplace because this, after all, constitutes learning. The final exam remains, however, an assessment of the individual student's abilities, and there can be no collaboration in its completion. With a more traditional exam model, ensuring there is no collaboration in a non-proctored or 'take home' exam can be difficult. With the OBOW model, unethical practice is much easier to detect. One advantage of using an authentic assessment approach is that, presented with a very open and unstructured problem, it is unlikely that any two exam candidates will present similar responses. Students may refer to the same broad concepts, but the highly contextualised way in which they are required to articulate and present the concepts makes cheating difficult (Williams 2002). It is impossible, for example, for someone to buy a 'ready-made' essay from one of the numerous online 'paper mills' because in an authentic assessment setting, where the *application* of theory in a real-world context is the quintessential factor, one will never see, for example, the likes of "Define eBusiness. What are key characteristics of a sound eBusiness strategy?" This type of assessment task is quite antithetical to constructivist pedagogy and clearly at odds with a commitment to authentic assessment (Herrington & Standen 2000). To date, where students have presented OBOW exam answers that are very similar, these are easily detected by U21Global professors and the individual students have been called to account.

In OBOW exams, as the example in the Appendix demonstrates, students are encouraged to make use of the course materials, the Web, and other available resources in preparing their answer. This is consistent with the philosophy of authentic assessment, where students would have access to similar resources in a real-world setting. However, making exams open in such a manner brings its own set of problems. Not least of these is the vexed issue of plagiarism.

Plagiarism is a phenomenon that is general to education, of course, but it warrants further attention in relation to authentic assessment. At U21Global, like other institutions, the policy to deal with plagiarism is quite unambiguous in that the inclusion of any external material must be appropriately referenced. Therefore, in the case of a student who has done a 'cut and paste' from a website into their OBOW exam response without attributing the source – something easily detected with the assistance of a search engine like Google or Dogpile – there is little room for debate. However, one has to be mindful of the somewhat of blurred line between plagiarism and what might be considered 'knowledge reuse' where, for example, a student has identified solutions from elsewhere and tailored them to solve the OBOW problem at hand. This case is much 'greyer' than the straightforward cut and paste, and it could be argued that a student has reused knowledge from elsewhere to solve a problem in a new context. This is not inconsistent with an authentic assessment philosophy and, ultimately, it may boil down to the professor's judgement.

When quizzed about the opportunities for plagiarism and cheating in the 2004 survey on OBOW (referred to above), many U21Global students elected to take a neutral stance. When asked the question whether the format of the OBOW exam meant students can cheat, around half disagreed (30%) or strongly disagreed (20%). Meanwhile, 27% remained neutral and 23% agreed (but did not strongly agree) that students can cheat. Interestingly, when asked the question whether the format of a closed book, invigilated exam meant students *cannot* cheat, a broadly similar picture emerges. This time, slightly less remained neutral (20%), with the balance split fairly evenly among those that disagreed (22%) or strongly disagreed (18%) that students cannot cheat in a closed book, invigilated exam, and those that agreed (27%) or strongly agreed (13%).

A point often overlooked is that there is a tendency for people to implicitly assume that the on-campus model is the perfect system. If one were to ask the Registrar on every campus of every university world-wide whether they caught anyone cheating this semester they would, of course, answer in the affirmative. The U21Global position is that, in the absence of a perfect system, it is better to concentrate one's efforts on developing an assessment instrument that caters for the vast majority of students who are motivated by the quality and depth of learning, rather than go for a pedagogically inferior option that may (or may not!) thwart the cheats.

A steep learning curve

U21Global is heavily reliant upon adjunct professors drawn from many business schools from around the world. Many of U21Global's adjunct professors (around one half) experience significant difficulties in writing OBOW exams. This difficulty stems, in part, from an unfamiliarity with an authentic assessment approach and the fact that are used to more traditional methods of exam question setting. A dedicated Authentic Assessment Website has been set up to assist with professional development and some professors are very keen to learn. Unfortunately, however, such a resource tends to be of little benefit in the case of those professors who have been using instructivist forms of assessment their entire academic career, and who are generally very resistant to any form of change. A further difficulty encountered is that writing OBOW exam questions requires professors to have an understanding of real-world problems in relation to the subjects that they deliver. This can be a testing experience for professors who have had little or no experience of solving real-world problems, either through research or consultancy.

The grading of OBOW exam responses can represent a challenge for the uninitiated. Given their open-ended and unstructured nature, OBOW exams do not lend themselves to any pre-defined 'model answer'. Rather, students may provide a multitude of very different answers, all of which are equally valid responses to the problem presented in the OBOW exam. Like in real-life, one student may propose a solution to a problem, while another may think along different lines to propose a radically different solution. Hence, it is difficult for the professor to develop a detailed marking scheme beforehand, something that might be unsettling for some professors. To further complicate matters, there may be no clearly-defined basis for saying that one solution is superior to the other, and should therefore receive a higher mark. Consistent grading is therefore more difficult to achieve given that solutions may not be meaningfully compared (Svinicki 2005). While U21Global has developed an assessment cover sheet with generic assessment criteria that focus on a student's powers of analysis and synthesis, and an associated grade descriptions document, the professor must still use his or her judgement in evaluating the utility and soundness of a solution and the cogency with which it is being described and presented by the student. As mentioned earlier, if a professor has little experience of solving real-world problems themselves, they may find it difficult to evaluate OBOW exam responses, causing them to take longer complete the job.

While the OBOW exam is a summative piece of assessment, meaning that professors are not normally expected to provide feedback to students, they do have the right to request such feedback from their professors. Although this does not happen too often, it can be a challenge for a professor who is accustomed to having the 'safety blanket' of a model answer or detailed marking scheme that is heavily content-oriented. Instead, the professor must 'get to grips with' the response provided by each and every student, probing the strengths and weaknesses of each answer. The feedback given to a student is therefore of a highly personalised nature which is a positive point, of course, but it may require greater effort on the part of the professor.

The transferability of the model

Since their introduction, OBOW examinations have been used in 130 separate class sections within 30 individual subjects in U21Global's MBA program, across a variety of disciplines, including subjects of a qualitative nature (e.g, organisational behaviour, marketing management, and human resource management) as well as subjects of a largely quantitative nature (e.g. accounting, finance, and data analysis). It can be stated with some degree of confidence, therefore, that the OBOW examination instrument has general applicability in management-type subjects at the graduate level. Experience has shown, however, that some subjects are more naturally amenable to OBOW examinations than others. Devising OBOW examinations for qualitative subjects has, on the whole, been an exercise that most professors have adapted to quite easily. On the other hand, it has been a greater challenge for professors of quantitative subjects. In part, this can be explained by the fact that professors in this domain have become accustomed to setting examinations in a particular way. An authentic and constructivist pedagogy is not as common in these subjects (Fitzsimmons & Williams 2005), so setting an OBOW examination which requires students to demonstrate how they interpret and apply the results of quantitative analysis to solve an unstructured problem can be a 'counter-cultural' experience; these professors typically being used to setting questions that require students to perform a calculation that leads to a 'right' answer. As such, it has been necessary for U21Global full-time faculty to 'coach' such professors to think differently about how they examine quantitative subjects.

Summary and conclusions

The use of OBOW exams has certainly been adjudged a success at U21Global by staff and students alike. The experience has also caused U21Global to rethink certain aspects of the learning design within the MBA and other programs. Some subjects were developed long before OBOW exams were introduced, and were designed without such an examination instrument being considered. One specific area of course revision following the introduction of OBOW exams has been to revisit the learning objectives associated with each subject. Some of the learning objectives were formulated in a descriptive fashion; e.g. "identify and explain the main concepts in IT planning in large organisations". However, OBOW exams, and authentic assessment more generally, is less concerned with recall (declarative knowledge) and more to do with reasoning (procedural knowledge). In the information age, in an online graduate school of all places, it is appropriate that a lot more energy can now be devoted to what students can accomplish in terms of real-world problem-solving. In an age when information is literally (and metaphorically) at our finger tips, time is better spent making sense of this information rather than trying to memorise it. Thus, many of the descriptive learning objectives have been re-cast prescriptive learning objectives, incorporating higher level cognitive tasks (Bloom 1956); e.g. “develop an IT plan for a large organisation”.

In summary, the authors of this paper believe that the introduction of authentic assessment in the form of OBOW exams has been a positive step from a pedagogical standpoint particularly given the applied business disciplines in the MBA program. Significantly, the OBOW learning design is not something exclusive to online education, and it is clear that campus-based institutions could also implement a similar form of authentic assessment either as formative assessment or, as U21Global has done, in the form of a summative assessment instrument. We would recommend professors introduce one assignment as a formative piece of assessment as a pilot in order to develop a level of comfort with authentic assessment. We do remain concerned about the high proportion of adjunct professors at U21Global who experience difficulties in writing OBOW exam cases, clearly indicating that some form of training or faculty development program is needed particularly to support those who are unfamiliar with authentic assessment.

One of the early reservations when U21Global was deliberating over the introduction of authentic assessment was that it would develop students who could solve problems but not be able to master the ‘basics’ pertaining to a particular domain. So far, there is little evidence to suggest that this is the case at U21Global, particularly as U21Global adopts a pluralist approach to its pedagogy through the use of other assessment instruments such as self-assessment exercises, discussion board assignments and business case analyses. Hence, a broad mix of assessment instruments may be the ideal.

The authors acknowledge that research into the efficacy of the OBOW instrument is still at a relatively formative stage and have noted several avenues for further work. One of these, quite simply, is to gather additional data aimed at answering more specific research questions related to the OBOW examination approach. For example, comparing the feedback on OBOW examinations in qualitative versus quantitative subjects would throw further light on the issue of the transferability of the model. Another interesting question would be to see if there is any correlation between the feedback on OBOW examinations and examination results; i.e. are students more likely to give positive feedback on OBOW examinations if they perform well? Another avenue for research, in conjunction with the first, is to improve the richness of the data collected. To this end, a project is under way to collect qualitative data from both student and faculty focus groups to enable research results to date to be better corroborated. Finally, there is the complex issue of whether OBOW examinations do, in fact, contribute to real-world problem solving skills in the way they have been purposely designed. For this, U21Global is in the process of creating survey instruments for its MBA graduates aimed at establishing whether or not the skills amassed though taking OBOW examinations have proved useful post-graduation.

References

Biggs, J. (1999). *Teaching for Quality Learning at University*, Oxford: Oxford University Press.

Bloom, B. S. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals: Handbook I, Cognitive Domain*, London: Longman Group.

Cole, V. (2006). *Hot Coffee is a lesson for MBA students*, Retrieved June 1, 2007, from http://www.joystiq.com/2006/03/01/hot-coffee-is-a-lesson-for-mba-students/.

Fitzsimmons, J., & Williams, J. B. (2005). Creating authentic learning environments: a strategy for student engagement and deeper learning in introductory statistics. *OLT-2005: Beyond Delivery Conference*, Retrieved June 1, 2007, from https://olt.qut.edu.au/udf/OLT2005/index.cfm?fa=getFile&rNum=2420394.

Hanna, N. R. (2002). Effective use of a range of authentic assessments in a web assisted pharmacology course. *Educational Technology & Society, 5*(3), 123-137.

Herrington, J., & Herrington, A. (1998). Authentic assessment and multimedia: how university students respond to a model of authentic assessment. *Higher Education Research and Development, 17*(3), 305-322.

Herrington, J., & Standen, P. (2000). Moving from an instructivist to a constructivist multimedia learning environment. *Journal of Educational Multimedia and Hypermedia*, *9*(3), 195-205.

Hung, D., Tan, S. C., Cheung, W. S., & Hu, C. (2004). Supporting problem solving with case-stories learning scenario and video-based collaborative learning technology. *Educational Technology & Society, 7*(2), 120-128.

MacKinnon, G. R. (2000). The dilemma of evaluating electronic discussion groups. *Journal of Research on Computing in Education*, *33*(2), 125-131.

Laurillard, D. (2002). *Rethinking University Teaching: A Conversational Framework for the Effective Use of Learning Technologies* (2^{nd} Ed.), London and New York: Routledge.

Mueller, J. (2005). *Authentic Assessment Toolbox*, Retrieved June 2, 2007, from http://jonathan.mueller.faculty.noctrl.edu/toolbox/index.htm.

Savery, J. R., & Duffy, T. (l995). Problem-based learning: an instructional model and its constructivist framework. *Educational Technology*, *35*(5), 31-38.

Svinicki, M. D. (2005). Authentic assessment: testing in reality. *New Directions for Teaching and Learning, 100*, 23-29.

Wiggins, G. (1998). *Educative Assessment: Designing Assessments to Inform and Improve Student Performance*, San Francisco: Jossey-Bass.

Wiggins, G. (1990). The case for authentic assessment. *Practical Assessment, Research & Evaluation*, *2*(2), Retrieved June 2, 2007, from http://pareonline.net/getvn.asp?v=2&n=2.

Williams, J. B. (2002). The plagiarism problem: are students entirely to blame? *Proceedings of the 19^{th} ASCILITE Conference*, 721-30, Retrieved June 2, 2007, from http://www.ascilite.org.au/conferences/auckland02/proceedings/papers/189.pdf.

Williams, J. B. (2004). Creating authentic assessments: a method for the authoring of open book open web examinations. *Proceedings of the 21^{st} ASCILITE Conference,* 934-937, Retrieved June 2, 2007, from http://www.ascilite.org.au/conferences/perth04/procs/williams.html.

Williams, J. B. (2006). The place of the closed book, invigilated final examination in a knowledge economy. *Educational Media International*, *43*(2), 107–119.

Appendix

MBA 770 IT Systems for Business
Final Examination for Sections MBA650-0501-3
August 2005

PLEASE READ THESE INSTRUCTIONS CAREFULLY

This is an open-book, 'open-web', essay-type examination that you can complete at a location of your own choice.

The maximum time period allowed for this exam is 24 hours. Importantly, ***you get to pick which 24-hour period you want to utilise over the weekend***. For our purposes 'the weekend' is defined here as the 75-hour period between 12 noon (Singapore time), Friday 19 August 2005, and 3pm (Singapore time), Monday 22 August 2005.

You must select a 24-hour period that falls *WITHIN* these 75 hours. No exam submissions will be accepted after 3pm (Singapore time), Monday 17 January 2005.

When you have completed this assessment item, upload your work via the **Final Exam** option.

This examination material is purely confidential and remains the property of Universitas 21 Global.

By taking this examination, you acknowledge this and agree not to disclose, publish or disseminate the examination materials or make infringing copies, either in whole or in part.

THE CONTEXT

FARLEY LASERLAB specialises in the design, manufacture and installation of computer-controlled plate processing machines. The machines employ the most advanced cutting and drilling technologies. For almost 20 years now, the name FARLEY LASERLAB has been synonymous with high performance cutting and drilling systems, and the company has developed a well-established reputation for both innovation and reliability.

Image source: http://www.farleylaserlab.com.au/

The competitive advantage of FARLEY LASERLAB specifically lies in its deployment of advanced technologies that provides added-value to clients in a way that competitors find hard to replicate. Clients tend to seek improvements in overall productivity, which is dependent not only on computer-controlled machinery, but also the job scheduling and materials planning systems servicing the client. While many competitors provide a limited selection of these services, FARLEY LASERLAB is the only company in Australia that provides the whole range of services required by most clients in its industry.

With head-quarters in Melbourne, Australia, the company now employs over 400 people. FARLEY LASERLAB has close to 600 installations across Australia, and has an annual turnover close to AUS$50 million. FARLEY LASERLAB's strategic performance has so far been sound. Though it is still a small player in global terms, its market share in Australia is over 70%. The company's sales and profits have been growing steadily in recent years. Sales revenue grew at an average 10% per annum in the last 5 years, and average operating profit after tax was also in a healthy upward trend in the last 3 years.

FARLEY LASERLAB's main customers are in the domestic Australian industry. It also supports a few overseas agents for limited exporting. Though it keeps an eye on the world market, it has acted prudently to avoid over commitment.

Strategic Business Review

At a recent strategic business review meeting between Bernard Ragon, CEO of FARLEY LASERLAB and the senior management team, the key issue of offshore markets were discussed.

Like many companies, FARLEY LASERLAB faces critical issues of how to sustain its growth and survive in an increasingly competitive environment. Though the company is currently well positioned, Australia is almost a saturated market. There is no big room left for further expansion. While maintaining the market leader's position in Australia, CEO Bernard Regan recently announced a strategy to expand more actively in offshore markets.

Bernard Ragon, CEO FARLEY LASERLAB
Image source: http://www.farleylaserlab.com.au/

Though FARLEY LASERLAB has a wide range of products covering most of the market segments in Australia, Bernard and the management have determined to penetrate overseas market with its high end products which demonstrate FARLEY LASERLAB's core competency of technological advancement. It plans to adopt a focus-differentiation strategy to avoid direct competition with other industry giants such as ESAB which has a century of history in cutting machines. The focused area is of high technology components that provide new features no other suppliers can provide.

IT Architecture

To support the new offshore markets strategy, Bernard has asked the Chief Technology Officer (CTO) at FARLEY LASERLAB to move forward with the upgrade of the company's current IT/IS infrastructure and architecture which has been overdue for some time. Technology plays a key role in the industry and the rapidly changing nature of information technology often changes the playing field of competition.

At the present, FARLEY LASERLAB has a number of IT systems servicing various functional departments. Most of the systems were implemented many years ago. Though these systems still meet the basis needs of individual business units in a discrete way, the interfaces between the systems has not only been described as obsolete, but even as dangerously inadequate, jeopardising the strategic mission of the company. To support the new strategic mission of the company, FARLEY LASERLAB will need to set up international offices outside of Australia. The issue of systems integration therefore becomes critical. The company is also keen to explore the use of web technology to help penetrate global markets.

A few years ago, FARLEY LASERLAB developed a web-based remote operations, support, diagnosis and maintenance system (ROSDAM), endeavoring to revolutionize customer service support in manufacturing industries. ROSDAM uses the Internet to capture a wide range of information from the end user's machine installation, and feeds this data back into software, design, and service improvements. It then creates process and service databases, and establishes an expert system to help remote users with problem diagnosis and process improvement. However, the full potential of the system was yet to be realised due to FARLEY LASERLAB's limited global market presence.

Bernard is also concerned that with offshore expansion and the establishment of international offices, better ways are needed for sharing information within the company. For example, the senior engineers in the Australian offices need to impart technical know-how and advice to individuals working in offices outside of Australia. Teams would also need to work together comprising of individuals from different offices. He recently heard an online talk given by Marc Eisenstadt, from the Knowledge Media Institute of the Open University in the UK about how knowledge management and online collaboration tools could facilitate information sharing and wondered if such tools would also be useful at FARLEY LASERLAB as part of their IT/IS strategy.

YOUR TASK

It is in this context that you have been approached by Bernard Regan, CEO of FARLEY LASERLAB, to provide your consultancy services as he is aware that you have recently completed the MBA 770 - IT Systems for Business subject in your U21Globallobal MBA course. Your task is to produce a draft discussion paper on how FARLEY LASERLAB might move forward.

After reflecting upon what you have studied in the IT Systems for Business subject, you have decided, in your paper, to evaluate, critically, the current situation and recommend strategic plan and implementation approaches for IT/IS infrastructure upgrade for FARLEY LASERLAB.

GUIDE TO THE TASK

To help guide your thinking, you have discussed the matter with your classmates and, amongst other things, they suggest that you contemplate the following:

- Critically analyse the business environment and using strategic tools, such as SISP alignment process, to re-align the company's information systems with its business strategy, and identify specific and critical leverage points where FARLEY LASERLAB can use information technology most effectively to enhance its competitive position.
- Identify major implementation risks and, based on your risk assessment, select the kind of organisational changes which maximises the opportunity of success, and list other organisational factors that can potentially affect the implementation success.

IMPORTANT INFORMATION REGARDING THE PREPARATION OF YOUR WORK

1) In completing this task, be sure to draw on the concepts and analytical tools you have learnt about during MBA 650 eBusiness, making direct references to the subject materials (ie, the prescribed text, courseware and other resources). Students who fail to comply with this directive will not receive a passing grade.
2) You must upload a written response of 2,000 words (+/- 10%, excluding references) in 24 hours' time via the 'Final Exam' option on the left hand side of your eClasses page. You are allowed to upload only ONE file. If you need to upload more than one document, use WinZip to zip up your documents as a single file.
3) The piece of writing you submit should be referenced in the normal way, using an internationally recognised referencing system. Students who fail to comply with this directive will not receive a passing grade.
4) This is a broad question that invites a variety of 'equally correct' answers.
5) High marks will be awarded for good, critical analysis, rather than content cut and pasted from websites and other electronic sources.
6) The expectation is that you will not have the time to submit an answer of the quality of a term-time assignment. However, you should try, as much as possible, to submit an answer of similar quality.

END OF PAPER

Wisdom. J. P., White, N., Goldsmith, K., Bielavitz, S., Rees, A., & Davis, C. (2007). Systems Limitations Hamper Integration of Accessible Information Technology in Northwest U.S. K-12 Schools. *Educational Technology & Society*, 10 (3), 222-232.

Systems Limitations Hamper Integration of Accessible Information Technology in Northwest U.S. K-12 Schools

Jennifer P. Wisdom[1], Nathan White[2], Kimberley Goldsmith[3], Sarann Bielavitz[4], Amy Rees[5], Charles Davis[6]

[1]Center for Health and Disability Policy, Oregon Health & Science University, Portland, OR, USA // Tel +1 503.494.2558 // wisdomj@ohsu.edu // Fax: 503.494.4981
[2]Carleton College, Northfield, MN, USA // Tel +1 507.646.7175 // nwhite@acs.carleton.edu
[3]MRC Biostatistics Unit, Institute of Public Health, University Forvie Site, Cambridge, UK // Tel +44 1223 330 389 // kim.goldsmith@mrc-bsu.cam.ac.uk
[4]Center for Health and Disability Policy, Oregon Health & Science University, Portland, OR, USA // Tel +1 503.494.2566 // bielavit@ohsu.edu
[5]Graduate School of Education and Counseling, Lewis & Clark College, Portland, OR, USA // Tel: +1 503.768.6074 // arees@lclark.edu
[6]Center on Community Accessibility, Oregon Health & Science University, Portland, OR, USA // Tel +1 800.949.4232 // davisc@ohsu.edu

ABSTRACT

Although federal U.S. regulations require schools to provide equal access to educational opportunities for all students, many technologies used in K-12 schools present accessibility barriers for students with disabilities. Interviews assessed knowledge of educational department staff, teachers, and parents of children in K-12 schools in the Pacific Northwest U.S. regarding accessible electronic and information technology, barriers to technology access, and the capacity of these school systems to address information technology (IT) accessibility issues. Results indicate staff and parents have some basic knowledge of IT accessibility issues, but significant barriers remain regarding appropriate implementation of accessible IT within Northwest K-12 schools. These schools continue to address information technology accessibility on a case-by-case basis, rather than making systemic improvements to the accessibility of technology for all students. Systemic barriers exist regarding system-wide policies of accessibility, a lack of funds for training and implementation, and lack of communication between educators, administrators, IT staff and parents. Recommendations for improving services are provided.

Keywords

Accessible information technology, Assistive technology, Needs assessment, Disability

Introduction

Accessible information technology helps make equal educational opportunities possible. While information technology has the potential for positively impacting all children in K-12 classrooms, for many students with disabilities the use of information technology is the vital link that enables them to participate fully in learning. Federal regulations require that schools make education accessible, which for many students involves the use of accessible information technology. The underutilization of technology in the classroom to *enhance* learning has been amply demonstrated (e.g., Cuban, 2001; Norris, Sullivan, Poirot & Soloway, 2003); the accessibility of technology in the classroom for students with disabilities has not been well-explored. In this paper, we describe findings from our regional needs assessment of K-12 educators and parents regarding their understanding of requirements related to accessible information technology, concerns related to accessibility for students with disabilities in their schools, and educators' and parents' perspectives on opportunities to improve access to information technology.

Accessible Information Technology and Assistive Technology

Accessible information technology includes computer hardware and software, computer operating systems; web applications; telephones and other forms of telecommunication; video equipment and multimedia products; and other devices used to transmit or manipulate electronic information. One characteristic of accessible information technology is that users can access information in more than one way; software that is compatible with assistive technology devices, multimedia devices that present captioning for audio features and spoken directions for visual prompts, and Websites that can be navigated using keystrokes in addition to a mouse, are all examples of accessible information technology.

Accessible information technology is designed to meet the needs of a diverse user base, with and without disabilities, and differs from "assistive technology," which describes products or devices used by an individual. An assistive technology device is "any item, piece of equipment, or system, whether acquired commercially, modified, or customized, that is commonly used to increase, maintain, or improve functional capabilities of individuals with disabilities" (Assistive Technology Act, 1998). Many assistive technology solutions are inexpensive and easy to implement. A student who has limited manual dexterity may find a trackball easier to use than a mouse. Students with learning disabilities may benefit from computer software that can read content out loud. The provision of appropriate assistive technology is an important component of an accessible information technology environment.

Assistive technology improves the functional capacity of an individual, but its effectiveness can be limited when accessible information technology is not present. Screen reading software, for example, is assistive technology that can read electronic text out loud. On a Website built with accessibility in mind, the screen reader can access text descriptions of visual elements, and the user can choose to use the keyboard or the mouse to navigate. An inaccessible site may require the user to navigate with a mouse, and the navigational links may be images with no text description. The screen reader user, while provided with the necessary assistive technology, is still unable to use the inaccessible Website because he/she needs accurate text descriptions of navigational elements, and the ability to activate links using the keyboard.

Although most schools do provide assistive technology to some students, they are just beginning to address the accessibility of information technology environments system wide. Incorporating accessible information technology into schools is more complex than the provision of assistive technology for individuals, and involves coordination between administrators, school disability services, and information technology personnel. In order to understand schools' information technology environments, we first review regulations that address accessible information technology.

Regulations Addressing Accessible Information Technology

U.S. regulations provide standards that prohibit discrimination against individuals with disabilities, require public schools to furnish appropriate aids and services to assist individuals with disabilities, and establish a structure for schools' determination of appropriate aids. Section 508 of the Rehabilitation Act of 1973 (http://www.section508.gov/index.cfm?FuseAction=Content&ID=12), enforceable only for federal agencies, outlines specific standards for all types of information technology, including Websites, software, hardware, and telecommunications devices. The Americans with Disabilities Act (United States Equal Employment Opportunity Commission, 1990) prohibits state and local government entities from excluding people with disabilities from services or activities that are offered to people without disabilities. It also requires covered entities (including public schools) to furnish appropriate auxiliary aids and services where necessary to ensure effective communication with individuals with disabilities, unless doing so would result in undue burden or a fundamental alteration to the program or service (auxiliary aids can include audiotaped texts, materials in Braille or large print, captioning and other methods of making audio and visual media available to people with disabilities). The ADA has also been interpreted to include the Internet as a "place of public gathering" (United States Department of Justice, 2002), which means it is also covered.

Section 504 of the Rehabilitation Act of 1973 (http://www.ed.gov/policy/rights/reg/ocr/edlite-34cfr104.html) prohibits recipients of federal financial assistance from discriminating against people with disabilities; its coverage includes public K-12 schools. Public K-12 schools are further governed by the Individuals with Disabilities Education Act (http://www.webaim.org/articles/laws/usa/idea.php), which mandates a "free appropriate public education" for all students, regardless of disability status and requires the creation of an Individual Education Plan (IEP) for each student who requires accommodations for his or her disability. Specific assistive technology needs may be written into a student's IEP.

Work outside the U.S. has also promoted accessible information technology. The European Union has adopted anti-discrimination statutes and the EuroAccessibility Consortium (founded in 2003) seeks to develop and promote standards for web accessibility (WebAIM, 2005). The United Kingdom has required organizations with Websites to make them disability-friendly since 1999, and in 2005 the British Standards Institution developed guidelines for good accessibility practice (Adams-Spink, 2005). Canada, Hong Kong, and Japan, among others, have also taken steps to improve their national efforts to promote accessibility (WebAIM, 2005). These efforts, however, focus primarily on web accessibility, and their implications for K-12 services are not clear.

All U.S. states have responded to federal regulations to create accessible information technology environments. Golden & Buck (2003) indicate states have taken a policy approach to institutionalizing accessibility, with 9 states having statutes, 2 with executive orders, and 20 with statewide policies requiring accessibility. Of the remaining states, 13 have statements supporting accessibility and guidelines or best practices, and 6 states have issued web accessibility standards or guidelines without accompanying policy.

Few projects have described the impact of state efforts to promote accessibility on the K-12 learning environment, but Kentucky and New Mexico provide useful examples. The Kentucky General Assembly passed the Kentucky Accessible Information Technology Act in 2000, requiring all state-supported institutions to have accessible information technology (Noble, 2005). The Kentucky Department of Education implemented a network that provided a Website with resources, clear guidelines for what schools need, and technical standards checklists for school district use in improving their services. They report significant increases in the use of accessible information technology, and stress in their findings the importance of considering accessibility as a technology issue, not an issue of special education or disability (Noble, 2005). In New Mexico, a team implemented both top-down (legislation, regulation, and policy) and bottom-up (district demonstration projects) approaches to increase knowledge and implementation of accessible information technology (Peterson, 2005).

The clear intention of federal and state regulations is to ensure that all students have equitable access to education and the opportunity to succeed; planning for accessible information technology helps ensure compliance with federal disability law and helps ensure student access to educational opportunities.

This needs assessment sought to answer the following research questions:

- What do educational staff and parents know about disability law, guidelines for accessible electronic and information technology, and how to access accessible technology in their school system?
- What barriers exist to full and appropriate implementation of technology access?
- What is the capacity of school systems to address IT accessibility issues and how can this capacity be improved?

Methods

The authors created a semi-structured interview that addresses areas of current knowledge, current uses and purposes of information technology at schools, and participant-identified gaps and training needs. The University's Institutional Review Board provided approval to conduct the study. Participants were required to verbally assent to the interview, and were assured their identities would not be discernible in any study reports.

Experienced research staff contacted potential participants in the Pacific Northwest (Alaska, Idaho, Oregon, and Washington) via telephone or email to invite them to participate in the individual phone interviews or in-person focus groups. Initial contacts for administrators, teachers, assistive technology specialists, parents, advocates, and representatives from agencies that provide technical assistance to K-12 schools came from the Northwest Americans with Disabilities Act and Information Technology Center (NW ADA & IT Center) and from school Websites. Sampling proceeded via a snowball method: the authors asked each interviewee about others who would have information, experience, or expertise in accessibility issues and/or equipment purchasing. Additional contacts came from potential participants who were contacted but declined to participate in the interview. We continued interviewing individuals in each state until we were no longer receiving new information. Washington and Oregon educational staff were interviewed in focus group format; all parent-advocates and other state educational staff were interviewed individually in person or over the phone. Individuals who were identified as potential interviewees but did not respond to phone calls were called a minimum of three times to attempt an interview.

Interviewers typed detailed notes during each interview and focus group. Interviews varied in length; most interviews lasted about 20 minutes. Interviews addressed the following topics: (a) accessible information technology; (b) legal requirements for accessible information technology (e.g., Section 508, IDEA); (c) availability of resources for information; (d) understanding of universal design; (e) instances of students' successful use and limitations regarding accessible information technology; (f) school or district capacity to address accessible information technology; (g) what changes respondents suggest to increase awareness and implementation of accessible information technology; and (h) the usefulness of training and what topics would be helpful to increase awareness and implementation of accessible information technology. Copies of the interview guide are available from the first author.

To analyze data, notes from interviews and focus groups were summarized and one document was created for each interview or focus group. Data analysts reviewed all materials and developed themes to address research questions. Results were refined through an iterative process. The research team took several steps to increase methodological rigor: (a) multiple staff participated in data collection and analysis to ensure multiple viewpoints and discussion of perceptions of data and (b) analysts sought consensus on coder agreement to ensure more accurate coding (Boyzatis, 1998).

Results

In this assessment of K-12 schools, 273 telephone calls and emails resulted in individual or focus group interviews with 36 individuals at K-12 schools, advocacy organizations, and technical assistance centers in Alaska, Idaho, Oregon, and Washington. We interviewed educational staff within each state's school system (e.g., state administrators, individual school staff) and contacted state consultants and parent-advocates as well (See Table 1). Input from participants revealed a wide range of knowledge about, and opinions of, accessible information technology in K-12 schools. Recommendations mentioned throughout the report are summarized in Table 2.

Table 1. Description of Respondents by Job Field and State

Job Field*	Alaska	Idaho	Oregon	Washington	Total
State level					
Special education	2				2
Information technology		1	1	1	3
ESD level					
Special education				1	1
District level					
Special education	1		2		3
Information technology		3			3
School level					
Principal	1				1
Teacher			2		2
Special education				1	1
Other					
Parent/Advocate	2	2	2	4	10
Technical assistance consultants	4	1	1	4	10
Total	10	7	8	11	36

*Note: We identify participants by job field only to ensure individuals with unique job titles cannot be identified.

Respondents report knowledge of school-related disability laws regarding accessibility and information technology

The most informed respondents tended to be those affiliated with university-based or non-profit groups acting as accessible IT consultants to the schools. Accordingly, they expressed confidence in their knowledge of laws regulating accessibility and information technology, specifically mentioning IDEA, ADA, Section 508, Section 255 of the Telecommunication Act, and the Rehabilitation Act/Section 504. Many respondents knew generally of legal guidelines and their obligations to students with disabilities—including providing assistive technology when necessary, providing the least-restrictive learning environment, and making school Webpages accessible if government funding is received—but did not know the specifics of the laws. Several respondents said they would turn to other school staff, including special education teachers at the school, district, or Educational Service District (ESD) level if an issue arose; a few respondents had access to attorneys or other experts in disability law who could provide training or answers to specific questions. Generally, staff with less knowledge indicated that they learn about laws when specific issues arise, rather than operating under an ongoing philosophy of accessibility. One respondent said he suspected that most schools were aware of the existence of such guidelines, but lacked the time and motivation to research and implement them.

Table 2. Opportunities to Address Accessible Information Technology

Issue	Recommendations	Implications
Low awareness among teachers of universal design and benefits of accessible information technology	ADA & IT Centers can provide training to teachers about accessible information technology and how to implement it into their classrooms. School psychologists can serve as training resources for teachers.	Teachers who wish to use technology in their classrooms can ensure it uses universal design and is accessible to all students.
Low awareness among parents of how accessible information technology may benefit their children	ADA & IT Centers can provide training to parents about accessible information technology and how to implement it into their classrooms. School psychologists can serve as training resources for parents.	Parents of children with disabilities can coordinate with teachers and school staff to ensure new technology is accessible to all students both in the classroom and at home.
Need for information regarding specific programs and recommendations for purchase	ADA & IT Centers can coordinate with district information technology, disability, and purchasing offices regarding recommendations for accessible technology purchases. School psychologists can serve as liaisons between ADA & IT Centers and schools.	Districts and schools have resources for consultation regarding programs, purchase recommendations, and student needs.
Challenge in keeping up with latest legal requirements	ADA & IT Centers can provide up-to-date information regarding school responsibilities for accessibility.	Districts and schools are aware of legal requirements and can plan accordingly.
Integration of disability, information technology, and purchasing services in educational districts	Districts can consult with ADA & IT Centers to integrate disability, information technology, and purchasing to ensure communication between the three departments about disability-related information technology issues.	Integrated services increase likelihood that accessibility and information technology processes are streamlined.
Limited funding and resources for implementing changes	Counter lack of school funding by securing grant funding for basic infrastructure improvements, with support of and coordination with school psychologists and ADA & IT Centers.	Districts and schools can consider larger-scale change to ensure they are meeting student needs and complying with federal regulations.

More respondents were familiar with the concept of universal design than with Section 508 standards and other guidelines. Nine respondents said that they were very familiar with the concept and recognized its application to Websites as well as for non-technological purposes.

Three respondents said they were only vaguely familiar with the idea of universal design, and another eight were not at all familiar with the concept.

Despite gaps in their knowledge, respondents indicated that they had access to the information they needed about disability laws. They obtained information in a variety of ways, including by attending annual special education conferences or department of education trainings; receiving training from qualified organizations; receiving information from district administrators or consulting attorneys; and looking up information on the Internet. One focus group participant said that disability laws were well covered in pre-service teacher training, but that teachers often do not receive updates following the beginning of their tenure in the district and may therefore be relying on outdated information. Interviewees also were able to identify resources for obtaining accessible equipment and software. Many respondents were either readily aware of resources for obtaining accessible materials or knew of ways to find such resources: they turned to equipment or software lending libraries, or directly to companies that manufacture equipment. They also reported attending conferences on the subject; reading about resources; subscribing to listservs; consulting with organizations and associations that provide information about disabilities or technology (e.g., associations for the blind, the Organization for Education Technology Consortium, Washington's Disabilities, Opportunities, Internetworking, and Technology (DO-IT) Center, the Special Education Technology Center, and the NW ADA & IT Center); or consulting the Internet (e.g., http://www.ClosingTheGap.com, http://www.section508.gov). Other respondents looked to their school systems for guidance, including consulting with information technology staff.

Respondents who were well informed were sometimes less optimistic about the efforts of their colleagues to obtain information about accessible technology. Special education staff and a teacher indicated separately that staff often do not even know enough about accessible technology to know whether they need it. If a teacher or administrator did not already have a working relationship with a resource center, he or she might not know to seek out that help. Some respondents were less aware of how to obtain accessible materials; such responsibility was often perceived to fall outside their scope of work.

Numerous barriers hamper implementation of accessible information technology

When asked about specific instances of K-12 students being unable to access appropriate information technology, many respondents merged the concepts of accessible IT and assistive technology. Respondents recounted many occasions when an inability to access information could have been remedied with an assistive device. Sometimes, a school owned a particular device and limited the amount of time or the setting in which its use was allowed; other times, the need for a device was not recognized at all.

Education system respondents also recognized problems with system-wide accessibility. In some cases, existing technology did not meet the needs of students with disabilities. Examples include: (a) students unable to access Websites because the sites were not properly coded for users with disabilities; (b) struggling readers, who had problems accessing information on computers because of screen layout; and (c) students with sensory disabilities who had trouble accessing educational software and Websites. In some cases, existing technology was underutilized or not used at all; for example, (a) students with disabilities had been given assignments on paper when word processing software or calculators could have been suitable alternatives; (b) students with disabilities had access to computers in a special education classroom, but not when they were in their regular or mainstream classrooms; and (c) technology for a reading intervention program was available at a school, but was not available to a student with a disability who wanted to study from home.

One education system respondent reported that most school districts have technology specialists, but the specialists often do not have experience with access issues and do not know much about policies around accessibility. Another observed that part of the problem was teachers' perceptions of technology. Some teachers reportedly were concerned that other students would be jealous of their classmates' use of computers during class. Another respondent cited teachers' difficulties in modifying curricula to make them accessible, and in obtaining equipment to access computerized curricula. She said that teachers are not always aware of technology options that would benefit their students, and are not always aware that they should have assistive or accessible technology available.

Many educational system respondents were not aware of any specific incidences of students unable to access information because of a disability; or they knew of such cases, but their schools had either successfully acted to resolve the issue, or a solution was in progress.

Parent-advocate respondents also reported specific challenges communicating with schools about technology accessibility. Respondents indicated concern that educators were not trained in ADA issues, and that the educators did not know whom to consult when questions arose. Parent-advocate respondents described teachers and other school staff who were reluctant to learn new software programs, afraid of breaking assistive technology equipment, unable to assist students with equipment, or distrustful of advocacy agencies offering information and training. Parent-advocate respondents reported frustration with wait lists for local disability law advocacy centers and with school districts that were "backed up" with ADA-related litigation. Some parents said they gave up on an expensive litigation process to purchase equipment and software themselves.

School systems have limited capacity to address IT accessibility issues

A primary barrier identified by respondents across states was that of communication and cooperation across levels of school system governance and across disciplines. For example, a respondent indicated that her state updated its technology plan five years ago and implemented policies regarding accessibility, but the policies "haven't trickled down to the field yet." There were also barriers regarding the logistics of technology purchasing. Bidding and ordering processes may take months, which can be difficult for a student waiting for accommodations. General software purchasing procedures in some districts required a review of system compatibility but not accessibility; ensuring accessibility was reviewed before purchasing could save districts and staff time and effort. Another concern regarded the funding systems. For example, correspondence courses (which include online instruction) in one state do not qualify to receive special education funding, so money from other programs must fund special education accommodations for those courses.

Communication across disciplines was also a concern. Many individuals described a lack of communication between information technology staff, special education staff, and teachers. One state was described as having a division between "educational technology" and "special education technology." One respondent said special education classrooms end up with "funky technology" because of lack of input from educational technology staff during purchasing. Most teachers interviewed reported challenges determining how to address a student's request for accommodations with information technology, and that it was difficult to communicate with both disability/special education staff and information technology staff. An information technology staff member said accessibility issues are sometimes not addressed because teachers feel overloaded with their responsibilities and lack the time and personnel support to give the issues proper attention. She said, "If a student needs something for a disability, it is unique and requires brainstorming and planning [to integrate that into a classroom]…it takes time and people."

Rural schooling environments also provided a unique challenge. In Alaska, for example, there is great variability among districts' ability to address accessibility issues. Some rural respondents noted a problem with staff turnover. Rural, remote schools often have less plentiful resources than do urban ones; however, rural schools, including some only accessible by plane or boat, may be more technologically accessible because technology is generally necessary to interact with the rest of the state and world.

Finally, many educational systems staff indicated that due to a gap between what the schools should provide, and available time and funding, accessible information technology is often provided on an as-needed basis rather than on a programmatic basis. Respondents reported they knew some schools were not complying with disability laws because they did not have the money to do so. One consultant reported that schools in his state tend to have antiquated technology that did not support Internet access, and some schools were reportedly still using Apple II computers. Other schools have had to manage two different operating platforms—PCs and Macs—with technology support for only one. One district was sharing a T1 line among all its schools, compromising students' access to the Internet. They noted a lack of funds for training, even for programs identified as priorities, such as special education.

Training on accessible information technology strongly supported

Respondents indicated that education and training could empower teachers to control how technology is used in their classrooms. Several respondents said that in some districts network technology, not teachers, dictates curricula. Better-informed teachers could have more input into the selection of accessible equipment and software. Teachers must also know how to communicate with network technicians who may want to limit software choices to better manage a district's network.

Teachers and staff who are not already "tech savvy" may need basic technical training; one respondent noted that teachers are at different levels of readiness to add technology to their teaching plan. Using technology sometimes requires more time and a different way of teaching, which may push many outside of their "comfort zone."

Systems reorganization and information sharing key to effort

When asked for suggestions to improve schools' provision of accessible information technology for students with disabilities, respondents most commonly responded with system-level suggestions. Some respondents suggested continual attention to and improvement of existing policies and procedures regarding accessible information technology. Respondents suggested addressing state standards for IEPs to ensure accessible information technology is addressed in a meaningful way during the assessment process, or lobbying for improvements to, and enforcement of, state policies on information technology. One respondent noted that schools will soon need to address principles of accessible technology regarding wireless networks, handheld devices, and other new technologies, and expressed concerns about educational systems' ability to anticipate new technology and respond in a timely manner. Other organizational suggestions included addressing purchasing processes to decrease the amount of time it takes to obtain accessible technology, and improving procedures for assessing compatibility of accessible IT with existing standard technology.

Respondents were also interested in sharing information among schools and between schools and parents, especially information regarding successful methods of making information technology accessible. Respondents wanted information from technical assistance centers, specifically requesting a list of available resources including regional and state-specific resources for teachers, administrators, and purchasers to call with questions. Some parents were frustrated with a lack of basic information from their children's schools. One parent-advocate said that she was not getting any information from her child's school and that she had to put her child's needs on their agenda. Other respondents wanted to see joint meetings of technology staff and teachers to discuss curricula and how accessible technology can support learning objectives.

Barriers to change may limit efforts

Many respondents cited lack of funding as a barrier to addressing accessibility issues. One respondent was adamant that schools in his state do not have the funding they need for teacher training or alternative programs. Another respondent expressed frustration that choosing to spend money on technology could result in larger class sizes. And, although it was usually possible for schools to get the technology to address the needs of individual students with disabilities, the quality of access for entire schools could still be substandard. One respondent noted that limited funds can make schools inflexible in their choices—taking a one-size-fits-all approach to software, regardless of disability, or buying software that does not interface correctly with existing platforms.

Not all respondents saw a need for change. One respondent said that he would not want to "spend much time, energy, and resources to address something that is not broken." Another response was that when an issue arises for an individual student, then an Individual Education Plan (IEP) is the correct way to address the problem, rather than revising the whole system. A few respondents felt that their districts were already well-connected and networked.

Incentives to change may support efforts

Money was commonly cited as a motivator for school districts to adopt a more accessibility-focused perspective. With so many schools experiencing budget cuts, administrators are often unable to send teachers to trainings unless expenses are paid by another source. One respondent worked for an organization that had received funding from the National Science Foundation. They in turn distributed mini-grants of $4,000 to schools for them to buy equipment and software that help create a "more inclusive environment in areas of science and math, and engineering." Such a program provides equipment that schools may find difficult to provide otherwise. Another respondent suggested school administrators may be persuaded to improve and enforce existing policies if technical assistance centers emphasize the business case that providing accessible information technology may reduce costs of individual aid services for students; implementing technology that observes the principles of universal design could also prevent costly changes later.

Legal pressure and the need to meet federal standards, such as the No Child Left Behind Act, were also cited as motivators. One respondent pointed out that providing better learning opportunities to all students would lead to making progress toward meeting assessment standards. An accessible technology specialist believed legal pressure would be the most effective motivator. He said, "It comes down to lawsuits, unfortunately. If a district is facing a lawsuit, they act quickly." Another respondent's point of view was that the whole issue needs to be approached as a "problem solving exercise" rather than with any punitive measures, acknowledging the challenges of the state, and the fact that the problem is systemic and will take a long time to resolve.

Discussion

This study was designed to assess knowledge about federal requirements for accessible IT, barriers to implementation, and school capacity to provide these services. We found general knowledge about requirements to provide service, and variable knowledge about how to implement specific accommodations for students. We also identified a significant lack of system-level organization to address accessible information technology. Current barriers present in schools include difficult communication between teachers, information technology staff, other school staff, and parents and a lack of understanding about how to implement specific accommodations. Systemic barriers include: communication within school systems and across disciplines about accessible information technology; difficulty navigating purchasing and logistical procedures to obtain needed accommodations; unique challenges for rural environments; and a lack of funding.

General awareness of accessible information technology

The commonality among the states was lack of knowledge of the issue of accessible information technology among staff. Although there were many respondents with expertise in disability laws, universal design, and assistive technology, few people had considered the broader view of information technology accessibility, and teachers were cited as having insufficient training and knowledge of information technology to adequately determine appropriate uses of technology for students who would benefit from it. Even in cases where participants were guided to think beyond assistive technology devices, it was difficult to get answers that took into account a whole system of hardware, software, operating systems, and purchasing decisions. This may reflect a disconnect that exists among departments; if special education staff are not in close communication with information technology staff, then special education staff may not realize the technological options available to them, and IT staff may not be aware of the need to consider accessibility in all the choices they make in purchasing and installing programs. These findings are similar to those reported by Noble (2005), who indicated that stakeholders in the Kentucky Accessible Information Technology in Schools Project viewed accessible information technology as a disability issue, rather than a systems information technology issue. In these findings, the best-informed respondents tended to be outside of the school systems, specifically those working for technical assistance or advocacy organizations.

Issues and barriers to improving technology access

The most important barriers to improving technology access we identified are a lack of systemic focus, prioritization, and organization regarding accessible technology in K-12 schools. Respondents throughout the region identified a number of issues related to this lack of system integration. They indicated that limited money and teacher time was a barrier. Budget cuts have reduced money for training and equipment. School administrators may face challenges justifying funds for equipment or software perceived to benefit a very small number of students. Teachers have limited time for training, and they may not see accessible technology as a priority.

The common solution to educational issues or problems is often to increase teacher training. While in theory this appears to be a logical solution, expecting teachers to meet all facets of student educational need is not reasonable.

The greatest change could occur by dealing with the larger cultural and political issues, including addressing the need for accessible information technology for all students. The general public and the legislators who represent them tend to place a focus on numbers of teachers as a benchmark in educational funding while viewing the need for support services as “non-essential.” Legislative lobbying and public education and advocacy for appropriate funding for IT support services is the core of creating larger systems change (Cunningham, Young & Senge, 1999). While lobbying efforts are underway, however, some training can be conducted with the aid of ADA & IT Technical Assistance Centers, organized by the ADA National Technical Assistance Program (http://www.adata.org/).

In addition, at the school level it may be helpful to identify current personnel who can bridge the communication gap between educators and IT services and assist in implementing systems change. Peterson (2005) and Noble (2005) report strong leadership as a key aspect for implementing accessible information technology change. For students with disabilities, school psychologists may be able to fulfill this role. Current training standards for school psychologists include a focus on consultation skills and multidisciplinary collaboration, and they have responsibility for providing services to larger numbers of students than the typical classroom teacher does. School psychologists are knowledgeable about IDEA and Section 504, are involved in initial eligibility determinations for special education, and could flag the need for computer accessibility at that time while providing a systems perspective to administrators and education leaders. While school psychologists frequently have high caseloads and their roles and functions vary from district to district, training school psychologists may provide the most economical and effective way to reach administrators, teachers, and students regarding accessible information technology. It would be especially helpful to identify school psychologists who are particularly interested in technology to take the lead in addressing education regarding accessible technology and consult with information technology staff and administrators to improve system organization.

Limitations of this study

There are several limitations to this study. The authors present information from a sampling of schools and districts in each state collected via a snowball sampling method; they did not randomly sample participants or interview representatives from every school. Further, the scope of the project limited contacts per state. There could be within-state differences that were not directly assessed. The authors believe they have obtained a sample that can provide valuable insights regarding the knowledge of and needs of K-12 schools. The information in this study is entirely self-reported; while self-report is not necessarily the best method to obtain complete and accurate information, for this needs assessment it is an ideal way to determine the breadth and depth of knowledge of interviewees.

Further research

System change will require more information before substantial improvements can be realized. Key to implementing improvements is further justification of a need for them; a cost-benefit analysis and financial evaluation would be useful in determining the extent to which funding is allocated to accessible information technology and the potential improvement among students if these efforts were more widespread. In public educational environments where funds are limited, an evaluation can include how best to balance district limitations with student needs. Individual schools and districts may benefit from conducting their own local needs assessments to determine specific training needs in accessibility and information technology. Additional topics worth researching include accessibility of relatively new technologies, the role of online/distance learning in reaching students with disabilities, and an examination of “model” schools and districts that have made accessible information technology a priority and a reality. Further, differences between urban, suburban, and rural educational environments can be elucidated in an effort to tailor implementation efforts to districts’ needs.

Conclusions

The results of this needs assessment indicate that many stakeholders in the Pacific Northwest K-12 school systems are aware of the need for accessible information technology for their students, and are also aware of significant systemic and organizational shortcomings in being able to implement the desired technology. Current challenges include (a) limited funding, staff time, and emphasis on accessible information technology; (b) limited understanding of legal requirements for accessible information technology and limited expertise in applying requirements for appropriate accommodations; and (c) lack of awareness of a need for a system-wide focus on implementing accommodations, most noticeable in the communication divide between information technology and disability/special education staff. Individual schools also face unique challenges, including locations in rural areas and high staff turnover. The recommendations described in this report give interested parties many directions for helping K-12 schools in their quest to provide the best and most accessible services to their students and community.

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References

Adams-Spink, G. (2005). *New standards for Website access*, Retrieved June 2, 2007, from http://news.bbc.co.uk/go/pr/fr/-/1/hi/technology/4783686.stm.

Assistive Technology Act (1998). *Assistive Technology Act of 1998*, Retrieved June 2, 2007, from http://www.section508.gov/docs/AT1998.html#3.

Boyzatis, R. E. (1998). *Transforming Qualitative Information: Thematic Analysis and Code Development*, Thousand Oaks, CA: Sage.

Cuban, L. (2001). *Oversold and Underused: Computers in the Classroom*, Cambridge, MA: Harvard University Press.

Cunningham, C., Young, G., & Senge, J. (1999). Advocacy for K-12 students with disabilities: How to get everything except a bad rep. *Information Technology and Disabilities, 6*(1), Retrieved June 2, 2007, from http://www.rit.edu/~easi/itd/itdv06n1/article1.htm.

Golden, D. C., & Buck, D. V. (2003). State IT accessibility policy: The landscape of today. *Information Technology and Disabilities, 9*(1), Retrieved June 2, 2007, from http://www.rit.edu/~easi/itd/itdv09n1/golden.htm.

Noble, S. (2005). The Kentucky Accessible Information Technology in Schools project. *Information Technology and Disabilities, 11*(1), Retrieved June 2, 2007, from http://www.rit.edu/~easi/itd/itdv11n1/noble.htm.

Norris, C., Sullivan, T., Poirot, J., & Soloway, E. (2003). No access, no use, no impact: Snapshot surveys of educational technology in K-12. *Journal of Research on Technology in Education, 36*(1), 15-27.

Peterson, K. (2005). Systems change regarding accessible information technology in the K-12 educational environment. *Information Technology and Disabilities, 11*(1), Retrieved June 2, 2007, from http://www.rit.edu/~easi/itd/itdv11n1/peterson.htm.

United States Department of Justice (2002). *A guide to disability rights laws*, Retrieved June 2, 2007, from http://www.ada.gov/cguide.htm.

United States Equal Employment Opportunity Commission (1990). *The Americans with Disabilities Act*, Retrieved June 2, 2007, from http://www.eeoc.gov/ada/adatext.html.

WebAIM (2005). *World Laws*, Retrieved June 2, 2007, from http://www.webaim.org/articles/laws/world/.

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Examining Teachers' CBT Use in the Classroom: A Study in Secondary schools in Taiwan

Yi-Wen Hung and Ying-Shao Hsu
National Taiwan Normal University, Department of Earth Sciences,88 Sec. 4 Ting-Chou Road, Taipei 116, Taiwan // Tel: +886-2-2934-7120 ext 63; Fax: +886-2-2933-3315 // v3256@ms36.hinet.net // yshsu@ntnu.edu.tw

ABSTARCT

The purpose of this study was to analyze the current status of computer-based technology (CBT) use in secondary schools in Taiwan. A questionnaire was developed to investigate teachers' attitudes toward computers and their application of CBT in instruction. We randomly sampled 100 secondary school science teachers and found that in general they did use CBT for accessing the internet and other teaching-related work. The surveyed teachers had a very positive attitude toward computers, yet we found their attitude was significantly correlated with their age and seniority. The older and more senior teachers generally held a less positive attitude toward computers. As for the application of computer-based technology in classroom instruction, most teachers claimed at least a moderate degree of implementation of CBT in the classroom. In gender difference, male teachers in general used more CBT in their instructional strategies than did female teachers. As far as age was concerned, middle-aged and more experienced teachers tended to integrate more CBT into their instruction than younger and novice teachers, even though the latter group held a more positive attitude toward computers. In correlation analysis we discovered that with male but not with female teachers, there was a direct correlation between degree of positive attitude toward computers and degree of application of CBT in classroom instruction.

Keywords

Computer-based technology (CBT), Computer-based instruction, Attitudes toward computers, Secondary school teachers

Introduction

This article starts with a brief review of attitude toward computer and computer-based technology (CBT) application in instruction. We then introduce a self-developed questionnaire investigating the current status of teachers' attitude toward computers and their different kinds of CBT use. The relevant personal variables such as gender, age, teaching seniority and number of "computer hours" per week were further analyzed to generate more data for discussion. Finally, the correlation between teachers' attitude toward computers and their actual application of CBT in their instruction was examined in order to attain greater clarity on this issue.

During the last two decades, the use of CBT has developed rapidly. Ravitz, Wong and Becker (1999) showed that more than 80% of all teachers were using computers at home or in their schools in America. Cuban showed that in 2001, CBT was still generally underused as an instructional tool by teachers at all levels of education in the U.S.A., despite the widespread use of computers outside the classroom in daily life. Meanwhile, in 1996 the Ministry of Education in Taiwan decided there would be at least one computer, and also access to the internet, in every classroom (http://140.111.1.22/tanet/tan-intro/3.html). However, even though there has been since then a significant increase in the number of computers in schools on the island, the extent to which CBT directly affects classroom teaching still remains unknown.

The teacher's role in the integration of CBT into classroom instruction is an important issue. Yet whether teachers use CBT in their classrooms will depend on their attitude toward computers (Mortz and Nash, 1997). Generally speaking, attitude can be regarded as a multidimensional construct which includes cognition, affection and conation (Hewstone, Stroebe, & Stephenson, 1996). Moreover, affection is considered to be the core element of attitude. In fact, when we set out to evaluate a person's attitude toward X we must first consider how this person would evaluate his/her own attitude toward X—in terms of subjective feelings like anxiety, confidence and so forth (Ajzen, 1988)—and then secondly consider the degree to which this person consistently acts regarding X in conformity with his/her attitude toward X (Shrigley, 1990). That is, both of these measures must be taken into account if we are to accurate predicting a person's behavior from his/her attitudes.

Thus, while we have reason to believe that teachers' attitude toward computers will be an important factor in their CBT application to classroom instruction (Loyd and Gressard, 1984; Yildirim, 2000), we also know it will not be such a simple matter to precisely measure attitude and its effect on behavior. Indeed, much research has already been done on attitudes toward computers (Beaudion, 1990; Gardner, Discena & Dukes, 1993; Mortz and Nash, 1997; Yildirim, 2000). Some of the most frequently investigated constructs include "computer liking", "computer anxiety," "computer confidence," the sense of "computer usefulness," and "computer enjoyment."

As to other variables regarding attitude toward computers, gender has been the one most often analyzed (Woodrow, 1994). Most studies have pointed out that males have in general a more positive attitude toward computers than do females (Comber et al., 1997; Shashaani, 1997). Besides gender, Lloyd and Gressard (1984) have claimed that age is the most significant determinant of attitude toward computers. Comber et al. (1997) found that younger people tend to have a more positive attitude and thus also more experience (despite their age) in using computers. Therefore, in studies of computer use by school teachers the teacher's seniority, which directly correlates with age, becomes a significant factor. Russell et al. (2003) showed that new teachers had in general a higher level of comfort with technology than the more experienced teachers. Besides gender and age/seniority (though also to a degree correlated with these), personal acceptance of technological innovation is also a predictive factor of attitude toward computers (von Braak, 2001). Although there have been a number of research instruments, most scales have measured attitudes toward computers in the general sense, without differentiating specific computer applications.

There has been, then, a lot of research focusing on teachers' use of CBT during the past two decades. Across these researches, the definition of teachers' application of technology varied widely. According to Russell et al. (2003) teacher technology use may be divided into six categories: delivery, preparation, student use, accommodation, grading, and communication. What happens when applications of technology take place inside the classroom? What are the actual roles of CBT when teachers apply them in the classroom? Sometimes teachers just use CBT to deliver traditional means of instruction. For example, a teacher might use a computer connected to a liquid-crystal display projector to show lecture sheets or pictures. Some teachers even regarded their computers as CD-ROM players. But others regarded the integration of CBT as a mind-tool in teaching, using computers to design educational software, integrate teaching resources on the internet and help students learn by themselves (Salomon, Perkins, and Globerson, 1991; McKenzie et al., 1996; Hakkarainen et al., 2001).

Aims of this study

In order to provide valuable insights into the application of CBT in secondary education, this study employed a questionnaire to find out the current status of secondary school teachers' attitude toward computers and CBT use. We then further identified the detailed states of different groups of teachers regarding their demographic background (gender, age, teaching seniority, school level and hours of computer using). At last, the correlation between teachers' attitude toward computers and their application of CBT in instruction was explored to better understand this vital educational issue. This study will provide information about current trends of computer attitudes and classroom applications by teachers in Taiwan. It can help both administrators and researchers better understand the needs of teachers' professional development for CBT use in classroom.

Method

This study employed a survey method to investigate (1) teachers' attitudes toward computers and (2) the extent of CBT integration in the classroom.

Subjects

The subjects of this study were a randomly selected group of 100 secondary high school teachers who taught earth science, mostly in Taiwan, from August 2002 to July 2003. According to the latest educational statistics, there were at that time nearly 1000 schools in Taiwan, 30% of them junior high schools and 70% senior high schools. We sorted these schools into four areas island-wide and sampled 10% of the schools in each area. This may then be considered as a national sample.

The questionnaires were returned by 77% of the intended teacher population. Unfortunately, 7 teachers answered abnormally whose questionnaires were left over 20% unfinished. We then further divided the responding subjects, of which 66% were junior high school teachers and 34% were senior high school teachers, into groups based on four major factors: gender, age, teaching seniority and hours of computer use per week. There were 43 male and 27 female in the valid sample. As for age, there were 34 teachers (49%, the mode) between the ages of 31 and 40; 17 (24%) between the ages of 21 and 30; 11 (16%) between the ages of 41 and 50; and 8 (11%) between the ages of 51 and 65. Thus 73% of all the teachers were under 40 years of age.

Four groups were also created based on degree of teaching seniority: less than 4 years of service as a teacher, between 4 and 10 years, between 11 and 20 years, and more than 21 years. The corresponding number of teachers for each group were 12 (17%), 24 (34%), 25 (36%) and 9 (13%). Since secondary education in Taiwan has two levels, junior high school and senior high school, there are three years in each level. A secondary teacher was supposed to take three years to get acquainted with whole curriculum in each level. So those who had been teachers for less than 4 years were relatively new to the field and were considered “novices.” Those who had been teachers for 4-10 years were considered intermediate-level teachers; the others had taught for more than 10 years were deemed expert or experienced teachers.

After reviewing domestic literatures and undergoing several discussions, we considered that as for hours of computer use per week there were five groups: less than 3 hours, 3 to 5 hours, 6 to 10 hours, 11 to 20 hours, and over 21 hours. The first two groups are the teachers who averagely used computers less than 1 hour per day, and the last group who used computers over 21 hours per week was averagely more than 3 hours in using computer per day. The corresponding number of teachers was found to be 6 (9%), 17 (24%), 13 (19%), 12 (17%), and 22 (31%). Thus over 30% of all the teachers averaged at least 3 hours of computer use per day; conversely, there were also more than 30% who averaged less than 1 hour per day.

Instrument

For this study we developed a questionnaire, “The Integration of CBT into Instruction Questionnaire.” It was divided into three sections: (1) demographic background and general nature of teachers’ computer use, (2) teachers’ attitude toward computers (3) the extent of integration of CBT into their instruction. The first section was demographic background included information about age, gender, teaching seniority and school level taught. The rest of this section included type of CBT use (purpose and place, e.g. only at home or also at school) and number of “computer hours” per week. And the last two sections consisted of 20 items: each item had a five-point Likert scale with choices ranging from “I fully agree” (5 points) to “I fully disagree” (1 point). Thus, 3 points would imply moderate extent.

As for the items regarding “attitude toward computers,” we emphasized three factors that had been found to be crucial by earlier researchers: liking computers, having confidence in computers, and feeling anxiety about computers. However, Mortz and Nash (1997) found that “computer confidence” and “computer anxiety” had a high negative correlation, so that they might be considered two opposite poles of the same component. Thus we decided that “attitude toward computers” could be analyzed in terms of two factors: “computer liking” and “computer anxiety.” In the rest part of this subscale we also took personal acceptance of technological innovation to be a general and antecedent factor which helped to determine attitude toward computers (Braak, 2001). Thus there were 10 items on the “attitude toward computers” subscale, including 7 which described teachers’ feeling, reception and anxiety about computer use and 3 which described teachers’ acceptance of technology in their daily life.

Section three also included a subscale for application of technology in instruction, designed to examine to what extent teachers used CBT in their instructional practice inside the classroom. We tried to see whether teachers used CBT primarily as a basic instructional tool for doing things like playing videos, demonstrating instructional contents with the word processor and applying instructional software to help students learn. The more advanced instructional uses we set out to investigate were, for instance, use of CBT to craft new curricula and teaching methods. Furthermore, we wanted to see if there might be some teachers who regarded CBT as a mind-tool for creating a student-centered learning environment that could enhance learning (Salomon, Perkins, and Globerson, 1991).

Since there were not enough samples to perform factor analysis on the third section of the questionnaire, this study still used exploratory factor analysis, and principle component analysis with varimax rotation, to clarify the underlying structure of the two primary constructs of these two subscales individually. In the first subscale, subjects' attitudes toward computers were grouped into three factors: "computer affection," "computer anxiety" and "acceptance of technological innovation." They accounted for 67.35% of variance. The second subscale, subjects' application of computer technology to their classroom instruction, was divided into two factors: basic instructional use and advanced instructional use. They accounted for 67.38% of variance. The *eigen* value of these factors from principle component analysis was larger than one. The overall reliability of this questionnaire was given a Cronbach's alpha coefficient of 0.89; in addition, the two subscales were given values of 0.82 and 0.89. Table 1 shows the factor loadings and Cronbach's alpha coefficient for each item in the questionnaire.

Table 1: Questionnaire Items and Rotated Factor Loadings

No	Item and Factors	Factor Loading	Variance Explained	Cronbach's alpha coeff.
	Construct 1: Attitude Toward Computers		0.67	0.82
	Factor 1: Affection for Computers			
1	I enjoy using computers..	0.796		
2	I feel bored and time-wasting when I use a computer.	0.864		
3	I like to surf the internet with my computer.	0.656		
4	I feel confident in using computer.	0.695		
	Factor 2: Computer Anxiety			
5	I feel nervous and uncomfortable when learning a computer software application.	0.858		
6	I feel nervous and uncomfortable when leaning about computer hardware.	0.855		
7	I feel anxious about using computers because I have never taken any computer-related course.	0.663		
	Factor 3: Acceptance of New Information Technology			
8	I consider myself less able to adjust to the newest high-tech (IT) devices than most other people.	0.639		
9	I am curious about the most recent high-tech devices (new home appliances, audio-video entertainment equipment)..	0.719		
10	I try to avoid operating high-tech devices that seem too complicated (like home appliances, audio-video entertainment equipment).	0.631		
	Construct 2: Application of Technology in Instruction		0.67	0.89
	Factor 1: Basic Instructional Use			
11	I have played a film (VCD/DVD) using a computer CD-ROM and a projector in the classroom.	0.802		
12	I have used computer software, such as Microsoft Word and PowerPoint, to demonstrate lesson contents.	0.830		
13	I have adopted educational software, which was bought or downloaded from the internet, to enhance students' leaning.	0.763		
	Factor 2: Advanced Instructional Use			
14	I have collected and evaluated students' works through the internet.	0.721		
15	I have developed and applied instructional software in the classroom.	0.677		
16	I have developed on-line courses for students with computer-based technology.	0.823		
17	I have applied computer-based technology to integrate different discipline lessons.	0.714		
18	I have promoted students' cooperative learning through computer-based technology and the internet.	0.851		
19	I have enhanced students' problem-solving ability by integrating computer-based technology into instruction.	0.803		
20	I have assisted students in their individual learning through computer-based technology.	0.853		

Results

Current status of CBT use

This survey investigated the frequency of different types of teacher computer use in daily life, including the editing of documents, accessing the internet, using E-mail, and other teaching-related jobs. Figure 1 shows that 65 teachers (93%) used computers to access the internet in order to search for information: this is the most common type of computer use. About 60 teachers (87%) reported that they used computers to deal with teaching-related jobs like lesson preparation, grading and so on. Other uses include playing games, chatting, and other forms of relaxation and entertainment.

To further explore teachers' computer use for teaching-related jobs, this survey investigated five different types of instructional use in particular: making spreadsheets of students' grades (Grading); developing instruction-related contents (Preparation); using computers for teaching (Computer-Aided Instruction or CAI), encouraging students to go on the internet in order to seek information (Student Use for Information Searching), and encouraging student use of the internet for collaborative learning (Student Use for Collaborative Learning). We found that 63 teachers used computers for spreadsheet grading. This was a relatively high percentage (90%) because it is now official school policy that teachers should put students' grades on a computer website in most areas of Taiwan. 53 teachers (76%) used computers to develop instruction- related contents, for instance by making a syllabus or handouts with Microsoft Word, using Powerpoint to organize lecture contents, and using graphic software to display data. When teachers integrated CBT in their classroom teaching, they sometimes used CBT for teaching and sometimes tutored their students in employing CBT as self-learning tools. According to teachers' self-report, there were 56 teachers (80%) exhorted their students to access the internet for information-searching, but only 10 % directed their students to conduct collaborative learning on the internet. The results are illustrated in Figure 1.

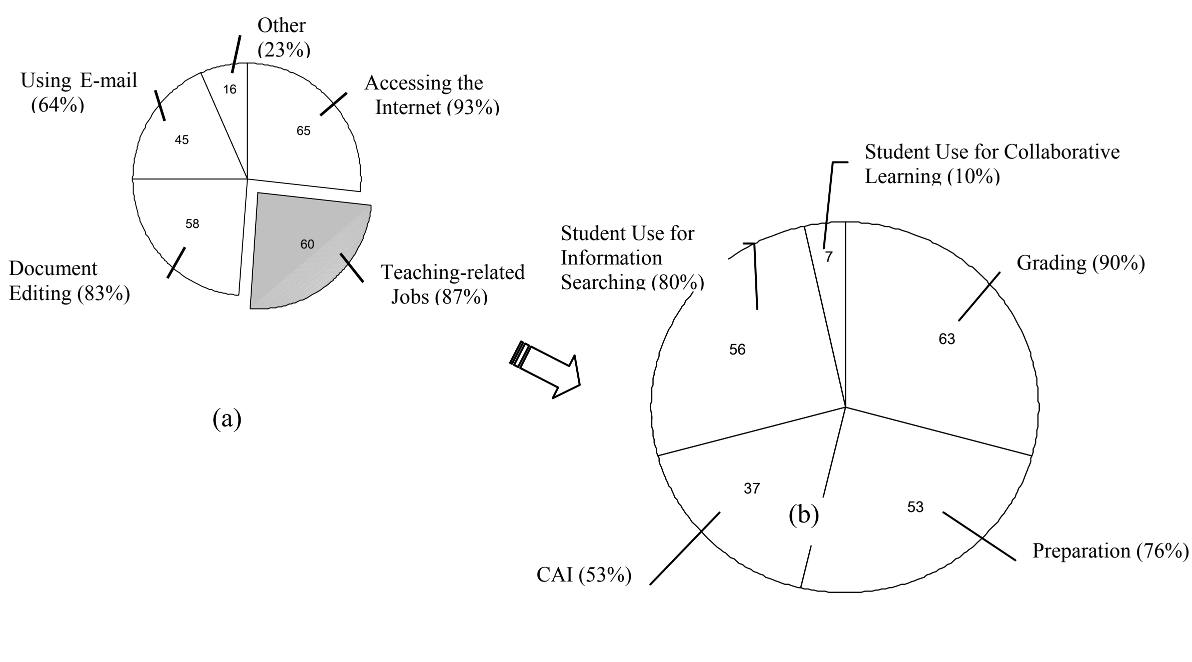


Figure 1: Percentage of (a) Types of Computer Use (b) Types of Teaching-related Jobs

If we consider these various teaching-related jobs, we could divide all of them (except for grading) into two categories, those used to support teaching and those used to support learning. As for teaching, we found most teachers still preferred to develop their own instructional contents rather than use CAI software. Perhaps CAI was considered by some teachers to be inadequate or insufficient for their instructional purposes, and perhaps some were still not familiar with its use; in any case, more data is still needed to provide greater clarity on this issue. As for learning, we found that 80% of the teachers asked students to search for information *via* CBT, but only 10% conducted collaborative learning projects with their students on the internet. The main reason for this might be that teachers regarded CBT as a teaching tool, a supplement to instruction, rather than as a higher-level cognitive tool for the enhancement of students' learning.

Analysis of "Attitude toward Computers"

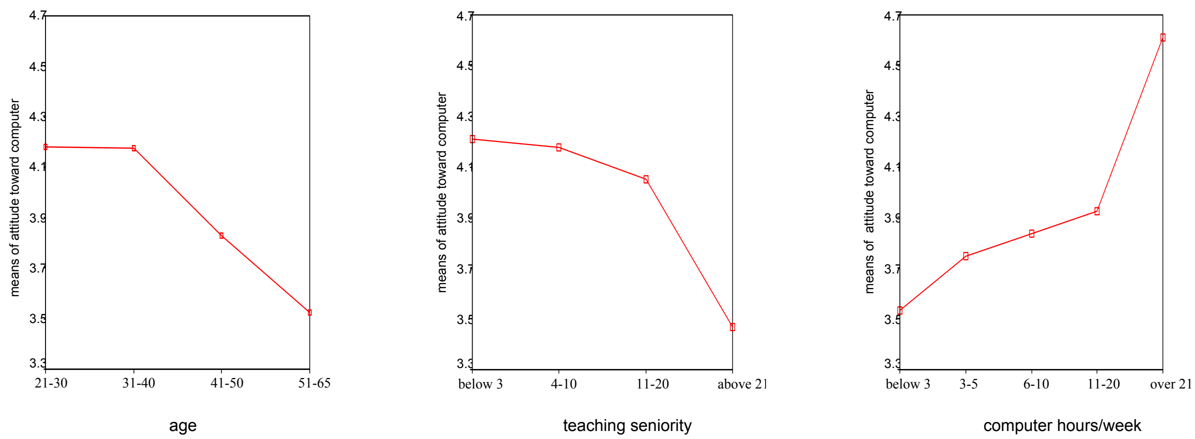
The mean for "attitude toward computers" was 4.04, with a standard deviation of 0.59. This rather high mean indicated that the teachers generally held a positive attitude toward computer use. Furthermore, after the Independent Sample t test was conducted at the significant level α=0.05, we found that gender ($t=1.20,\ p< 0.234$) and school level ($t=0.581,\ p< 0.563$) had no significant effect on "attitude toward computers" scores. But age ($F_{(3,66)}=3.837,\ p< 0.014$) and teaching seniority ($F_{(3,66)}=4.088,\ p< 0.01$) reached the significant level when ANOVA was also conducted at the significant level α=0.05. The Post Hoc showed that teachers above 51 years of age tended to have a less positive attitude than the other two groups, the 21-30 age group and the 31-40 age group. Yet there was no significant difference between the over-50 group and the 41-50 group. As for teaching seniority, teachers who had been teaching for more than 21 years generally held a less positive attitude toward computers than all the other groups. From the ANOVA analysis we also found, as could easily be predicted, a significant correlation between number of hours of computer use per week and attitude toward computers ($F_{(3,66)}=13.297,\ p <0.001$). The Post Hoc showed that teachers using computers more than 21 hours per week had a more positive attitude toward computers than all the other groups.

Table 2: Analyses of Different Variables Related to Attitude toward Computers

Related variable	Number	Mean	SD	t-test / *F* (ANOVA)	Post hoc test
Gender				1.20	
Male	43	4.11	0.67		-
Female	27	3.94	0.43		
School Level				-0.58	
Junior High	46	4.02	0.54		-
Senior High	24	4.10	0.69		
Age				3.837*	
21- 30	17	4.18	.55		
31- 40	34	4.17	.53		21-30 > 51-65
41- 50	11	3.83	.71		31-40 > 51-65
51- 65	8	3.53	.41		
Teaching Seniority				4.088*	
Below 4 years	12	4.21	.63		
4-10 years	24	4.18	.47		All the others>
11-20 years	25	4.05	.63		Above 21 years
Above 21 years	9	3.47	.41		
Hours of Computer Use per Week				13.297**	
Below 3 hours	6	3.53	.53		
3- 5 hours	17	3.75	.50		
6- 10 hours	13	3.84	.41		Over 21 hours>
11- 20 hours	12	3.92	.44		All the others
Over 21 hours	22	4.61	.41		

* $p < 0.05$
** $p < 0.01$

By the same token, we could see a clear tendency for attitude toward computers to become less positive with increasing teachers' age and seniority, as shown in Figure 2(a) and 2(b). Thus the mean for "attitude" decreased sharply when we moved from the 11-20 year seniority group to the above-21 year seniority group and, as could easily be predicted, the oldest and most senior teachers tended to embrace the least positive attitude toward computers. On the other hand and again quite predictably, those teachers who used computers more than 21 hours per week got relatively high scores (around 4.6) on attitude toward computers. Yet while it may seem obvious that the more time someone spends using computers the more positive his/her attitude toward computer use will tend to be (Beckers and Schmidt, 2003), the "direction of causality" here (better attitude promotes more use or more use promotes better attitude, or both?) may not be so certain.



(a) (b) (c)

Figure 2: Means for Attitude toward Computers against (a) Age (b) Teaching Seniority (c) Hours of Computer Use per Week

Analysis of "Application of Technology to Instruction"

There were 11 teachers who had never used CBT in actual practice. After their scores were excluded, we found the mean score for "application of technology in instruction" was 3.13 and the standard deviation was 0.75. This indicated that teachers had a slight tendency to like to implement CBT in their own teaching. The "application of technology in instruction" scores showed different means for males and females: 3.34 for males and 2.86 for females. This suggests a clear gender difference. After the t-test was conducted at the significant level $\alpha=0.05$, we found that gender ($t=2.504$, $p<0.015$) indeed contributed significantly to the "application of technology in instruction" scores. In a survey of information and communication technology (ICT) use in Finland, Hakkarainen et al. (2001) pointed out that male teachers got higher scores than female teachers in ICT use in education for all age groups. Supporting the argument of Hakkarainen et al. (2001), our findings suggested that male teachers applied more CBT in their instructional strategies than females did, though they did not show a significant difference in attitude toward computers. The school level taught ($t=0.05$, $p> 0.963$) also had no significant impact on "application of technology in instruction" scores.

From the analysis of ANOVA also at the significant level $\alpha=0.05$, we also found that, in general, teaching seniority ($F_{(3,55)}=0.991$, $p< 0.404$) and hours of computer use per week ($F_{(3,55)}=1.506$, $p< 0.214$) had no significant impact on "application of technology in instruction" scores. But age ($F_{(3,55)}=3.128$, $p< 0.033$), as predicted, reached the significant level. The Post Hoc showed that teachers in the 31- 40 age group integrated CBT in their classroom teaching significantly more than those in the 41-50 age group. Also as seen in Figure 3(a), and quite interestingly, those between 21 and 30 years of age, most likely because they were still "novices" in teaching, tended to adopt less CBT for instructional purposes than did those in the 31-40 age group. We also found that teachers with a seniority of above-21 years had a distinctively low mean (2.68) for technology use in teaching, as seen in Figure 3 (b). Moreover and quite predictably, mean scores for technology use tended to steadily rise with hours of computer use, as shown in computer hours in Figure 3(c), though the differences are not significant.

Table 3: An Analysis of Different Variables Related to Application of Technology in Instruction

Related Variable	Number	Mean	SD	t-test / *F* (ANOVA)	Post hoc test
Gender				2.504*	
Male	33	3.34	0.83		Male > Female
Female	26	2.86	0.56		
School Level				0.256	
Junior High	41	3.14	0.75		-
Senior High	18	3.09	0.78		
Age				3.128*	
21- 30	13	3.15	.33		
31- 40	31	3.34	.79		31-40 > 41-50
41- 50	10	2.60	.91		
51- 65	5	2.78	.50		
Teaching Seniority				0.991	
Below 4 years	8	3.05	.35		
4- 10 years	21	3.12	.51		-
11- 20 years	24	3.27	.96		
Above 21 years	6	2.68	.89		
Hours of Computer Use per Week				1.506	
Below 3 hours	3	2.57	1.21		
3- 5 hours	12	2.88	.70		
6- 10 hours	12	2.98	.42		-
11- 20 hours	12	3.27	.75		
Over 21 hours	20	3.37	.83		

* $p < 0.05$

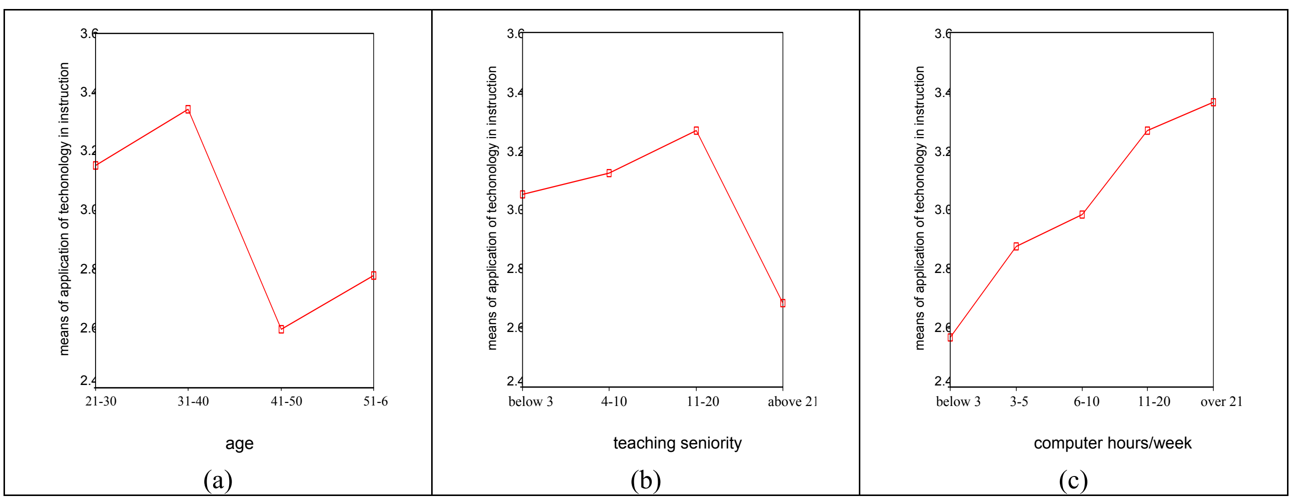


Figure 3: Means for Application of Technology in Instruction against (a) Age, (b) Teaching Seniority, (c) Computer Hours per Week

As might have been predicted, we found that attitude toward computers tended to decrease in positive with teachers' increasing age and teaching experience seniority which was closely correlated with age. This is clear from Figure 2

(a) and Figure 2 (b). However, as is clear from Figure 3 (a) and Figure 3 (b), the situation was different with regard to "application of technology in instruction." Here it appears to be the teachers "in the middle range" of age and experience who scored highest for "application". More specifically, in Table 4 we see that the teachers in the 31-40 age group with 11-20 years of teaching experience owned the highest mean "application" score: 3.58. Moreover, there were 16 teachers, the majority, in this seniority group. And this would cause a higher mean: 3.26 in this group.

Table 4: Crossing Age and Teaching Seniority with the Means for Application of Technology in Instruction

		Teaching Seniority				
		Below 4 Years	4-10 Years	11-20 Years	Above 21 Years	Sum
Age	21-30	3.04 (7)	3.28 (6)	0	0	3.15 (13)
	31-40	3.10 (1)	3.08 (14)	3.58 (16)	0	3.34 (31)
	41-50	0	2.70 (1)	2.58 (6)	2.60 (3)	2.60 (10)
	51-65	0	0	2.80 (2)	2.77 (3)	2.78 (5)
Sum		3.05 (8)	3.12 (21)	3.26 (24)	2.68 (6)	3.12 (59)

Note: number of teachers was in the parentheses

All the above results are summarized in Table 5. We might note that the age of (around) 40 years appeared to be a critical "cut-off point" for both attitude toward computers and application of technology in instruction. This might be because CBT has been used in secondary school teaching in Taiwan for almost 20 years. Thus teachers less than 40 years old would likely have been exposed to this trend at a point much nearer the beginning of their teaching careers, where the new trend would have had a much more formative influence on them, a more profound impact on their whole conception of classroom teaching.

Table 5: Summary of Results

Related Variables	Attitude toward Computers	Application of Technology in Instruction
Gender	-	Male > Female
School level	-	-
Age	21-30 years old >above 50 years old 31-40 years old >above 50 years old	31- 40 years old >41-50 years old
Teaching Seniority	All the others > Above 21 years	-
Hours of Computer Use per Week	Over 21 hrs > all the others	-

Correlation analysis

What was the general relationship between teachers' attitude toward computers and their behavior with regard to CBT use in the classroom? As seen in table 6, the correlation coefficient between "attitude toward computers" and "application of technology in instruction" was 0.47 (p<0.01). Though this correlation coefficient was significant, there was only a medium degree of correlation between teachers' attitude and CBT application. The usual way to approach an understanding of correlation coefficient r is to consider r^2, since the square of the correlation coefficient is the proportion of variance. In this case we found $r = 0.47$, $r^2 = 0.21$, so that 21% of the variance in teachers' application of technology in instruction might be attributed to differences among them with regard to attitude toward computers.

As we examined the correlation between attitude toward computers and application of technology in instruction in the context of the related variables, we came upon several interesting findings. These results are listed in Table 6. First, the correlation coefficient for male teachers, at 0.59, is significant; on the other hand this coefficient is quite low, at 0.006, for female teachers. This indicates that more clearly for males than for females, a more positive attitude toward computers means there will be greater application of technology in instruction. After examining computer use and attitudes among college students, Mitra et al. (2001) found that females held less positive views of computers and used them less often than males, but our point here is that even a positive attitude on the part of females seems to be a less clear determinant of greater classroom computer use than is a positive attitude on the part of males. Secondly, as far as age was concerned, there was a high and significant correlation, $r = 0.725$, between attitude toward computers and application of technology in instruction among 41-50 year old teachers. Yet after cross checking, we found this group of teachers had relatively low scores in both attitude toward computers and application of technology in instruction, therefore the two were highly correlated. When teaching seniority was considered, we also found there was only one group, those with 11-20 years of teaching experience, with a significant correlation- the coefficient was 0.58- between attitude and application. Third, there were no significant correlations when teachers were grouped according to hours of computer use per week. Although there was a high correlation—with a coefficient of 0.805—for those who spent less than 2 hours using computers per week, it was not significant due to the small number of people, only 3, in the group.

Table 6: Pearson Correlation Coefficients for Attitude toward Computers and Application of Technology

Related variable	Attitude toward Computers * Application of Technology	Effect Size
Total	0.470**	0.51
Gender		
Male	0.590**	0.68
Female	0.006	0.00
Age		
21- 30	0.259	0.27
31- 40	0.341	0.36
41- 50	0.725*	0.92
51- 65	-0.610	-0.70
Teaching Seniority		
Below 4 years	0.581	0.68
4-10 years	0.255	0.26
11-20 years	0.581**	0.68
Above 21 years	0.254	0.26
Hours of Computer Use per Week		
Below 3 hours	0.805	1.11
3- 5 hours	0.397	0.42
6- 10 hours	0.362	0.42
11- 20 hours	0.426	0.45
Over 21 hours	0.365	0.42

* $p < 0.05$
** $p < 0.01$

Discussion

Factors influencing CBT use

Successfully integrating CBT into teachers' classroom instructions is influencing by many factors, including environmental factors and personal factors. Environmental factors, or institutional factors, are primarily coming from school context like insufficient number of computers, lack of technical assistance, insufficient peripherals and software, and technological infrastructure (Pelgrum, 2001). The other school contextual factors are administrative leadership and norms from peers.

As to teachers' personal factors, Ravitz et al. (1999) suggested that teachers' attitudes and beliefs regarding technology were of great importance in their decisions to adopt and frequently use technology in the classroom. Hung, Hsu & Tsou (2004) also showed the importance of teachers' attitude toward computers as an important predictor of technology use in instruction. We wanted to explore this as a central construct but we were also interested in the possible impact of such related variables as age and teaching seniority, as well as normal (including non-instructional) amount of time spent per week using computers, on teachers' attitude toward computers and/or toward their classroom application of computer technology.

Though there were documented literatures suggested that teachers' attitude toward computers often was a key factor associated with their CBT uses (Becker, 2000; Hadley & Sheingold, 1993; Sandholtz *et al.*, 1997; Zhao & Frank, 2003). Through this study, we found there was merely a medium degree of correlation between teachers' attitude and CBT application in classroom instruction, that is, the relation between attitude and use is not as straightforward as it seems. Meanwhile, Sugar, Crawley and Fine (2005) indicated both teachers' attitude toward computers and their teaching attitude should altogether put into consideration when examining their CBT application in instruction, for these two kinds of attitude were in dynamic relationship. That is, teachers who increased the applications of CBT in the classrooms tended to also hold more constructivist teaching attitude, and *vice versa* (Ertmer *et al.*, 2001; Rakes *et al.*, 1999). This viewpoint will provide additional insights in future researches.

Teaching seniority and CBT use in instruction

Somehow as we compare Figure 2 with Figure 3 and Table 4, the most obvious explanation of what might seem an anomaly is this: while the youngest teachers may have the most positive attitude toward computers they will nonetheless, because relatively new to the teaching profession and inexperienced in the classroom, be less inclined or indeed less able to apply CBT to their actual teaching than will teachers in the "middle range" of age and teaching experience. More specifically in the present context, many teachers began their teaching careers around 25 years old in Taiwan and became "experienced teachers," with roughly 10 years of experience, in around their mid-thirties. While this group might hold a less positive attitude toward computers than the novices, since after all attitude-toward-technology is largely generation-based or "generational," these teachers in the middle-range of age and experience have a better knowledge (as compared with the novice teachers) of the curriculum they are teaching, of the students in their classrooms, of pedagogical principles and practical classroom management strategies.

We consider it to be a significant finding that the more experienced (but not most experienced) teachers applied more CBT in their teaching, even though they had a less positive attitude toward computers, than the novice teachers. A report by the U.S. National Center for Education Statistics (NCES) (2000) suggests that new teachers, having grown up with computers, should have both high comfort computer level and computer skills to enhance their classroom instructional practices with CBT. Yet we have found that although novice teachers do score high on attitude, they apparently cannot translate their very positive attitude toward computers into higher degree of application of computer technology into their classroom instruction. This supports the argument of Russell et al (2003) that although new teachers reported higher levels of comfort with technology, more experienced teachers reported using technology more often in the classroom.

Implications for enhancing CBT use in instruction

Although the novice teachers, as mentioned above, were generally familiar with working or studying with computers when they were students, they had not been exposed to regular applications of CBT in instruction by their teachers. Thus, when becoming a teacher in the classroom, their teachings mostly based on their prior experiences as students did not comprise the integration of technology. Moreover, their teacher education programs would put more emphasis on how to use CBT rather than on how to teach with CBT and then further add to their comfort with CBT (Russell et al., 2003). Based on the above, one approach to preparing novice teachers actually apply CBT in their classroom instructions is to move away from focusing on teaching CBT and instead focus on teaching with CBT in their teacher-training programs. That is, we must provide the pre-service teachers with all kinds of experiences necessary to prepare them to use CBT in their future teachings beyond what the traditional teaching methods were.

As for those teachers whose teaching seniority were above 21 years, they might had better behavior management techniques toward students, became familiar with the curriculum and adapted to the school culture, yet held less positive toward computers and had less CBT applications in instruction. The way to improve their attitudes and applications is to increase their experiences getting along with computers with the help from school colleagues and administrative. Because they were not familiar and comfortable with using computers so that they might be afraid of using them, needless to say, applying them in classroom instruction. Once they could be accustomed to using computers, they might change their attitudes and try to apply CBT in their teachings.

Conclusion

This study examined the current status of teacher computer-technology use in Taiwan's secondary schools, in their daily life and especially in their teaching-related jobs. We found that most teachers were using computers mainly for accessing the internet, writing documents, sending email and dealing with teaching-related jobs—primarily grading. Although they of course encouraged students to seek information on the internet, most teachers used CBT mainly in connection with their own teaching rather than in connection with their students' learning. That is, they still regarded CBT primarily as a supplemental tool in instruction and in establishing a teacher-centered environment.

As for "attitude toward computers," the findings showed that the teachers had a quite positive attitude. While gender and the school level taught (junior or senior high) had no significant impact here, age and years of teaching experience (seniority) were significant factors. That is, with increasing age and years of experience the attitude toward computers became, in general, increasingly less positive. We also found that, predictably, the more time teachers spent using computers the more positive their attitude toward computers—though there was no way to determine the "direction of causality" here.

As for "application of technology in instruction," the over-all findings suggested a moderate degree of CBT application in the classroom. Gender and age both had a significant impact here. Male teachers tended to integrate more CBT into their instructional strategies than did female teachers, even though, interestingly enough, there was no significant difference in attitude toward computers. Regarding age and seniority there was a very significant finding: the group most inclined to apply CBT to their classroom instruction was the "middle-range" group, middle-aged teachers with a medium level of teaching experience. Although the younger teachers had grown up in a technology-rich environment and had the most positive attitude toward computers, they adopted less CBT in instruction.

There was, significantly, just a medium degree of correlation between teachers' attitude toward computers and their application of technology into classroom instruction. Upon further examination we discovered that the more positive the attitude of male teachers toward computers, the more they would apply CBT in their teaching. As for female teachers, this same correlation was found to be significant only among those in the 41-50 age brackets. With female and novice teachers over-all it became clear that a positive attitude toward computer technology while it might be a necessary one, is not a sufficient cause or determinant of the desire and/or ability to apply CBT to classroom teaching.

As the use of computer-based technology continues to increase rapidly in schools as well as homes, it seems inevitable that CBT will impact not only practical classroom teaching and learning strategies, but even the pedagogical theories which stand behind them, with an ever greater force. No doubt the attitude of teachers toward computer technology, as well as their attitude toward the practice of teaching and the subject(s) they teach, will be an important factor in the degree to which CBT may be increasingly integrated directly into classroom teaching. Efforts to further explore and clarify this complex web of issues will surely be needed.

References

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology, 22*, 453-474.

Beaudoin, M. F. (1990). The instructor's changing role in distance education. *The American Journal of Distance Education, 4*, 21-29.

Becker, H. J. (2000). Findings from the teaching, learning, and computing survey: Is Larry Cuban right? *Educational Policy Analysis Archives, 8*, Retrieved June 7, 2007, from http://www.crito.uci.edu/tlc/findings/ccsso.pdf.

Beckers, J. J., & Schmidt, H. G. (2003). Computer experience and computer anxiety. *Computers in Human Behavior, 19*(6), 785–797.

Comber, C., Colley, A., Hargreaves, D. J., & Dorn, L. (1997). The effects of age, gender and computer experience upon computer attitude. *Educational Research, 39*(2), 123-133.

Cuban, L. (2001). *Oversold and underused: Computers in the classroom*, Cambridge, MA: Harvard University Press.

Ertmer, P. A., Gopalakrishnan, S., & Ross, E. M. (2001). Technology-using teachers: Comparing perceptions of exemplary technology use to best practice. *Journal of Research on Technology in Education, 33*(5), 1-5.

Gardner, D. G., Discenza, R., & Dukes, R. L., (1993). The measurement of computer attitudes: An empirical comparison of available scales. *Journal of Educational Computing Research, 9*(4), 487-507

Hadley, M., & Sheingold, K. (1993). Commonalities and distinctive patterns in teacher's interaction of computers. *American Journal of Education, 101*(3), 261-315.

Hakkarainen, K., Muukonen, H., Lipponen, L., Ilomaki, L., Rahikainen, M., & Lehtinen, E. (2001). Teachers' information and communication technology (ICT) skills and practices of using ICT. *Journal of Technology and Teacher Education, 9*(2), 181-197.

Hewstone, M., Stroebe, W., & Stephenson, G. M. (1996). *Introduction to social psychology: A European perspectives* (2nd Ed.), Oxford: Blackwell Publishers.

Hung, Y. W., Hsu, Y. S., & Tsou, C. H., (2004). Integrating computer-based technology into instruction - A preliminary study in Taiwan. *Paper presented at the Annual Meeting of the National Association for Research in Science Teaching*, April 1-3, 2004, Vancouver, Canada.

Lloyd, B. H., & Gressard, C. (1984). Reliability and factorial validity of computer attitude scales. *Educational and Psychological Measurement, 44*(2), 501-505.

McKenzie, B. K., Mims, N. G., Davidson, T. J., Hurt, J., & Clay, M. N. (1996). The design and development of a distance education training model. *Paper presented in SITE Conference*, Orlando, Florida.

Mitra, A., LaFrance, B., & McCullough, S. (2001) Differences in attitudes between women and men toward computerization. *Journal of Educational Computing Research, 25*(3), 227-244.

Moroz, P. A., & Nash, J. B. (1997). Bath county computer attitude scale: A reliability and validity scale. Retrieved June 2, 2007 from http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED408319.

National Center for Education Statistics (NCES) (2000). *Teachers' tools for the 21st century: A report on teachers' use of technology*, Washington, DC: NCES.

Pelgrum, W. J. (2001). Obstacles to the integration of ICT in education: Result from a worldwide educational assessment. *Computers & Education, 37*(2), 163-178.

Rakes, G. C., Flowers, B. F., Casey, H. B., & Santana, R. (1999). An analysis of instructional technology use and constructivist behaviors in k-12 teachers. *International Journal of Educational Technology, 2*, 18.

Ravitz, J., Wong, Y., & Becker, H. (1999). *Report to participants*, Irvine, CA: Center for Research on Information Technology and Organizations, Retrieved June 7, 2007 from http://www.crito.uci.edu/tlc/findings/special_report/index.htm.

Russell, M., Bebell, D., O'Dwyer, L., & O'Conner, K. (2003) Examining teacher technology use: Implication for preservice and inservice teacher preparation. *Journal of Teacher Education, 54*(4), 297-310.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition: extending human intelligence with intelligent technologies. *Educational Research, 20*(3), 2-9.

Sandholtz, J. H., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology: Creating student-centered classrooms*, New York: Teachers College Press.

Shashaani, L. (1997). Gender differences in computer attitudes and use among college students. *Journal of Educational Computing Research, 16*(1), 37-51.

Shrigley, R. L. (1990) Attitude and behavior are correlates. *Journal of Research in Science Teaching, 27*(2), 97-113.

Sugar, W., Crawley, F., & Fine, B. (2005). Critiquing theory of planned behaviour as a method to assess teachers' technology integration attitudes. *British Journal of Educational Technology, 36*(2), 331-334.

Von Braak, J. (2001). Individual characteristics influencing teachers class use of computers. *Journal of Educational Computing Research, 25*(2), 141-157.

Woodrow, J. J. (1994). The development of computer-related attitudes of secondary students. *Journal of Research on Computing in Education, 11*(4), 307-338.

Yildirim, S. (2000). Effects of an educational computing course on pre-service and in-service teachers: A discussion and analysis of attitude and use. *Journal of Research on Computing in Education, 32*(4), 479-496.

Zhao, Y., & Frank, K. A. (2003). Factors affecting technology uses in schools: An ecological perspective. *American Educational Research Journal, 40*(4), 807-840.

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Distinguishing between games and simulations: A systematic review

Louise Sauvé[1], Lise Renaud[2], David Kaufman[3] and Jean-Simon Marquis[4]
[1]Télé–Université, Québec, Canada // lsauve@teluq.uqam.ca
[2]Université du Québec à Montréal, Canada // renaud.lise@uqam.ca
[3]Simon Fraser University, Burnaby, BC, Canada // Dkaufman@sfu.ca
[4]Télé–Université, Québec, Canada // jsmarquis@savie.qc.ca

ABSTRACT

Based on the hypothesis that inconclusive research results with regard to the impact of games and simulations are linked to the absence of clear concept definitions, research was undertaken to fill this methodological gap by identifying the essential attributes of games and simulations. This paper first introduces the context for our study. This is followed by a description of the analysis grid used to create a database of the literature, and the methodology employed to conduct our systematic review of this literature. The essential attributes of games and simulations are then described and the distinctions between these two concepts are presented.

Keywords

Game, Simulation, Learning, Education

Introduction

The research network entitled *Simulation and Advanced Gaming Environments (SAGE) for Learning* (in French, *ApprentisSAGE par les jeux et les simulations*) is a bilingual Pan-Canadian initiative that studies the effects of games and simulations on improving learning through new media, recent technologies and knowledge of how people learn. Through its ten research projects across Canada, the SAGE project will help to better understand and improve learning, make it more engaging, more motivating, more relevant, more fun and accessible to a greater number of Canadians.

SAGE researchers consider it important to establish a common conceptual framework for the various ongoing projects. Similar to conclusions reached by Sauvé (1985), Crookall (1995), Wolfe et Crookall (1998), Jones (1998), Feinstein, Mann & Corsun (2002), Sauvé & St-Pierre (2003), it is clear that the lack of consensus on the terminology used with regards to games and simulations results in contradictory findings about learning. A study of the fundamental concepts (Sauvé et al, 2005) helped establish the essential attributes of games and simulations. During this study, we relied on many articles that were written without really proposing or validating the exact definition of these concepts. Other authors either opted to treat games and simulations as similar activities or proposed conceptual distinctions between a game and a simulation, which are based more on learning than the actual concepts of games and simulations. By essential attributes, we mean the elements that are indispensable and common to all the activities that we define as a game or simulation. This reasserts the importance and relevance of identifying these essential attributes and this article will focuses on this issue.

We first describe the methodology used in our study of fundamental concepts, followed by a description of critical game and simulation attributes.

Methodology

In our study, we conducted a systematic review of the available literature on the essential attributes of educational games and simulations. To conduct this analysis, we used a triangulation method based on research hypotheses to first create and validate an analysis grid for articles and research reports about the conceptual foundations of educational games and simulations. We consulted many bibliographic databases and the Internet in order to create a corpus for our analysis. We then conducted an audit of bibliographical references to identify the critical attributes and created a knowledge database in which research assistants entered data as they progressed in their literature review. Finally, we synthesized this knowledge database in order to identify the occurrences and establish critical attributes of educational games and simulations. In this section, we will present briefly the first two stages of our methodology.

The design and validation of a textual analysis grid and research reports

Based on an original hypothesis that differentiates the critical attributes of educational games and simulations (Sauvé et Chamberland, 2003), an analysis grid for articles and research reports was developed and validated by the triangulation method which ensured reliability of data coding (Lincoln et Guba, 1985). Then researchers, other than those coding the information, proceeded by counter coding the units and their identifiers for the categories and sub-categories created by the coder. This operation was applied to several articles until a higher than 90% agreement was obtained. More precisely, each time the coding was not identical from one researcher to another, it was discussed in order to understand the points of divergence and to readjust the categories, if necessary. This validation allowed us to establish the relevance of the categories and to refine the interpretation of certain units of meaning to make sure that mutual comprehension was relatively identical.

Once the grid was validated, these units of meaning and their interpretation were transferred, in the form of descriptors, to a relational knowledge database: SAGE-BC, accessible on the Internet. At the date of this article, the knowledge database contained the analysis of more than 450 articles and research reports. SAGE-BC gathers the analysis grids of articles and research reports and can be accessed at: http://www.savie.qc.ca/BaseConnaissances/index.asp?Lang=en.

Consultation of bibliographical databases

To collect articles and research reports, we consulted bibliographical databases by using the following keywords: *game*, *simulation*, *simulation game*, *simulation impact*, *education*, *learning*, *educational game*, *learning game*, *game & experimental*. Articles published between 1998 and today were identified and added to our bibliographic corpus. The compilation of this corpus was developed in two stages.

In 2004, we examined the following bibliographical databases: Eric, Francis, First search education, Ariane These/Mémoire, Tecnedoc, Emile, Current Contents, Repère, MedLine as well as Web sites about games. This first extraction allowed us to identify 1,303 references. From June to December 2005, we examined the following bibliographical databases: Academic search premier, Religion and philosophy collection, Scholar Scholar, Sage Full-text collections, Ingenta, Emerald, Web of Science. This second extraction turned up 481 references that we added to our bibliographical corpus.

In order to analyse the articles and research reports relevant to our research objectives, we established a conceptual framework that helped evaluate the relevance of 1,784 articles identified since 1998. By identifying essential attributes of educational games, simulations and simulation games, we were able to retain 1,063 articles after reading their summaries (abstracts.) Of these 1,063 articles, we found 280 texts to date and rejected 337 articles that did not include activities often identified as an educational game, simulation or simulation game. Many articles and reports focused more on the impact of educational games, simulations or simulation games but they did not define the concepts or identify the critical attributes. In conclusion, the current article is based on the analysis of 98 texts that provided a definition or discussed critical attributes of educational games and simulations.

In this article, we focus more on the critical attributes of educational games and simulations, since not many authors outlined the critical attributes of educational and simulation games. Therefore, in the following sections, we summarize the essential attributes of games and simulations taken from reports of Sauvé et al (2005).

Essential attributes of educational games

Numerous authors have studied games and have provided a description that defines their essential elements. Through our study of these diverse definitions, five attributes have emerged that encapsule the concept of "game' (Sauve et al, 2005): player or players, conflict, rules, predetermined goal of the game, and its artificial nature. Since the focus of this research is on educational games, the pedagogical nature of the game provides a sixth attribute.

The player or players

A player is an individual or players are a group of individuals who are put in a position of assuming a role or of making decisions within a game context. An educational game cannot work without at least one player (Griffiths, 2002) or several players (Gosen et Wabush, 1999). An individual can play against him- or herself (in which case we would speak of a competition against oneself where the purpose is, for instance, to play the perfect match, or to improve on one's score from one match to the next), or one can play with others (which would lend the game a cooperative character) or one can play against others or against the computer (which would lend the game a competitive character). Although the number of players may vary from one to infinity, there is usually either a prescribed number of players or a variable number of players permitted within a given range. Several studies also describe the characteristics of players and teams and the impact of these on learning.

Conflict/ Cooperation

Conflict is represented in games by dynamic, human- or computer-controlled obstacles which prevent a player or players from easily reaching his/her/(or) their goal. Obstacles must be active, even "intelligent", to create conflict and may, minimally, provide the illusion of reacting to player action (Kasvi, on 2000). Conflict also includes the notions of struggle, competition and challenge which motivate the players to maintain their gaming role and make decisions. Struggle is often used as a synonym for conflict and is defined in the same sense. In games such as Chess, Monopoly, and Bridge, a struggle or competition exists between players or teams.

Competition is present as much in single-player games (which require that a player improve his or her performance from match to match) as in team games (which require that one team wins the game). In single player games, conflict takes the form of a confrontation between the player and luck (for example, solitare, crap games, and roulette) or between oneself and another player, who may be a computer using a decision algorithm. Finally, a challenge occurs when player action provokes an opponent's reaction, thus creating a competition or a struggle (Kirriemur et McFarlane, 2004).

Cooperation emerges when players ally themselves against other players in order to reach a common goal. Group tasks are always present and required in team games (Gray et al, 1998) which are governed by rules. In team games, levels of cooperation and competition vary and must therefore be moderated by rules to make sure that all team members master the contents. For example, in the Earth Ball game, players are challenged by certain obstacles or difficulties which can only be overcome by the pooling of player resources.

Rules

Rules comprise another essential attribute of games (Jenkins, 2005). Rules are a set of guidelines, being either simple or complex, which describe the relationships existing between players and the game environment. These guidelines specify the extent and the nature of allowable player action and they establish the sequence and the structure according to which participant actions may take place (Gray et al., 1998). Rules perform three types of functions (Thiagarajan et Stolovitch, 1980). Procedural rules describe the game components, that is, the number of players or the number of teams, the role of each of the participants, their activities and the move or moves that can be made. Game-over rules govern how the game is won and specify the results as well as the contributions expected from each player (Thiagarajan, 1998). Control rules describe the consequences for players who do not follow the previous rules (Martin et al, 1998). For example, a player who makes false accusations is excluded from a detective game.

Brougere (1999) states that rules are either the result of an external regulation which is accepted by players or the result of an agreement or a negotiated settlement between players which the game seeks to promote. In any case, rules must be clear, organized, complete, pre-set and accepted by all players before starting a game. Without such pre-set rules recognized by all players, a game becomes a playful activity where one or several players are free to create their own rules or modify them according to their whims and/or game progress (de Grandmont, 2004). However, in a growing number of electronic games, players are called upon to deduce the rules through play, thus adjusting their decision-making as their understanding of the stakes involved in the game increases.

Predetermined goal of a game

The predetermined goal of a game refers to the end of the game and to the notion of victory, winning or reward (Salopek, 1999; Dickey, 2005). It indicates how the game ends and, for educational games, it includes the objectives which the player(s) seek to attain. It is governed by rules which determine: (1) who wins and, often, who loses, and (2) when and how the game can end. These rules may also specify time limits as well as points accumulation limits leading to success or elimination. The desire to reach this goal affects choices made by players during a match. According to game type, this may involve overcoming an opponent or opponents by competing in skill and craftiness with him/her/or them, or by triumphing over chance or overcoming an obstacle in the aim of winning, of being victorious or of being rewarded.

The artificial character

The artificial character of games refers to two rather different notions according to the authors consulted. For Sauvé and Chamberland (2003), it is a fictitious activity without reference to reality (for example, the Tic Tac Toe game) or that escapes the usual standards which apply to reality. In this sense, Bingo or card games do not refer to reality. It is through immersion in such a fictitious situation that a player can experience a fun, unreal and sometimes even absurd dimension. If the limits of reality were applied, the activity would no longer be a game. Garris et al (2002: 240) refer to this fanciful aspect which they define a constructed environment as “mental, physical or social images which do not exist”. This attribute is not unanimous in the research community. Several authors tend to omit defining game attributes which allows them to include the notion of reality (Crawford, 1984; Eyraud, 1998; Kasvi, 2000). Some would qualify this as something other than a game, that is, a simulation game.

Educational character or its potential for improving learning

An activity is thus a game when it possesses the attributes described previously, as is the case of chess. Regularly playing chess makes us better at it but it does not, for that matter, make chess an "educational" game. De Grandmont states that a game which is not used in an educational or a didactic context is a game for fun. Essentially, the purpose of an *educational* game is only implicitly centred on learning since the purpose is hidden from the player and the notion of pleasure which it engenders is rather extrinsic. In contrast, the purpose of a *didactic* game is clearly focused on the task of learning and that is explicitly identified, appealing to the intrinsic pleasure of performance. In both cases, games have to contribute to learning which we define as a process of new behavior or knowledge acquisition through the influence of interaction with one’s environment. According to the authors consulted, and more recently Whelan (2005), learning by games translates into the acquisition of new knowledge, the transfer of learning, the development of intellectual skills (abstraction, anticipation, strategy-building, problem-solving, lateralization, spatial representation, function-movement relationships), and the development of behavior and attitudes. In order for these types of learning to occur, the games must contain the mechanisms to promote them. These mechanisms, which all educational games should have, include immediate feedback, interaction, active participation by the learner, player control of their learning, repeated practice, challenge, motivation, dialogue between players, and teamwork Barnet et al, 2005; Griffin & Butler, 2005; Schwabe & Göth, 2005; Shreve, 2005; Virvou et al, 2005; Ward & O’Brien, 2005). Giordan (1998) and Merieu (2002) assert that these mechanisms allow for the use of a socioconstructivist pedagogy inherent in games that responds to the needs of the new generation of learners.

The “gamer generation” has a cognitive style characterized by multitasking while learning, short attention span during learning, and an exploratory and discovery approach to learning (Asakawa & Gilbert, 2003; Bain & Newton, 2003; Prensky, 2005). During the game, the learner plays first, understands after, and then generalizes in order to apply this learning in a new situation (Saethang & Kee, 1998; Shaffer et al, 2004). These authors, drawing on a constructivist approach, affirm that the learner becomes active during the game and participates in the construction of his/ her knowledge. Oblinger & Oblinger (2005) suggest that games respond to today’s adolescents, who have a profile as communicators, intuitive and visual. They have strong visual/ spatial aptitudes no doubt developed through their videogame practice. They prefer to learn through experimentation rather than by direct instruction; they move easily and quickly from one setting or activity to another if the first does not interest them. They respond rapidly to questions and demand a rapid response in return. In brief, young learner expect from their learning" interactivity, interaction, active visualization, kinesthesis, and immediacy.

In summary, the literature reviewd helped us define a game, starting from its essential attributes, as a fictional, fantasy or artificial situation in which players, put in a conflict with one another or against other forces, are governed by rules that structure their actions in order to meet learning objectives and a goal determined by the game (for example, winning, being victorious or overcoming an obstacle).

Essential attributes of simulations

In order to identify the essential attributes of simulation, we focused on writers who used simulation to address learning objectives (Sauvé et al, 2005). Four attributes were identified: a model of reality defined as a system; a dynamic model; a simplified model; and a model that has fidelity, accuracy and validity. A fifth attribute can be added to this list: the simulation should address directly the learning objectives.

A model of reality defined as a system.

The model is first defined as an abstract (digital) or concrete (analog) representation of a real system in which the variables are clearly specified and their behaviour around a phenomenon is similar to that of the system being modeled. (Arthur, Malone & Nir, 2002). Reality is generally defined as an individual's perception of a system, event, person, or object. This perception can vary and be interpreted differently across individuals. Milrad (2002) states that a model which supports learning has to feign real situations and provide feedback to participants which will allow for an improved knowledge of reality. Reality can take on several forms but, as for the concept of simulation, it generally reproduces a dynamic system (Arthur et al, 2002). Moreover, Cioffi et al (2005) noted that the simulation offers a miniature version of a sphere of concrete activities in real life. Medley et Horne (2005) findings completely agree with our research when they maintain that simulation is a realistic model that can simulate real-life scenarios. Therefore, educational simulation is similar to real life (Martin, 2003; Swanson & Ornelas, 2001) and offers a type of controlled reality, where learners can experiment with aspects of reality that otherwise would be impossible to study outside of real life.

Dynamic Model

Swanson and Ornelas (2001) explain that a critical factor which differentiates a simulation from other types of models is that simulations copy the essential elements of reality in a dynamic model and allow participants to control this reality in order to study it, according to their own desired pace as well as when it is convenient to do so. By definition, a model is static because its components are not designed to be modified. A simulation becomes a dynamic model when it reproduces, to some extent, the behavior of a real system in real-time through the movement of its components. In other words, there is a manipulation of the model through the combination of individually-selected variables. Any effective simulation places learners in real situations in which they can act and make decisions with the aim of obtaining real-time feedback (Maier & Grobler, 2000; Goldenberg et al., 2005).

Simplified model

A simplified model is defined by the distance between the model of reality which has been produced and reality itself as well as the introduction of a degree of abstraction necessary for understanding the system's functions and inherent tasks (Borges & Baranauskaus, 1998; Cioffi et al, 2005). Garris et al (2002), Medley & Horne (2005), Hung et al (2005) define this simplification by the incomplete representation of reality but which, nonetheless, reproduces its essential characteristics. These essential characteristics are considered as relevant to the designer to reach set objectives for which the simulation has been built, be it educational or not. Designed to arouse interest in learners or to become a teaching object for a specific purpose, a simulation is thus a mockup of reality, certain elements of which having been removed in order to highlight others.

A true, precise and valid model

"Fidelity" is defined as "the degree of similarity between the training situation and the operational situation which is simulated." It is a two dimensional measurement of this similarity in terms of : (1) the physical characteristics, for example visual, spatial, kinesthetic, etc ; and (2) the functional characteristics, for example the informational, stimulus, and response options of training situation". (Hay & Singer, 1989: 50***).*** Garris et al (2002) add to that definition "structural validity", i.e. processes which appear in the simulation, as well as its value in predicting reality given the degree of psychological realism in the simulation. From the point of view of learning, Claudet (1998) states that simulations reproduce situations, dilemmas and actors who participate in them as realistically as possible in order to provide learners with the opportunity to put into practice and to transfer their experience in a "quasi-real" situation.

The notion of validity refers to the degree of uniformity and coherence in the environment specifications in comparaison to reality (Garris et al*,* 2002). Pedgen et al (1995) state that results obtained by simulations have to be the same as those obtained in the real world with the system serving as a model for the simulation. Although simplified, the model must be precise because the essential function of a simulation is to provide users with a better understanding of reality. This is particularly important in the case of an educational simulation. The notion of precision with which the model represents reality is closely connected to an earlier introduced notion, that of the simplification of reality. Indeed, the simpler a model is, the more it runs the risk of distorting the reality under study. In order to choose the characteristics stemming from the reality which are to be included in the model, the simulation designer thereby has to determine which phenomena will be reproduced with precision.

Educational character and its potential in helping understanding of the model-related reality

Research in education (including continuing education) has demonstrated that simulations promote competency development, both basic and complex. For instance, the level of competency required by medical professionals is better acquired in an environment which uses varied examples in a realistic context and which provides educational activities of situations which imitate the real world (Demediatris et al, 1999; Swanson et Ornelas, 2001; Zhu, Zhou & Yin, 2001). Simulations are particularly appropriate in producing such environments because they offer high-level interactivity, strengthen concept and theory acquisistion and place objects or systems within the center of learning (Johnson et al, 1998; Charrière & Magnin, 1998).

Regardless of the type or size of simulation used, Milrad (2002) asserts that the main purpose of simulations remains the offering of an environment: (1) which promotes the development of mental models in learners; (2) which allows for efficiency testing of the models used to explain or to predict events in a system, and (3) which optimalises the discovery of the relationships between variables and the confrontation of divergent approaches. Goldenberg et al (2005) and Hung et al (2005) reached similar conclusions as Milrad (2002) in relation to this last objective (3).

Schnotz et Rasch (2005: 48) consider that the educational character of simulations includes two types of functions that are based on a decrease in the cognitive load: enabling function and facilitating function. Enabling function: "If they reduce the cognitive load of tasks in order to allow cognitive processing that would otherwise be impossible, then animations have an enabling function". Facilitating function: "If they reduce the cognitive load of tasks that could otherwise be solved only with high mental effort, then animations have a facilitating function."

In short, the literature allowed us to reassert that simulation is a simplified, dynamic and precise representation of reality defined as a system.

Conclusion

Our study focused on the conceptual foundations and distinguishing features of games and simulations. Besides establishing this differentiation, we addressed the essential attributes of operational definitions of these two concepts: games and simulations. By essential attributes, we mean the features that are indispensable and common to all activities that quality as a game or a simulation.

Upon examination of their essential attributes, it is clear that games and simulations are distinctive concepts. A game is a fictitious, whimsical or artificial situation in which players are put in a position of conflict. At times, players square off against one another; at other times, they are together and are pitted against other forces. Games are governed by rules which structure their actions in view of an objective or a purpose which is to win, to be victorious or to overcome an obstacle. They are integrated into an educational context when the learning objectives are associated formally to the content and the game enhances learning in the cognitive, affective and/or psychomotor domains.

On the contrary, simulation is a simplified, dynamic and precise representation of reality defined as a system. A simulation is a dynamic and simplified model of reality and it is judged by its realism, by its correspondence to the system which it represents. A game is created without any reference to reality, what is never the case for a simulation or a simulation game. Simulation is not necessarily a conflict, a competition, and the person who uses it is not looking to win, what is the case in a game.

Simulation is defined as a simplified, dynamic and accurate model of reality that is a system used in a learning context. Through its model, judged by its fidelity and its similarity to the reality it represents, a simulation is distinguished from a game that makes absolutely no reference to reality (although a “simulation game” combines these, and this is the subject of another paper). These attributes of a simulation are essential to its use in addressing educational objectives and to allowing learners to study complex and real phenomena, which is not the case with a game.

Simulation does not necessarily involve conflict or competition, and the users are not trying to win, as they are always doing in a game. Many educational simulations, unlike games, can function without human intervention, for example, the dynamic representation a planetary movement in the solar system.

Even if certain simulations identify one or more “winners” or “losers,” this attribute (inherent in games) is not essential to its definition. All educational games, as distinct from other learning activities, add the notion of winner/loser in a competition. For example, imagine a person who responds to questions and receives points. Once the activity ends, there is nothing to indicate that (s)he has won. All games establish rules that allow the determination of a winner and one or more losers. These are the same rules that provide the challenge and competition in the game. If one or more players participate in a simulation and interact with its various components, the notion of a winner and loser s introduced, this activity defines a new concept of “simulation game.” This concept will be discussed in a later paper.

We wish to underscore that the identification of the essential attributes of “game” and “simulation” is important because this avoids the methodological weaknesses of many studies that we examined during our review of the literature on the impacts of games and simulations on learning. The notable weaknesses are: (1) poor theoretical framework; (2) weak and or deficient methodology (e.g., missing operational definitions of the study variables); and (3) a lack of a connection between the theory and application in the research environment (e.g., often the activity being studied is neither a game nor a simulation).

In closing, we offer the following quotation (Feinstein & Cannon, 2002) that provides the motivation for this literature review:

> *“This article rises out of frustration, the frustration from reading a wide variety of papers each using words like simulation, game, role playing, gaming, and symbolic modelling either without definition or inconsistency from one work to another.”*

References

Arthur, D., Malone, S., & Nir, O. (2002). Optimal Overbooking. *The UMAP Journal, 23*(3), 283-300.

Asakawa, T., & Gilbert, N. (2003). Synthesizing Experiences: Lessons To Be Learned from Internet-Mediated Simulation Games. *Simulation & Gaming, 34*(1), 10-22.

Bain, C., & Newton, C. (2003). Art Games: Pre-Service Art Educators Construct Learning Experiences for the Elementary Art Classroom. *Art Education, 56*(5), 33-40.

Barnett, D. J., Everly, G. S. Jr., Parker, C. L., & Links, J. M. (2005). Applying educational gaming to public health workforce emergency preparedness. *American Journal Prevention Medical, 28*(4), 490-495.

Borges, M. A. F., & Baranauskas, M. C. C. (1998). A user-centred approach to the design of an expert system for training. *British Journal of Educational Technology, 29*(1), 25-34.

Brougère, G. (1999). Some Elements Relating to Children's Play and Adult Simulation/Gaming. *Simulation & Gaming, 30*(2), 134-46.

Charrière, P., & Magnin, M. C. (1998). Simulations globales avec Internet: un atout majeur pour les départements de langues. *The French Review, 72*(2), 320-328.

Cioffi, J., Purcal, N., & Arundell, F. (2005). A Pilot Study to Investigate the Effect of a Simulation Strategy on the Clinical Decision Making of Midwifery Students. *Journal of Nursing Education, 44*(3), 131-134.

Claudet, J. G. (1998). Using multimedia case simulations for professional growth of school leaders: Administrator Case Simulation Project. *T.H.E. Journal, 25*(11), 82-86.

Crawford, D. C. (1999). Managing the process of review: playing "Baseball" in class. *Intervention in School and Clinic, 35*(2), 93-95.

Crookall, D. (1995) Simulation/Gaming: A guide to the literature. In D. Crookall & K. Arai (Eds.), *Simulation and gaming across disciplines and cultures: ISAGA at a watershed*, Thousand Oaks, CA: Sage.

De Grandmont, N. (2004). *Pédagogie du jeu…philosophie du ludique...*, Retrieved June 4, 2007, from http://cf.geocities.com/ndegrandmont/index.htm.

Demetriadis, S., Karoulis, A., & Pombortis, A. (1999). "Graphical" jog through: expert based methodology for user interface evaluation, applied in the case of an educational simulation interface. *Computers & Education, 32*(4), 285-299.

Dickey, M. D. (2005). Engaging By Design: How Engagement Strategies in Popular Computer and Video Games Can Inform Instructional Design. *Educational Technology Research and Development, 53*(2), 67-83.

Eyraud, E. (1998). Le jeu dans l'apprentissage d'une langue vivante. Application à l'espagnol. Bulletin APLV – Strasbourg sommaire du n° 60. *Résumé d'un mémoire de maîtrise LCE (Langue et Civilisation Étrangère) d'espagnol*, Université Paris X Nanterre, Retrieved June 4, 2007, from http://averreman.free.fr/aplv/num60-jeu-espagnol.htm.

Feinstein, A. H., Mann, S., & Corsun, D. L. (2002). Charting the Experiential Territory: Clarifying Definitions and Uses of Computer Simulation, Games, and Role Play. *Journal of Management Development, 21*(10), 732-744.

Feinstein, A. H., & Cannon, H. M. (2002). Constructs of Simulation Evaluation. *Simulation & Gaming, 33*(4), 425-440.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, Motivation, and Learning: A Research and Practice Model. *Simulation & Gaming, 33*(4), 441-467.

Giordan, A. (1998). *Apprendre*, Paris: Belin.

Goldenberg, D., Andrusyszyn, M., & Iwasiw, C. (2005). The Effect of Classroom Simulation on Nursing Students' Self-Efficacy Related to Health Teaching. *Journal of Nursing Education, 44*(7), 310-314.

Gosen, J., & Wabush, J. (1999). As Teachers and Researchers, Where Do We Go from Here? *Simulation & Gaming, 30*(3), 292-303.

Gray, A. R., Topping, K. J., & Carcary, W. B. (1998). Individual and group learning of the Highway Code: comparing board game and traditional methods. *Educational Research, 40*(1), 45-53.

Griffin, L .L., & Butler, J. I. (2005). *Teaching Games for Understanding*, Champaign, IL: Human Kinetics.

Griffiths, M. (2002). The educational benefits of videogames. *Education and Health, 20*(3), 47-51.

Hays, R. T., & Singer, M. J. (1989). *Simulation fidelity in training system design: Bridging the gap between reality and training*, New York: Springer.

Hung, D., Chee, T. S., & Hedberg, J. G. (2005). A framework for fostering a community of practice: scaffolding learners through an evolving continuum. *British Journal of Educational Technology, 36*(2), 159-176.

Jenkins, H. (2005). Getting Into the Game. *Educational Leadership, 62*(7), 48-51.

Johnson, L. A., Wohlgemuth, B., Cameron, C. A., Caughman, F., Koertge, T., Barna, J., & Schulz, J. (1998). Dental interactive simulations corporation (DISC): Simulations for Education, continuing Education, and Assessment. *Journal of Dental Education, 62*(11), 919-928.

Jones, K. (1998). What Are We Talking About? *Simulation & Gaming, 29*(3), 314-320.

Kasvi, J. J. (2000). Not Just Fun and Games - Internet Games as a Training Medium. In Kymäläinen, P. & Seppänen, L. (Eds.), *Cosiga - Learning With Computerised Simulation Games*, 23-34, Retrieved June 7, 2007, from http://www.knowledge.hut.fi/people/jkasvi/NJFAG.PDF.

Kirriemur, J., & McFarlane, C. A. (2004). *Literature Review in Games and Learning*, Retrieved June 7, 2007, from http://www.futurelab.org.uk/resources/documents/lit_reviews/Games_Review.pdf.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*, Beverly Hills: Sage.

Maier, F. H., & Grobler, A. (2000). What are we talking about? A taxonomy of computer simulations to support learning. *System Dynamics Review, 16*(2), 135-148.

Martin, A. (2003). Adding value to simulation/games through Internet mediation: The medium and the message. *Simulation & Gaming, 34*(1), 23-38.

Martin, E., Stork, S., & Sanders, S. (1998). Teaching Tips. Creating Games for the Physical Education Learning Center. *Journal of Physical Education, Recreation and Dance, 69*(4), 9-11.

Medley, C. F., & Horne, C. (2005). Using Simulation Technology for Undergraduate Nursing Education. *Journal of Nursing Education, 44*(1), 31-34.

Meirieu, P. (2002). *Apprendre, oui, mais comment*, Paris: ESF.

Milrad, M. (2002). Using Construction Kits, Modeling Tools and System Dynamics Simulations to Support Collaborative Discovery Learning. *Educational Technology and Society, 5*(4), 76-87.

Oblinger, D. G., & Oblinger, J. L. (2005). Educating the Net Generation. *EDUCAUSE report*, Retrieved June 4, 2007, from http://www.educause.edu/educatingthenetgen/.

Pegden, C. D., Shannon, R. E., & Sadowski, R. P. (1995*). Introduction to simulation using SIMAN* (2nd Ed.), Singapore: McGraw-Hill.

Prensky, M. (2005). Adopt and Adapt. 21st-Century Schools Need 21st-Century Technology. *Edutopia*, Retrieved June 7, 2007, from http://www.digitaldivide.net/articles/view.php?ArticleID=786.

Saethang, T., & Kee, C. C. (1998). A gaming strategy for teaching the use of critical cardiovascular drugs. *Journal of Continuing Education in Nursing, 29*(2), 61-65.

Salopek, J. J. (1999). Stop Playing Games. *Training and Development, 53*(2), 28-38.

Sauvé, L., & Chamberland, G. (2003). *Jeux, jeux de simulation et jeux de rôle : une analyse exploratoire et pédagogique,* Cours TEC 1280: Environnement d'apprentissage multimédia sur l'inforoute, Québec, Canada: Télé-université.

Sauvé, L. (1985). *Simulation et transfert d'apprentissage. Une étude sur les niveaux de fidélité pour le transfert d'apprentissage,* Thèse de doctorat, Montréal: Université de Montréal.

Sauvé, L., & Saint-Pierre, C. (2003). *Recension des écrits sur les jeux éducatifs*, Québec, Canada: Télé-université & SAVIE.

Sauvé, L., Renaud, L., Kaufman, D., Samson, D., Bluteau-Doré, V., Dumais, C., Bujold, P., Kaszap, M., & Isabelle, C. (2005). *Revue systématique des écrits (1998-2004) sur les fondements conceptuels du jeu, de la simulation et du jeu de simulation*, Québec, Canada: SAGE & SAVIE.

Schnotz, W., & Rasch, T. (2005). Enabling, Facilitating, and Inhibiting Effects of Animations in Multimedia Learning: Why Reduction of Cognitive Load Can Have Negative Results on Learning. *Educational Technology Research and Development, 53*(3), 47-58.

Schwabe, G., & Göth, C. (2005). Mobile learning with a mobile game: design and motivational effects. *Journal of Computer Assisted learning, 21*, 204-216.

Shaffer, D. W., Squire, K. R., Halverson, R., & Gee, J. P. (2004). *Video games and the future of learning*, Retrieved June 7, 2007, from http://www.academiccolab.org/resources/gappspaper1.pdf.

Shreve, J. (2005). Let the Games Begin. *Edutopia, April/May*, 29-31, Retrieved June 7, 2007, from http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED484796.

Swanson, M. A., & Ornelas, D. (2001). Health Jeopardy: A game to market school health services. *The Journal of School Nursing, 17*(3), 166-169.

Thiagarajan, S., & Stolovitch, H. D. (1980). *Frame Games,* Englewood Cliffs, NJ: Educational Technology.

Thiagarajan, S. (1998). The Myths and Realities of Simulations in Performance Technology. *Educational Technology, 38*(5), 35-40.

Virvou, M., Katsionis, G., & Manos, K. (2005). Combining software games with education: evaluation of its educational effectiveness. *Educational Technology & Society, 8*(2), 54-65.

Ward, A. K., & O`Brien, H. L. (2005). A gaming adventure. *Journal of Nurses Staff Development, 21*(1), 37-41.

Whelan, D. L. (2005). Let the Games Begin! *School Library Journal, 51*(4), 40-43.

Wolfe, J., & Crookall, D. (1998). Developing a Scientific Knowledge of Simulation/Gaming. *Simulation & Gaming, 29*(1), 7-19.

Zhu, H., Zhou, X., & Yin, B. (2001) Visible simulation in medical education: Notes and discussion. *Simulation & Gaming, 32*(3), 362-369.

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Evaluating Collaborative Learning Processes using System-based Measurement

César A. Collazos[1], Luis A. Guerrero[2], José A. Pino[2], Stefano Renzi[3], Jane Klobas[4], Manuel Ortega[5], Miguel A. Redondo[5] and Crescencio Bravo[5]

[1]IDIS Research Group, Department of Systems, FIET, University of Cauca, Colombia // ccollazo@unicauca.edu.co
[2]Department of Computer Science, Universidad de Chile, Chile // luguerre@dcc.uchile.cl // jpino@dcc.uchile.cl
[3]IMQ Institute of Quantitative Methods, Bocconi University, Milano, Italy // stefano.renzi@unibocconi.it
[4]UWA Business School, University of Western Australia, Australia // jane.klobas@uwa.edu.au
[5]Department of Information Technologies and Systems, University of Castilla, Spain // Manuel.Ortega@uclm.es // Miguel.Redondo@uclm.es // Crescencio.Bravo@uclm.es

ABSTRACT

Much of the research on collaborative work focuses on the quality of the group outcome as a measure of success. There is less research on the collaboration process itself, but an understanding of the process should help to improve both the process and the outcomes of collaboration. Understanding and analyzing collaborative learning processes requires a fine-grained analysis of group interaction in the context of learning goals. Taking into account the relationships among tasks, products and collaboration this paper presents a set of measures designed to evaluate the collaborative learning process. We emphasise: direct system-based measures based on data produced by a collaborative learning system during the collaboration process, and suggest that these measures can be enhanced by also considering participants' perceptions of the process.

Keywords

Evaluating collaborative learning processes, CSCL, Collaboration processes, Group interaction

Introduction

Research on collaborative learning was concerned, initially, with the role of the individual in the group, then later with understanding the group itself, comparing the effectiveness of collaborative learning with individual learning (Dillenbourg et al., 1995). A number of independent variables have been identified and widely studied, including group size, group composition, the nature and the objectives of the task, the media and communication channels, the interaction between peers, the reward system and sex differences, among others (Adams et al. 1996; Dillenbourg et al., 1995; Slavin, 1991; Underwood et al., 1990). An alternative approach is to study collaboration *processes* (Barros et al., 1999, Brna et al., 1997). Indeed, it has been argued that understanding the process of collaboration is necessary to understand the value of collaborative learning (Muhlenbrock et al., 1999). The work reported in this paper concerns collaboration processes in computer-supported collaborative learning (CSCL).

Collaboration is "the mutual engagement of participants in a coordinated effort to solve a problem together" (Roschelle et al., 1991). Research on collaboration processes in CSCL is difficult because it is hard to measure collaboration for a number of reasons. These include:

- Collaborative learning technologies must go beyond generic groupware applications, and even the basic technology is not yet well developed (Stahl, 2002a).
- CSCL technology is difficult to assess because it must be used by groups, not individuals (Muhlenbrock , 1998).
- System-based measures of collaborative interactions tend to lose the collaborative content (Stahl, 2002b).
- Effective collaborative learning depends on subtle social factors and pedagogical structuring, not just simple tasks and technologies (Dillenbourg, 1999).

A number of different theoretical and methodological approaches have been taken to deal with these problems. Barros and Verdejo (Barros et al., 1999) analyzed students' online newsgroup conversations and computed values for initiative, creativity, elaboration and conformity. Inaba & Okamoto (Inaba et al., 1997) implemented a system that used a finite state machine to determine the level of coordination taking into account the flow of conversation of the group participants. Muhlenbrock and Hoppe (Muhlenbrock, 1999) developed a framework and system for determining conflicts in focus setting as well as initiative shifts in collaborative sessions on problem solving. Constantino-González et al. (Constantino-González et al., 2001) developed a system which identifies learning opportunities based on studying differences among problem solutions and tracking levels of participation. An ICALTS Project identified indicators of students' interactions at the meta-cognitive level which might enable them to self-regulate or to assess their activity (ICALTS, 2004). Using activity theory as a theoretical framework, Barros et al. (Barros et al., 2001) developed a model to find "representational mechanisms for relating and integrating the collaborative learning elements present in real practical environments". Martínez et al. (Martinez et al., 2002) adopted a situated learning perspective. They defined a model that integrated group context and learning style. Soller & Lesgold (Soller et al., 1999) developed an approach to analyze collaborative learning using hidden Markov models, drawing on ethnomethodology (Garfinkel, 1967) and conversational analysis (Sacks, 1992). Drawing on the ideas in many of these earlier studies, Collazos et al. (Collazos et al., 2007) developed a mechanism which includes activities that provide the opportunity for students to examine a collaborative task from various perspectives so as to make choices and reflect on their learning both individually and socially. Their model is based on tracing all the activities performed during a collaborative activity similar to the affordances of video artifacts, through pauses, stops, and seeks in the video stream. Despite this wealth of studies, there has been a lack of attention to systematic evaluation of the quality of the collaboration process and definition of measures that might apply across different applications.

Several researchers emphasize the quality of the group outcome as a criterion for the success of collaborative learning. Typically, evaluation of collaborative learning has been made by means of examinations or tests to determine *how much students have learned*. That is to say, a quantitative evaluation of the *quality of the outcome* is made. Some techniques of collaborative learning use this strategy (e.g. "Student Team Learning" (Soller et al., 2000), "Group Investigation" (Sharan et al., 1990), "Structural Approach" (Kagan, 1990) and "Learning Together" (Johnson et al., 1975). This approach focuses on the intellectual product of the learning process rather than on the process itself (Linn et al., 1992). However, not all group learning is collaborative. It is common to find people in a group who have divisive conflicts and power struggles; or that a member sits quietly, and does not participate in the discussions; or that one member can do all the work, while the others talk about unrelated subjects; or maybe that a more talented member may come up with all the answers, dictate to the group, or work separately, ignoring other group members. While supporting individual learning requires an understanding of the individual thought process, supporting group learning requires an understanding of the process of collaborative learning (Soller et al., 1999). The designer of a collaborative learning activity needs therefore to design an activity that requires collaboration, i.e., so that the success of one person is bound up with the success of others (Collazos et al., 2001). This relationship is referred to as positive interdependence. Investigators have developed different ways to structure positive interdependence in software tools based on the interface design to ensure that students think "we" instead of "me" (Collazos et al., 2003a).

Because of the very complex interactions that occur in truly collaborative systems, where learning occurs through interaction among group members, understanding and analyzing the collaborative learning process requires analysis of group interaction in the context of learning goals. These goals may include both learning the subject matter ("collaborating to learn") and learning how to effectively manage the interaction ("learning to collaborate") (Soller et al., 2000). It is the second of these aspects of collaborative learning that is perhaps hardest to understand in detail. This is learning that is not merely accomplished interactionally, but is actually *constituted* of the interactions among participants (Suthers, 2005; Stahl, 2006). Therefore, whenever we are going to evaluate a CSCL system, it is not only important to try to evaluate the various mechanisms the software tool provides in order to help people learn through collaborative appplications but to include some elements which allow evaluation of how people are doing a collaborative activity, taking into account their attitude towards collaboration. Following Garfinkel, Koschmann et al., (Koschmann et al., 2005) argue for the study of methods of building meaning: "how participants in [instructional] settings actually go about *doing* learning". In addition to understanding how the cognitive processes of participants are influenced by social interaction, we need to understand how learning events themselves take place during interactions among participants. Thus, we note that additional work is needed to understand the process of collaboration. This knowledge could be applied to develop computational methods for determining how to best support and assist the collaborative learning process (Collazos et al., 2003b). Our paper addresses this challenge.

We begin by breaking down the collaborative learning process into stages. This allows us to identify indicators that can be used to evaluate collaborative learning during that part of the process where students are learning through interaction. It also allows us to focus on what might be the outcomes of learning to collaborate during the process. We then describe some software tools we have developed to analyze interactions, and show how the indicators can been used to evaluate the collaboration process for students using those tools. Finally, we discuss the benefits of the proposed approach, draw conclusions and identify opportunities for further work.

Stages of the collaborative learning process

Our interest is in designed collaborative learning processes, i.e. those processes that are designed by a facilitator in order to provide an environment for collaborative learning, rather than processes in which collaborative learning might occur spontaneously. Such a *collaborative learning process* is typically composed of several tasks that are developed by the cognitive mediator or facilitator and other tasks that are completed by the group of learners.

We divide the collaborative learning process into three phases according to its temporal execution: *pre-process*, *in-process* and *post-process*. *Pre-process* tasks are mainly coordination and strategy definition activities and *post-process* tasks are mainly work evaluation activities. Both the pre-process and post-process phases are typically accomplished entirely by the facilitator. On the other hand, the tasks accomplished during the *in-process* phase will be performed mainly by the learners (group members). This is where the interactions of the collaborative learning process take place. Our main goal is in evaluating this stage.

Drawing on Johnson & Johnson (Adams et al., 1996; Johnson et al., 1995), we can identify the tasks involved in the in-process stage of a collaborative learning process. Tasks completed by the learners are: application of strategies such as positive interdependence toward achievement of the goal, intra-group cooperation, reviewing success criteria for completion of the activity, monitoring, providing help and reporting. There are three facilitator tasks: providing help, intervention in case of problems and providing feedback.

Collaborative learning process indicators

Guerrero et al. (2000) developed an Index of Collaboration, measured as the simple average of scores on indicators that measured the learner tasks identified by Johnson & Johnson (Adams et al., 1996; Johnson et al., 1995). In this paper, we will develop a refinement of that Index of Collaboration. Four indicators will measure the following activities: use of strategies, intra-group cooperation, reviewing success criteria and monitoring. A fifth indicator is based on the performance of the group. All these indicators can be measured directly from data collected by the system as students participate in CSCL activities. In addition to these system-based measures of the collaborative learning process, we propose some additional measures of students' learning to collaborate based on participants' responses to the process.

Before we describe the indicators in detail, it is necessary to describe the collaborative environments from which metrics for estimation of the system-based indicators were gathered. In the next section, we therefore describe some software tools which we have developed to study the in-process stage of the collaborative learning process.

Software tools

We developed software tools to analyze the quality of the collaboration process for small groups working synchronously toward each of the two learning goals identified in the introduction to this paper: learning to collaborate and collaborating to learn. Four tools were used to study learning to collaborate and two tools were used to study collaborating to learn. Each of the tools is described in turn.

Chase the Cheese

For the first tool, we chose a small case in which a group of persons have to do some learning in order to complete a joint task. The task is a game of the labyrinth type.

The game –called *Chase the Cheese*– is played by four persons, each with a computer. The computers are physically distant and the only communication allowed is computer-mediated. All actions taken by the participants are recorded for analysis and players are made aware of that.

Players are given very few details about the game. The majority of the game's rules must be discovered by the participants while playing. They also have to develop joint strategies to succeed. In our studies, each person played the game only once.

Figure 1 shows the game interface. To the left, there are four quadrants. The goal of the game is to move the mouse (1) to its cheese (2). Each quadrant has a *coordinator* –one of the players– permitted to move the mouse with the arrows (4). The other participants –*collaborators*– can help the coordinator by sending messages which are seen at the right-hand side of the screen (10). Each player has two predefined roles: *coordinator* (only one per quadrant and randomly assigned) or *collaborator* (the three remaining players).

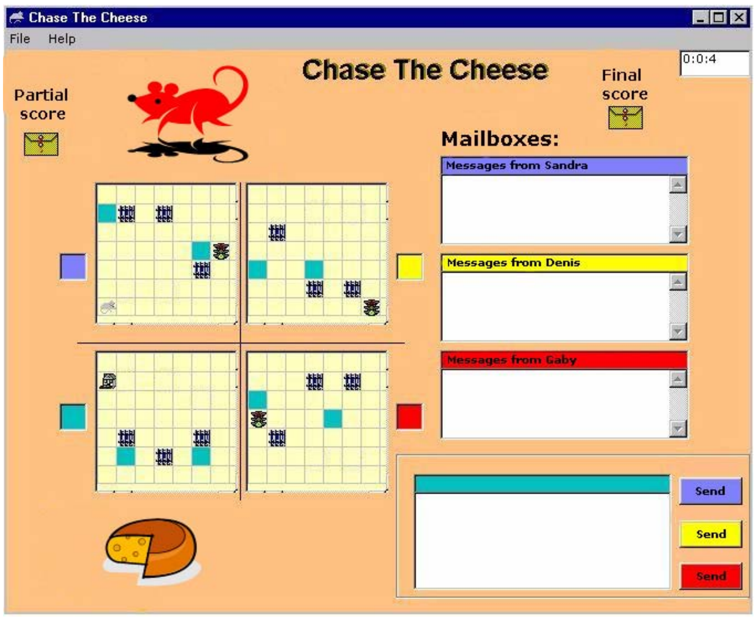

Figure 1. Chase-the-Cheese game interface

The game challenges the coordinator of a quadrant in which the mouse is located because there are *obstacles* to the mouse movements. Most of the obstacles are invisible to the quadrant coordinator, but visible to one of the other players. In each quadrant there are two types of obstacles through which the mouse cannot pass: general obstacles or grids (6) and colored obstacles (7). This is one of the features of the game which must be discovered by the players. The players must develop a shared strategy to communicate an obstacle's location to the coordinator of the current quadrant. No message broadcasting is allowed, so players have to choose one receiver for each message they send (9). Since each participant has a partial view of the labyrinth, they must interact with their peers to solve the problem. In order to communicate with them, each player has a dialogue box (8) from which they can send messages to each of the others explicitly (one at a time) through a set of buttons associated with the color of the destination (9). For example, in Figure 1, a player can send messages to the other players with blue, red and green colors. Since each player is associated with a color, their quadrant shows the corresponding color (5).

When starting to move the mouse, the coordinator has an individual score (11) of 100 points. Whenever the mouse hits an obstacle, this score is decreased by 10 points. The coordinator has to lead the mouse to the cheese (in the case of the last quadrant) or to a traffic light (3), where the mouse passes to another quadrant and the player's role is switched to collaborator while the coordinator's role is assigned to the next player (clockwise). When this event occurs, the individual score is added to the total score of the group (12). Both scores, partial and total, are hidden. If players want to see them, they must pass the mouse over the corresponding icon displaying the score for two seconds. If any of the individual scores reaches a value below or equal to 0, the group loses the game. The ultimate goal of the game is to take the mouse to the cheese and do it with a high total score (the highest score is 400 points).

TeamQuest

TeamQuest is another labyrinth with obstacles, similar to Chase the Cheese but with some refinements (Collazos et al., 2004b). The screen has three well-defined areas: game, communication and information (Figure 2). The game area has four quadrants, each one assigned to a player who has the “doer” role; the other players are collaborators for that quadrant. Each player is identified with a role image and name which appear on the screen. In a quadrant, the doer must move an avatar from the initial position to the “cave” that allows them to enter the next quadrant. On the way, the doer must circumvent all obstacles and traps in the map (which are not visible to all players). In addition, the doer must pick an item useful to reach the final destination.

In TeamQuest, the user interface has many elements showing awareness: the doer’s icon, score bars, items which were picked up in each quadrant, etc. The need to collect objects on the way means the players of a team must reach a goal by satisfying sub goals in each of the game’s stages. In order to reach the final goal it is necessary to pass through every quadrant avoiding all the obstacles, i.e., if a person is not able to pass his/her quadrant, then it will be impossible to continue and thus the whole group will not reach the goal.

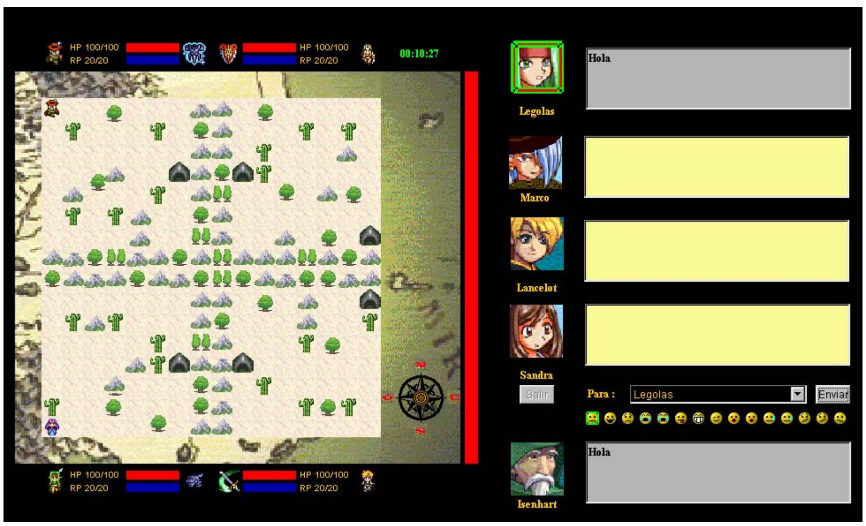

Figure 2. Team Quest User interface (in Spanish)

MemoNet

This game is loosely based on the classic “Memorize Game”, where the goal is to find an equal pair from several covered cards. This is repeated successively until there are no covered cards remaining. In the case of MemoNet, the idea is that four people try to find four equal cards from an initial set of ten different cards. The user interface is shown in Figure 3.

All players have the same set of cards but ordered in different ways. A person draws one card each time so they need to collaborate in order to solve the problem. A card is removed when all four players have found it. The game continues until all cards are uncovered and removed. The game is played in a distributed fashion, with communication allowed through a chat tool (Collazos et al., 2004a).

ColorWay

A fourth game designed to study learning to collaborate is *ColorWay*. This game has a 6 x 4 board of colored squares with obstacles (Figure 4). Players can see their own obstacles (with their own color). Each player has a token with his or her color, and this token can progress from the lower row to a target located on the upper row. The player can move the token using the arrows and back buttons only through gray squares which are not currently occupied by another token. Other tokens further restrict movement: no token can go to row n if there is a token in row n-2. In a similar way to MemoNet, this game allows communication through chat. The problem is that there is only one way to arrange the tokens, therefore the players need to communicate in order to win the game (Collazos et al., 2004a).

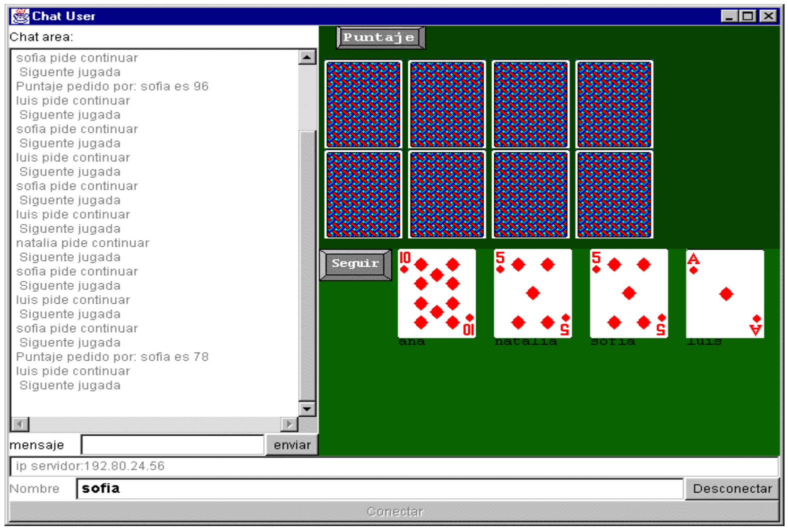

Figure 3. MemoNet user interface (in Spanish)

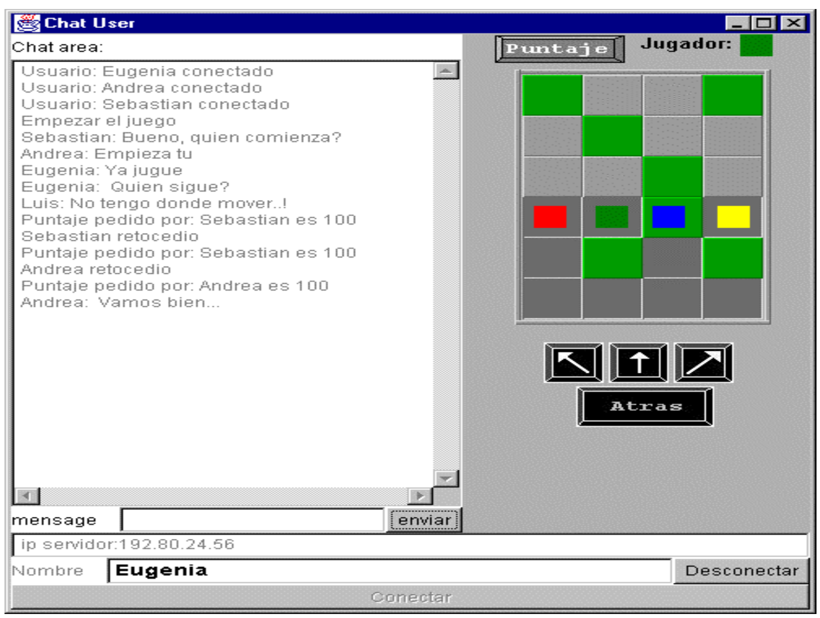

Figure 4. ColorWay user interface (in Spanish)

CCCuento

CCCuento helps a group to collaboratively write stories. Four participants work on four stories at the same time. Each story has four phases: introduction, body A, body B and conclusion. Each member must write a different section of every story. In a first stage every participant writes the introduction to one of the stories. In the second stage, every participant writes the first part of the development of a different story (body A) (Guerrero et al., 2003).

Then, they continue working until they finish all the stories. The group members may edit the parts they were responsible for at any time during the project (Figure 5).

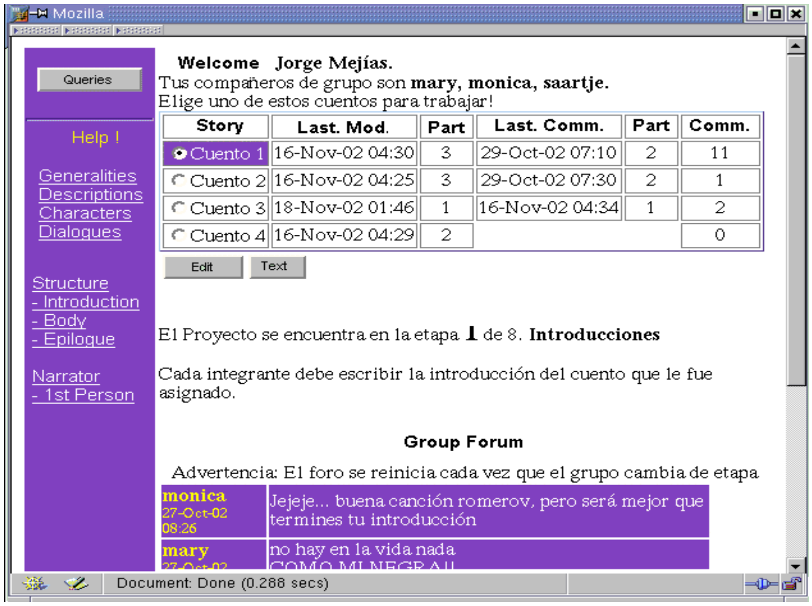

Figure 5. CCCuento user interface (in Spanish)

DomoSim-TPC

DomoSim-TPC supports collaborative learning of domotical design (also known as house automation or intelligent building design) by students working at a distance (Redondo et al., 2006a; Bravo et al., 2006a). Domotical design aims at designing a set of elements that, installed, interconnected and automatically controlled at home, release the user from the routine of intervening in everyday actions. The aim is to provide optimized control over comfort, energy consumption, security and communications.) DomoSim-TPC supports a collaborative PBL (problem based learning) approach (Koschmann et al., 1996). Students are given a domotical design problem which they must solve by working collaboratively. Each student works at their own computer at a distance from the others.

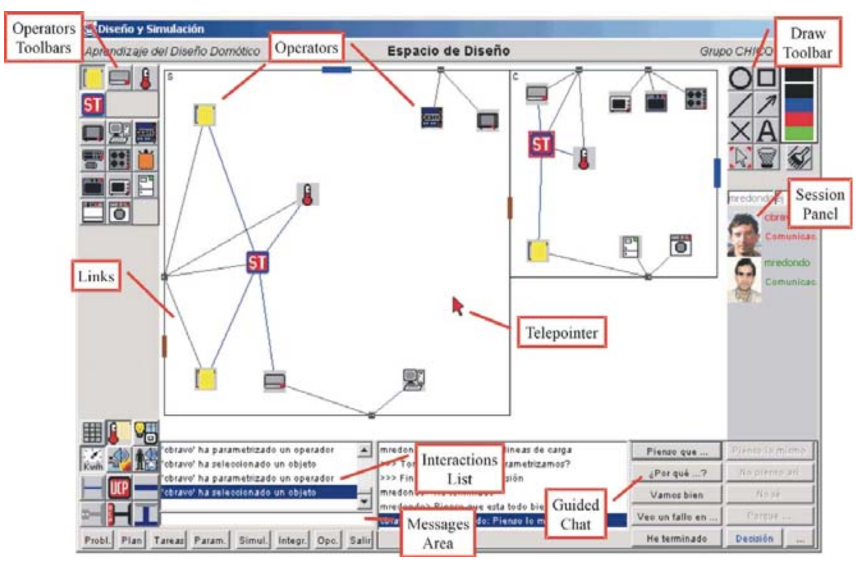

Figure 6. User interface of DomoSim-TPC design workspace (in Spanish)

The system is organized in different shared workspaces, each one for carrying out a specific task (planning, design or simulation). Figure 6 is a screenshot of the DomoSim-TPC design shared workspace (Bravo et al., 2006b). It contains tools for building models (designs), discussion and awareness. The work surface contains a house plan on which a set of operators has been inserted. On the left side of the window the domotical operator toolbars can be seen, and on the right is the drawing toolbar.

The discussion tool provides communication and coordination support. It consists of a Guided Chat and a Decision-Making tool. The awareness tool maintains a set of tele-pointers which show in which part of the model building area the users are working; a list of interactions which shows the actions taken by each user; and a panel containing the users' pictures, their names and their state (for example, editing, selecting, linking, simulating, designing, drawing, communicating). Each user has a unique color which is used to highlight their name and state and to identify their tele-pointer. In the central part of Figure 6, we can see the tele-pointer of the student collaborating with the student to whom the interface shown corresponds. As a user performs an action, it is shown immediately to the group members in the shared workspace. The action is recorded in the list of interactions and, optionally, the system will beep to capture the user's attention. All this allows users to know, for example, what the other students are doing, where they are, even what they may be likely to do next.

Measurement of indicators

As Jermann et al. (Jermann et al., 2001) note, measurement of system-based indicators begins with a data collection phase which involves observing and recording online interactions. Typically, users' interactions are logged and stored by the CSCL system. This raw data can be analyzed and summarized to provide simple interaction metrics. Indicators are higher level scores calculated from the metrics. In this section, we describe what raw data was gathered in our experiments and how it was aggregated into metrics and then indicators. We will conclude the section with some notes on measurement of additional user response variables.

Data collection

In order to analyze collaborative activity it is necessary to collect information about the collaboration process, recording information about the participants, actions performed, messages sent and received and time of each action. All the applications we developed include a mechanism to gather information. In *TeamQuest,* for example, we implemented a structured chat-style user interface through which the group conversation is held. The application records every message sent by any member of the group. Along with each message, it records the time of occurrence, sender, addressee and current quadrant (the mouse location –X and Y position) when the message was sent. Figure 7 shows an example of the information gathered by the application. In addition, the log records the partial scores and total score by quadrant. The tool also registers the start and finish time of the game, the time spent in each quadrant, and the number of times each player looked at the partial and total scores by quadrant.

X	Y	Quadrant	From	To	Message	Time
1	1	1				
			Andres1	Gaston	I need your coordinates	12:00:41 AM
			Andres1	Miguel	I need your coordinates	12:00:52 AM
			Andres1	Andres2	I need your coordinates	12:01:13 AM
			Andres2	Andres1	A2 y F4	12:01:25 AM
			Miguel	Andres1	A5 y G5	12:02:00 AM
			Gaton	Andres1	d3 y g3	12:02:08 AM
			Andres1	Gaston	your coordinates	12:03:13 AM
			Andres2	Andres1	ok	12:03:21 AM
1	2	1				12:04:27 AM
			Miguel	Andres1	Letters are arrows, columns numb	12:04:32 AM
1	3	1				12:04:37 AM
2	3	1				12:05:03 AM
2	4	1				12:05:52 AM
2	5	1				12:06:02 AM
3	5	1				12:06:07 AM
4	5	1				12:06:12 AM
			Gaston	Miguel	Well....	12:07:11 AM

Figure 7. TeamQuest interaction log

Metrics

In order to estimate each of the indicators, we first define some performance metrics. Metrics such as time, length of turn, and other countable events, are directly measurable and can often be automatically collected (Drury et al., 1999). The following table of metrics includes the observable data elements that were identified from our experiments as useful indicators of system and group performance. For each metric, we present its definition and some examples of ways to capture it in Table 1.

Table 1. Metrics

Metric	Meaning	Example
Number of Errors	Number of total errors performed during collaborative activity.	
Solution to the problem	The group is able to solve the problematic situation (Yes/No)	
Movements	Total number of mouse or pointer movements	
Queries	Total queries to the scores (Actions performed over the score icons)	
Explicit use of strategy	Outline a strategy for the problem solution in an explicit way (Yes/No).	
Maintain strategy	Use the defined strategy during all the activity.	
Communicate strategy	Negotiate, reaching consensus and disseminate information about strategy.	
Strategy messages	Total number of messages that propose guidelines to reach the group goal.	“Let's label the columns with letters and the rows with numbers”
Work strategy messages	Total number of messages that help the coordinator of the activity to make the most suitable decisions. These are typically sentences in the present tense that aim to inform the group about the current state of the group task.	“Stop, there is an obstacle in B3".
Coordination strategy messages	Total number of messages that correspond to activities whose main purpose is to regulate the dynamics of the process. These are typically characterized by prescribed future actions.	"I will move six squares to the right".
Work messages	Total number of messages received by the coordinator of the activity.	
Coordination messages	Total number of messages sent by the coordinator of the activity.	
Success criteria review messages	Total number of messages that review the boundaries, guidelines and roles of the group activity.	
Lateral messages	Total number of messages, such as social messages, that are not focused on the solution of the problem.	"Come on, hurry up, I'm hungry!!!!!!! “
Total messages	Total number of messages received and sent by the group during the activity.	

The system-based process indicators

We identified five system-based indicators of the success of the collaborative learning process in section 3: use of strategies, intra-group cooperation, reviewing success criteria, monitoring and the performance of the group. Having introduced the metrics, we can now describe these indicators and how they can be estimated and applied.

Use of strategies

The first indicator tries to capture the ability of the group members to generate, communicate and consistently use a strategy to jointly solve the problem. According to Johnson & Johnson in (Adams et al., 1996), to use a strategy is "to produce a single product or put in place an assessment system where rewards are based on individual scores and on the average for the group as a whole".

In our collaborations, group members are forced to closely interact with peers since each player has only a partial view of the game (e.g., obstacles in the labyrinth games) or the solutions. Therefore, successful completion requires a strict positive interdependence of goals. If the group is able to complete the task, we can say its members have built a shared understanding of the problem (Dillenbourg et al., 1995). They must have understood the underlying problem. For example, in Chase the Cheese, the coordinator does not have all the information needed to move the mouse in their quadrant without hitting an obstacle, so they need timely assistance from their collaborators. According to Fussell (Fussell et al., 1998), discussion of the strategy to solve a problem helps group members to construct a shared view or mental model of their goals and the tasks that must be executed. This mental model can improve coordination because each member knows how their task fits into global team goals.

In DomoSim-TPC, this aspect is explicitly considered. The students solve the problems with the help of specialized tools. To successfully develop a design, they need to organize and distribute their work, drawing up a resolution strategy that divides the problem into sub-problems (Redondo et al., 2006b).

Measurement of use of strategies is related to the software environment in which it is used. In general, however, measurement should consider both the outcome of the collaboration and the nature of the strategy applied. In our experiments, outcome could be measured simply as success or failure in solving the problem. Strategy is more complex, and consists of elements of a) the quality of the technique or strategy actually used to solve the problem, b) explicit definition of a strategy, c) consistency or maintenance of the strategy throughout the collaboration, and d) communication of the strategy among group members.

Having identified the elements of strategy, we needed to consider how to measure and combine them. We sought a method that would be simple to understand and apply but powerful enough to distinguish between the performance of different groups. Measurement was based on the metrics introduced in Table 1. All elements were scored from 0 to 1. The most complex element to measure was the quality of the strategy used. This was measured as the mean movement, error and time to solution scores where each of these scores was a value from 0 to 1 based on the performance of each group relative to the performance of the worst group.

Using a data driven approach, we experimented with different weightings for each of the five components of strategy (solution of the problem, quality of strategy, explicit use of strategy, maintenance, and communication) with groups playing Chase the Cheese and Team Quest. We assigned the strategy elements a weight four times larger than the one assigned to solution of the problem. This weighting reflects the emphasis of our first indicator (CI1) on the use of strategy; the outcome of use, although important, should not dominate the score. Thus, in calculating CI1, the strategy applied had a weight of 80% and success had a weight of 20%. After experimentation, the 80% available for strategy applied included a small score (5%) to represent the actual strategy used. This weight reflects the fact that many different strategies can be used in practice to solve a given problem, but permits us to penalize groups that use an unusually large number of movements, have a large number of errors and/or use a large amount of time, even if they have other elements of strategy in place. The remaining 75 percentage points were allocated as 20% if the group explicitly outlined a strategy, 25% to the group's ability to maintain the chosen strategy throughout the process, and 30% for strategy communication.

This set of weights produced scores that could be used to compare groups meaningfully. For example, the group with the highest score in one test of Chase the Cheese scored 0.75 (out of a maximum of 1), with quite high scores (but not the highest) on all indicators except communication. Indeed, this group performed consistently and moderately well throughout the game, but with better negotiation and communication of strategy could have performed better. On the other hand, the group with the lowest score performed consistently, but moderately badly, throughout the game and did not reach a solution (Collazos et al., 2002).

Intra-group cooperation

This indicator corresponds to the application of collaborative strategies during the process of group work. If each group member is able to understand how their task is related to the team's global goals, then members can anticipate actions. This requires less coordination effort. In the games, this indicator also includes measures related to the messages every player requires from their peers to reach their partial goal when acting as a coordinator. In DomoSim-TPC, group members need to communicate, exchanging information in relation to the domain, coordinating their actions and making decisions by coming to agreements in order to solve the problem (Bravo et al., 2006b).

A good application of collaborative strategies should be observed as efficient and fluid communication among members of the group. Good communication, in turn, means few, precise and timely messages. This component of the indicator was therefore measured as

CI2 = 1 - (Work strategy messages / Work messages)

Providing help is represented by the number of supporting messages from peers. Technically, this measure may be computed as the ratio between the number of work messages and the total number of messages generated by the group.

Reviewing success criteria

This indicator measures the degree of involvement of the group members in reviewing boundaries, guidelines and roles during the group activity. It may include summarizing the outcome of the last task, assigning action items to members of the group, and noting dates or times for expected completion of assignments.

In TeamQuest, for example, the success or failure of the group is related to achievement of partial and global goals. It is shown in the obtained scores (partial and global scores). This indicator should also take into account the number of messages concerned with the reviewing mentioned above. It reflects interest in individual and collective performance. CI3 is then computed from the total number of messages that review the boundaries, guidelines and roles of the group activity. It is calculated as

CI3 = 1 - (Reviewing messages / Total Messages)

Scores can range between 0 and 1, where 1 is the highest score. In DomoSim-TPC, e.g., this indicator is related to the correctness, validity and other characteristics of the design models built by groups of students. In this system, the relationship between success and strategies can be analyzed by studying the design plans and models that the students built.

Monitoring

This indicator measures regulatory activity. The objective is to measure the extent to which the group maintains the chosen strategies to solve the problem, keeping focused on the goals and the success criteria. If a player does not sustain the expected behavior, the group will not reach the common goal. In this sense, our fourth collaboration indicator (CI4) is related to the number of coordination messages (i.e. messages in which the coordinator requests coordination information from collaborators) where fewer messages means good coordination. CI4 is calculated as

CI4 = 1 - (Coordination strategy messages / Coordination messages)

Performance

Baeza-Yates and Pino (Baeza et al., 1997; Baeza et al., 2006) made a proposal for the formal evaluation of collaborative work taking into account three aspects: Quality (how good is the result of collaborative work), Time (total elapsed time while working) and Work (total amount of work done). In our experiments, Quality can be measured by three factors: errors made by the group, solution of the problem, and movements of the mouse. Work is measured by the number of messages sent by group members. In the games, the software records the play-time between the first event (movement of the mouse or message sent by any player) and when the group reaches the goal (e.g., cheese) or loses the game (a partial score goes down to zero). In this view, the "best" group does the work faster. We scored each of Quality, Work, and Time on a scale of 0 to 1 where 0 is the worst possible performance and 1 is the best possible performance. The performance indicator, CI5, was measured as the mean score on these three aspects.

Summary of system-based indicators

The indicators are summarized in Table 2.

Table 2: Summary of Indicators

<table>
<tr><td>Indicator</td><td colspan="7">Measurement</td></tr>
<tr><td rowspan="3">CI1</td><td colspan="2">Outcome</td><td colspan="5">Strategy</td></tr>
<tr><td colspan="2">Solution</td><td>Quality</td><td>Explicit use</td><td colspan="2">Maintainenance</td><td>Communication</td></tr>
<tr><td colspan="2">20%</td><td>5%</td><td>20%</td><td colspan="2">25%</td><td>30%</td></tr>
<tr><td>CI2</td><td colspan="7">1 - (Work Strategy Messages / Work messages)</td></tr>
<tr><td>CI3</td><td colspan="7">1 - (Reviewing messages / Total Messages)</td></tr>
<tr><td>CI4</td><td colspan="7">1 - (Coordination Strategy Messages / Coordination Messages)</td></tr>
<tr><td rowspan="2">CI5</td><td colspan="3">Quality</td><td colspan="2">Time</td><td colspan="2">Work</td></tr>
<tr><td>Few errors</td><td>Solution of the problem</td><td>Few movements</td><td colspan="2">Total elapsed time while working</td><td colspan="2">Total Messages</td></tr>
</table>

We tested these indicators with 11 diverse groups playing Chase the Cheese (Collazos et al., 2002). Table 3 shows that the indicators allow us to identify groups that perform consistently well or badly, while providing enough discrimination to distinguish the strengths and weaknesses of collaboration in each of the groups.

Table 3: Result of use of Indicators in Chase the Cheese

Group	**Strategy CI1**	**Cooperation CI2**	**Reviewing CI3**	**Monitoring CI4**	**Performance CI5**
Group 0	0.69	0.69	0.2	0.75	0.65
Group 1	0.31	0.71	0.2	0.80	0.57
Group 2	0.68	0.62	0.2	0.80	0.69
Group 3	0.48	0.61	0.5	0.74	0.63
Group 4	0.71	0.74	0.8	0.78	0.66
Group 5	0.75	0.84	1	0.86	0.61
Group 6	0.71	0.72	1	0.85	0.52
Group 7	0.47	0.80	0.2	0.80	0.53
Group 8	0.27	0.75	0.2	0.82	0.54
Group 9	0.28	0.75	0.2	0.81	0.54
Group 10	0.48	0.80	0.2	0.83	0.53

Other indicators of learning to collaborate

We have defined a set of system-based indicators that will permit us to evaluate students' learning to collaborate. Other indicators have been developed for specific projects, e.g., a method based on genetic algorithms to measure the relationship between process (level of collaboration) and product (correct solution) in activities carried out using DomoSim-TPC (Molina et al., 2006). All of these indicators rely on data generated by the CSCL system. They do not consider, however, the users' perceptions and psychological responses to participation. We have therefore included in our evaluation aspects related with community psychology and social and educational psychology. We defined meta-response variables that represent the personal development of individuals which psychologists believe can result from effective participation in collaborative learning processes (Francescato et al., 2006). These variables include cognitive empowerment, self-efficacy as a learner, self-efficacy for computer use, attitudes to computer-supported learning, and attitudes to collaborative work. Full detail of these measurements is provided in other works (Klobas et al., 2000; Klobas et al., 2002), but as an example, we discuss one of them, Attitudes to collaborative work, here.

To measure Attitudes to collaborative work, four items were adapted from the Grasha-Reichmann descriptions of the collaborative learning style (Hruska-Riechmann et al., 1982). Typical items were "I like to work with other students" and "Group work is a waste of time". They were measured on a 4-point scale with values of 0 (*Never*), 1 (*Rarely*), 2 (*Sometimes*), 3 (*Often*). Cronbach's alpha was satisfactory (above .7 in all administrations) and the scale was additive. Responses to the 4 items were summed to give an attitude to collaborative work rating on a scale of 0-12.

Discussion

Typically, evaluation of collaborative learning has relied on examinations or tests to determine how much students have learned, however, the model proposed in this paper is based on measuring collaborative learning processes. We have derived indicators of the quality of student work during the in-process phase of the collaborative learning process from a prominent model of collaborative learning (Adams et al., 1996) and shown how these indicators can be calculated from data recorded during the collaboration. Use of these indicators can provide insight into the collaboration process. Based on the results, evaluators can identify problematic situations and plan new strategies in order to improve collaborative learning.

System-based indicators can be used to monitor the learning process while a collaborative activity is proceeding. They may be used to alert an instructor to the need to intervene in the process. In such cases, it is necessary to design the collaboration so that the instructor knows how to intervene in order to improve the process (Katz, 1999). It is necessary for the teacher not only to monitor the activities of a particular student but also the activities of his peers to encourage some kind of interaction that could influence the individual learning and the development of collaborative skills, such as give and receive, help, and receive feedback and identify and solve conflicts and disagreements (Dillenbourg et al., 1995; Johnson et al., 1992; Webb et al., 1996). Interventions can be difficult to identify if they are managed in a manual way, especially when the teacher is working with several groups of students in the same class at the same time. Our model of evaluation allows the teacher to observe the interaction at an aggregated level and to be alerted to opportunities to intervene.

Monitoring can help a teacher to identify which aspects of the group process are more complicated. This is an extremely important aspect of any mechanism of evaluation because it provides the opportunity to determine how to improve the shortcomings of the group process that were detected from analysis of collaborative interactions. Ideally, monitoring will help not only to find the weaknesses of the group –a difficult task in itself– but also, with the aid of the computer, to overcome those weaknesses. It is possible to include in software tools mechanisms both to evaluate the collaborative learning process and to improve it. In a series of preliminary experiments in CSCL environments, it has been observed that groups with little experience in collaborative work do not understand, use or adopt cooperation strategies well (Collazos et al., 2002). Establishing common goals is an important component of strategy since actions cannot be interpreted without referring to the shared goals, and reciprocally, goal discrepancies are often revealed through disagreements on action (Dillenbourg et al., 1999). Members of a group do not only develop shared goals by negotiating them, but they also become mutually aware of these goals. TeamQuest includes a discussion environment that group members can use during a break. Breaks may be taken at any time during play. They provide opportunities for analysis of the work done, thus allowing the definition and reinforcement of common goals.

Monitoring can also help CSCL environment designers to improve their designs. For example, Collazos et al. have developed a mechanism called Negotiation Table, in which one widget supports discussions within the learning group and another supports monitoring of the tasks done by the group (Collazos et al., 2003b). These widgets are intended to improve the strategic aspect of group work. The information registered by the indicators permits the designers to modify or incorporate new mechanisms according to the information revealed by monitoring the collaborative activity.

The indicators we have developed permit evaluators to identify some weakness in the collaboration process in order to design strategies to better support it. As we mentioned in the first part of this article, however, measurement of collaboration is not an easy task. Although we have only briefly mentioned variables that correspond to students' personal development as a result of participation, we believe these measures are also important. They can give evaluators insights into the collaborative process performed and the perception of each user with respect to their participation within the group. They could, for example, be incorporated at the end of a collaborative game using a brief questionnaire or open ended question to gather students' perceptions of their experience. Analysis of participants' answers could be used to determine if the group is able to self-evaluate or if they were able to construct a shared understanding of the problem Such additional indicators could be compared with the system-based measures to understand which aspects of participation and interaction in the CSCL process are associated with users' perceptions and personal development.

In this project we did not develop indicators of social aspects of participation because the activities that we constructed for this initial test of the approach were activities for small groups working on activities that could be completed in a short time period. In real life collaborative learning, we recommend, however, evaluation of the social aspect as well as the aspects of the collaboration process measured here.

It is also important to note that collaborative learning processes are influenced by the personal style and individual behavior of every member of the group. In our collaborative games, for example, we noticed that group members behaved and communicated in consistent ways regardless of the role they were playing, coordinator or participant.

Although our indicators measure the collaboration process within a group, it is also possible to observe the individual contributions of every member in any group (Constantino-Gonzalez et al., 2000). This would permit a more specific analysis of interaction (movements and message) to evaluate the performance of every group member in their own group.

Conclusions and further work

Understanding the collaborative process of learning in groups is an interesting research field. In the case of collaborative activities, performing a task well implies not only having the skills to execute the task, but also collaborating well with teammates to do it. This complexity offers opportunities to develop tools and techniques for improving collaboration.

In this paper we have presented a set of indicators and software tools that have allowed us to experiment in the evaluation of collaborative work, and in particular, to study the collaborative processes that occur during collaborative learning. To evaluate collaborative processes, we proposed five system-based indicators and some indicators based on participants' psychological responses to the process of participation. We do not claim these are the only or the best indicators that could be developed to this end, but rather that they provide a direction to pursue in understanding and evaluating the process of CSCL. Nonetheless, these indicators were able to provide some insight into the collaborative work done by groups in our experiments. The system-based indicators can be used to detect group weaknesses in the collaborative learning process and to propose mechanisms to improve them. In this way, they can be used for both formative evaluation while students are collaborating using CSCL and summative evaluation once collaboration is complete. The meta-response indicators can be used for summative evaluation of the process.

Further work is needed to study the influence of many variables we did not isolate in our experimentation. Such variables include: genre or subject of the collaborative task, age, culture, homogeneous vs. heterogeneous groups, etc. Other experiments could also be made by changing the CSCL environments. Changes might include allowing broadcast messages or allowing the group to slightly modify the rules of a game (e.g., forcing the coordinator to receive all messages from members before enabling moves). Additionally, refinements might be made to the system-based indicators and experiments conducted to identify how the indicators behave when used to alert teachers and group members to aspects of the collaborative process that can be improved. Finally, the results of process tests can be compared with traditional tests of the success of CSCL to confirm that improvements in the CSCL process translate into improvements in the outcomes of CSCL.

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References

Adams, D., & Hamm, M. (1996). *Cooperative Learning: Critical Thinking and Collaboration across The Curriculum* (2nd Ed.), Springfield, IL: Charles Thomas Publisher.

Baeza-Yates, R., & Pino, J.A. (2006). Towards Formal Evaluation of Collaborative Work. *Information Research, 11*(4), Retrieved June 7, 2007, from http://informationr.net/ir/11-4/paper271.html.

Baeza-Yates, R., & Pino, J.A. (1997). A First Step to Formally Evaluate Collaborative Work. *Paper presented at the ACM International Conference on Supporting Group Work*, November 16-19, 1997, Phoenix, AZ, USA.

Barros, B., & Verdejo, M. F. (1999). An Approach to Analyse Collaboration when Shared Structured Workspaces are used for Carrying out Group Learning Processes. *Paper presented at the International Conference in Artificial Intelligence in Education (AIED'99)*, July 18-23, 1999, Le Mans, France.

Barros, M., Mizoguchi, R., & Verdejo, M. F. (2001). A platform for collaboration analysis in CSCL. An ontological approach. *Paper presented at the Artificial Intelligence in Education Conference*, July 9-13, 2001, Los Angeles, USA.

Bravo, C., Redondo, M. A., Ortega, M., & Verdejo, M.F. (2006a) Collaborative Distributed Environments for Learning Design Tasks by Means of Modelling and Simulation. *Journal of Networks and Computer Applications, 29*(4), 321-342.

Bravo, C., Redondo, M. A., Ortega, M., & Verdejo, M. F. (2006b). Collaborative environments for the learning of design: A model and a case study in Domotics. *Computers and Education, 46*(2), 152-173.

Brna P., & Burton M. (1997). Roles, Goals and Effective Collaboration. In Okamoto, T. and Dillenbourg, P. (Eds.), *Proceedings of Workshop on Collaborative Learning/Working Support Systems*, pp3-10, Kobe, Japan.

Collazos C., Guerrero, L. A., & Vergara, A. (2001). Aprendizaje Colaborativo: un cambio en el rol del profesor. Memorias del III Congreso de Educación Superior en Computación, *Jornadas Chilenas de Ciencias de la Computación*, pp. 10-20, Punta Arenas, Chile (in Spanish).

Collazos, C., Guerrero, L. A., Pino, J., & Ochoa, S. (2002). Evaluating Collaborative Learning Processes. *Lectures Notes in Computer Science, 2440*, 203-221.

Collazos, C., Guerrero, L. A., Pino, J., & Ochoa, S. (2003a). Collaborative Scenarios to promote positive interdependence among group members. *Lecture Notes in Computer Science, 2806*, 356-370.

Collazos, C., Guerrero, L. A., Pino, J., & Ochoa, S. (2003b). Improving the use of strategies in Computer-Supported Collaborative Processes. *Lecture Notes in Computer Science, 2806*, 247-260.

Collazos, C., Guerrero, L. A., & Pino, J. A. (2004a). Computational Design Principles to Support the Monitoring of Collaborative Learning Processes. *Journal of Advanced Technology for Learning, 1*(3), 174-180.

Collazos, C., Guerrero, L. A., Pino, J., & Ochoa, S. (2004b). A Method for Evaluating Computer-Supported Collaborative Learning Processes. *International Journal of Computer Applications in Technology 19*(3/4), 151-161.

Collazos, C., Ortega, M., Bravo, C., & Redondo, M. (2007). Experiences in Tracing CSCL Processes. In Nedjah, N.; Mourelle, L.d.M.; Borges, M.N.; de Almeida, N.N. (Eds.), *Intelligent Educational Machines: Methodologies and experiences* (Chapter 5), Berlin/Heidelberg: Springer.

Constantino-González, M., & Suthers, D. (2000). A Coached Collaborative Learning Environment for Entity-Relationship Modeling. *Lecture Notes In Computer Science, 1839*, 325-333.

Constantino-González M., & Suthers, D. (2001). Coaching Web-based Collaborative Learning based on Problem Solution Differences and Participation. In J.D. Moore, C.L. Redfield & W. L. Johnson (Eds.), *Proceedings AI-ED 2001*, Amsterdam: IOS Press, 176-187.

Dillenbourg, P., Baker, M., Blake, A., & O'Malley, C. (1995). The Evolution of Research on Collaborative Learning. In E. Spada & P. Reiman (Eds.), *Learning in Humans and Machine: Towards an interdisciplinary learning science*, Oxford: Elsevier, 189-211.

Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-Learning: Cognitive and Computational Approaches*, Oxford: Elsevier, 1-19.

Drury, J., Damianos, L., Fanderclai, T., Kurtz, J.,Hirschman, L., & Linton, F. (1999). Methodology for Evaluation of Collaborative Systems, Retrieved June 7, 2007, from http://zing.ncsl.nist.gov/nist-icv/documents/methodv4.htm.

Francescato, D., Porcelli, R., Mebane, M., Cudetta, M., Klobas, J., & Renzi, P. (2006). Evaluation of the efficacy of collaborative learning in face to face and computer supported university contexts. *Computers in Human Behavior, 22*(2), 163-176.

Fussell, S., Kraut, R., Lerch, F., Scherlis, W., McNally, M., & Cadiz, J. (1998). Coordination, Overload and Team Performance: Effects of Team Communication Strategies. *Paper presented at the CSCW'98 conference*, November 14-18, 1998, Seattle, Washington, USA.

Garfinkel, H. (1967). *Studies in Ethnomethodology*, Englewood Cliffs, NJ: Prentice Hall.

Guerrero, L. A., Alarcón, R., Collazos, C., Pino, J., & Fuller, D. (2000). Evaluating Cooperation in Group Work. *Paper presented at the 6th International Workshop on Groupware*, October 18-20, 2000, Madeira, Portugal.

Guerrero, L. A., Mejias, B., Collazos, C., Pino, J. A., & Ochoa, S. (2003). Collaborative Learning and Creative Writing. *Paper presented at the First Latin American Web Congress*, November 10-12, 2003, Santiago, Chile.

Hruska-Riechmann, S., & Grasha, A. F. (1982). The Grasha-Riechmann student learning style scales. In J. Keefe (Ed.), *Student learning styles and brain behavior*, Reston, VA: National Association of Secondary School Principals, 81-86.

ICALTS (2004). State of the Art: Interaction Analysis Indicators. Retrieved on June 7, 2007, from http://www.rhodes.aegean.gr/LTEE/KALEIDOSCOPE-ICALTS/Publications/D1%20State%20of%20the%20Art%20Version_1_3%20ICALTS_Kal%20NoE.pdf.

Inaba, A., & Okamoto, T. (1997). The Intelligent Discussion Coordinating System for Effective Collaborative Learning. *Proceedings of the IV Collaborative Learning Workshop in the 8th World Conference on Artificial Intelligence in Education*, Kobe, Japan, 175-182.

Jermann, P., Soller, A., & Muhlenbrock, M. (2001). From Mirroring to Guiding: A Review os State of the Art Technology for Supporting Collaborative Learning. *Paper presented at the Euro Computer Supported Collaborative Learning*, March 22-24, 2001, Maastricht, NL.

Johnson, D., & Johnson, R. (1975). *Learning Together and Alone, Cooperation, Competition and Individualization*, Englewood Cliffs, NJ: Prentice Hall.

Johnson, D., Johnson, R., & Holubec, E. (1992). *Advanced cooperative learning*, Edina, MN: Interaction Books.

Johnson, D., & Johnson, R. (1995). *My mediation notebook* (3rd Ed.), Edina, MN: Interaction Book Company.

Kagan, S. (1990). The Structural Approach to Cooperative Learning. *Educational Leadership, 47*(4), 12-15.

Katz, S. (1999). The Cognitive Skill of Coaching Collaboration. *Paper presented at the CSCL'99*, December 11-12, 1999, Palo Alto, California.

Klobas, J., & Renzi S. (2000). Students' psychological responses to a course supported by collaborative learning technologies: Measurement and preliminary results. *The Graduate School of Management Discussion Papers Series, 2000-2*, Nedlands, Australia: The Graduate School of Management, The University of Western Australia.

Klobas, J., Renzi, S., Francescato, D., & Renzi, P. (2002). Meta-Response to Online Learning. *Ricerche di Psicologia, 25*(1), 239-259.

Koschmann, T, Kelson, A. C., Feltovich, P. J,. & Barrows, H. (1996). Computer-Supported Problem-Based Learning: A Principled Approach to the Use of Computers in Collaborative Learning. In T. Koschmann (Ed.), *CSCL: Theory & Practice in an Emerging Paradigm*, Mahwah, NJ: Lawrence Erlbaum, 83-124.

Koschmann, T., Stahl, G., & Zemel, A. (2005). *The video analyst's manifesto (or the implications of Garfinkel's policies for the development of a program of video analytic research within the learning sciences)*, Retrieved June 7, 2007, from http://edaff.siumed.edu/tk/manifesto.pdf.

Linn, M. C., & Clancy, M. J. (1992). The Case for Case Studies of Programming Problems. *Communications of the ACM, 35*(3), 121-132.

Martínez, A., Dimitriadis, Y., Rubia, B., Gómez, E., Garrachón, I., & Marcos, J. (2002). Studying social aspects of computer-supported collaboration with a mixed evaluation approach. In G. Stahl (Ed.), *Computer Support for Collaborative Learning: Foundations for a CSCL Community*, Hillsdale, NJ: Lawrence Erlbaum, 631-632.

Molina, A. I., Duque, R., Redondo, M. A., Bravo, C., & Ortega, M. (2006). Applying machine learning techniques for the analysis of activities in CSCL environments based on argumentative discussion. In Panizo, L., Sánchez, L., Fernández, B., & Llamas, M. (Eds.), *Proceedings of the SIIE'06*, León, Spain: University of León,. 214-221.

Muhlenbrock, M., & Hoppe, U. (1998). Constructive and collaborative learning environments: What functions are left for user modeling and intelligent support? *Paper presented at the ECAI-98*, August 23-28, 1998, Brighton, UK.

Muhlenbrock, M., & Hoppe, U. (1999). Computer Supported Interaction Analysis of Group Problem Solving. *Paper presented at the CSCL'99*, December 11-12, 1999, Palo Alto, California.

Redondo, M. A., & Bravo, C. (2006a). DomoSim-TPC: Collaborative Problem Solving to Support the Learning of Domotical Design. *Computer Applications in Engineering Education, 14*(1), 9-19.

Redondo, M. A., Bravo, C., Ortega, M., & Verdejo, M. F. (2006b). Providing adaptation and guidance for design learning by problem solving: he DomoSim-TPC approach. *Computers and Education, 48*(4) 642-657.

Roschelle, J., & Teasley, S. (1991). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer Supported Collaborative Learning*, Berlin, Germany: Springer, 67-97.

Sacks, H. (1992). *Lectures on Conversation*, Oxford, UK: Blackwell.

Soller, A., Lesgold, A., Linton, F., & Goodman, B. (1999). What Makes Peer Interaction Effective? Modeling Effective Communication in an Intelligent CSCL. *Paper presented at the 1999 AAAI Fall Symposium: Psychological Models of Communication in Collaborative Systems*, November 5-7, 1999, North Falmouth, Massachusetts, USA.

Soller, A., & Lesgold, A. (2000). Knowledge acquisition for adaptive collaborative learning environments. *Proceedings of the AAAI Fall Symposium: Learning How to Do Things* (pp. 57-64), Cambridge: MIT Press, Retrieved June 7, 2007, from http://www.cscl-research.com/Dr/documents/Soller-Lesgold-AAAI-00.ps.

Sharan, Y., & Sharan, S. (1990). Group Investigation Expands Cooperative Learning. *Educational Leadership, 47*(4),17-21.

Slavin, R. (1991). Synthesis of Research on Cooperative Learning. *Educational Leadership, 48*(5), 71-82.

Stahl, G. (2002a). Groupware Goes to School. In J. Haake & J. Pino (Eds.), *Groupware: Design, Implementation and Use*, Berlin, Germany: Springer Verlag, 1-24.

Stahl, G. (2002b). Rediscovering CSCL. In T. Koschmann, R. Hall, & N. Miyake (Eds.), *CSCL2: Carrying Forward the Conversation*, Hillsdale, NJ: Lawrence Erlbaum, 169-181.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*, Cambridge, MA: MIT Press.

Suthers, D. (2005). Technology affordances for intersubjective learning: A thematic agenda for CSCL. *Paper presented at the International conference of Computer Support for Collaborative Learning*, May 30 – June 4, 2005, Taipei, Taiwan.

Underwood, G., Mc.Caffrey, M., & Underwood, J. (1990). Gender Differences in a Cooperative Computer-based Language Task. *Educational Research, 32*(1), 44-49.

Webb, N., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology*, NY, USA: Macmillan Library Reference, 841-873.

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Developing Domain Ontologies for Course Content

Sinéad Boyce[1] and Claus Pahl[2]
[1]Trinity College Dublin, Department of Biochemistry, Dublin 2, Ireland // sboyce@tcd.ie
[2]Dublin City University, School of Computing, Dublin 9, Ireland // cpahl@computing.dcu.ie

ABSTRACT
Ontologies have the potential to play an important role in instructional design and the development of course content. They can be used to represent knowledge about content, supporting instructors in creating content or learners in accessing content in a knowledge-guided way. While ontologies exist for many subject domains, their quality and suitability for the educational context might be unclear. For numerous subjects, ontologies do not exist. We present a method for domain experts rather than ontology engineers to develop ontologies for use in the delivery of courseware content. We will focus in particular on relationship types that allow us to model rich domains adequately.

Keywords
Domain ontology, Ontology development, Knowledge representation and modelling, Course content development

Introduction

Ontology is a discipline that is part of the knowledge representation field (Sowa, 2000). Ontology defines the kinds of things that exist in an application domain. In the computing context, an ontology is a framework for representing concepts (things, or ideas about things) and the relationships that exist between those concepts (Uschold & Gruninger, 1996). In an ontology, a precise definition is associated with each concept and relationship type that is used. Ontology technology is considered to be a highly suitable means of supporting educational-technology systems (Mizoguchi & Bourdeau, 2000; Sampson et al., 2004; Aroyo et al. , 2002). The increasing importance of the Semantic Web, which is based on ontology technology, will strengthen this argument (Berners-Lee et al., 2001). There are numerous areas where the use of ontologies would prove useful for the Web. One scenario is to allow Web tools to gather information that has more clearly defined meaning and, in this way, match the users' needs more closely. Another scenario is an application of ontology as a discipline in the teaching and learning context in order to structure the subject domain of interest as a set of concepts that are connected by defined relationships. A number of other scenarios have already been explored. Ontologies can, for instance, support the generation of content from knowledge represented in subject domain ontologies, its description and annotation can make properties and implicit knowledge explicit, and content based on ontologically represented subject, instruction, and user knowledge can be adapted (Devedžić, 2006).

Learning content allows learners to acquire knowledge about a subject, i.e. knowledge is an intrinsic, although often implicit aspect of content. Ontologies for educational content add flexibility through the explicit separation of knowledge and content. They allow the content to be adapted based on the user's level of knowledge. One of the areas most relevant is that of delivering educational content using agents. Agents are pieces of software that interpret the content on a Web server and present it to the user as a Web page (Pahl & Holohan, 2004). The building blocks required for this agent-based architecture are either developed or well under development.

The major problems to be overcome are the lack of domain ontologies from which to develop and organize course content, and a lack of standards and tools for the development of such ontologies. The tools that are currently available require a degree of expertise that does not favour the generation of ontologies by people who are experts in a particular subject area but not in ontological engineering. Currently, a joint effort by domain experts and ontology engineers is necessary for ontology development. To see the widespread development of domain ontologies would require ontological tools that could be used to create an ontology from scratch or to enrich a pre-existing ontology with minimal human intervention.

Questions that arise are how to develop ontologies if they are not readily available and what criteria should apply to these domain ontologies (Boyce, 2004). We aim to support instructors, instructional designers and content developers as domain experts with an adequate development methodology for the educational context. More specifically, regarding ontological modelling, we need to ask:

- Is the usual hierarchical organization of concepts in ontologies sufficient?
- If not, are there education-specific relationship types in addition to the more common subtype hierarchies?
- Are these education-specific relationships, if any, transferable between subjects?

We will illustrate, using a case study, how to develop a course subject domain ontology. We will answer the questions, and include comments on the quality of the resulting ontology. Our main case study is based on a computing subject, which will be complemented by a look at a biochemistry subject to broaden our focus and to address the question of transferability from one domain to another. We use an empirical research approach, starting with a traditional development method, analysing its limitations and discuss and evaluate solutions.

We start our investigation by giving an overview of ontology development in Section 2. We then adapt this to the educational context, presenting our methodology for course ontology development in Section 3. Section 4 applies this methodology in an extensive case study. The results are discussed in Section 5 in terms of knowledge modelling, transferability, and instructional design, before ending with some conclusions.

The Development of Ontologies

The design of ontologies is guided by their purpose of acting as domain conceptualisations of various degrees of formality in the form of taxonomies, metadata schemes, or logical theories.

Taxonomy and Ontology

A taxonomy is a way of classifying or categorizing a set of things using a hierarchical structure, which is a treelike structure, with the most general category as the root of the tree. Each node, including the root note, is an information entity that represents some object in the real world that is being modelled. Each link between two nodes in a taxonomy represents a “subclassification-of” relation or a “superclassification-of” relationship.

An ontology defines the terms used to describe and represent an area of knowledge. Ontologies are used by people, databases and applications that need to share domain information. Ontologies include computer-usable definitions of basic concepts in the domain and the relationships among those concepts. Ontologies range from simple taxonomies (such as the Yahoo hierarchy), to metadata schemes (such as the DCMI, 2003), to logical theories. The Semantic Web needs ontologies with a significant degree of structure. These need to specify descriptions for the following kinds of concepts:

- Classes (general things) in the many domains of interest.
- The relationships that can exist among things.
- The properties (or attributes) those things may have.

Ontologies are usually expressed in a logic-based language, so that accurate and meaningful distinctions can be made among the classes, properties and relations. Gruber (1993) defines an ontology as “an explicit specification of a conceptualization”, where conceptualization refers to the objects, concepts, and other entities that are assumed to exist within some domain of interest (the universe of discourse) and the relationships that hold among those entities.

A domain ontology specifies the concepts, and the relationships between concepts, in a particular subject area rather than specifying only generic concepts, as found in an upper ontology such as SUMO (the Suggested Upper Merged Ontology). A domain ontology models the information known about a particular subject and therefore should closely match the level of information found in a textbook on that subject.

Ontology Development

The development of an ontology is normally carried out by a team of people, such as domain experts, ontological engineers and pedagogues. Noy & McGuinness (2001) address reasons for developing ontologies and enumerate the stages involved in developing an ontology. The main reasons for developing an ontology are to share a common understanding of the structure of information among people or software agents, to enable reuse of domain knowledge

– a driving force behind the recent increase in ontology research –, and to make explicit those assumptions about a domain that are normally implied. If assumptions that underlie an implementation are made explicit in an ontology, then it is relatively easy to change the ontology if knowledge about the domain changes.

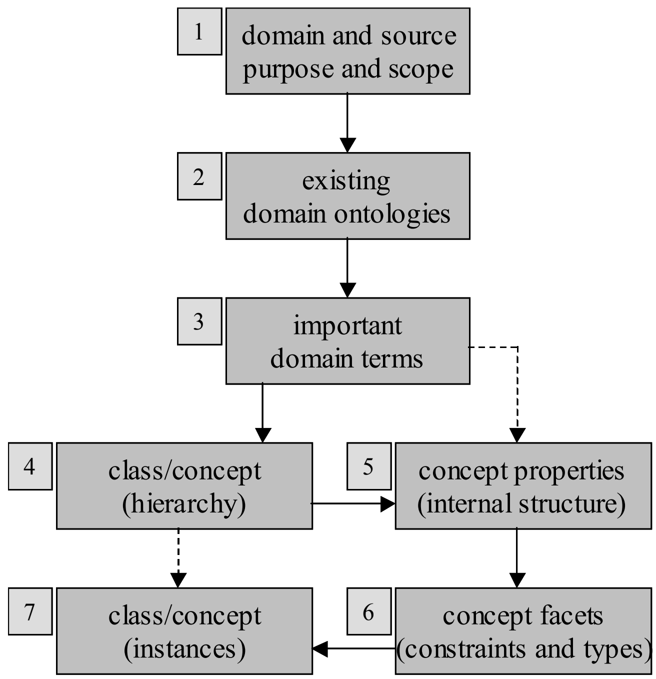

Figure 1. Ontology development process.

The general stages in the design and development of an ontology are as follows (see Figure 1):

- The first step involves determining the domain and source and also purpose and scope of the ontology. Questions that should be addressed at this stage include: what domain will the ontology cover?, what is the purpose of the ontology? and for what sorts of questions should the information in the ontology be able to provide answers?
- The second step is to ascertain if an ontology has been developed previously in the same subject area. If such an ontology exists, it is easier to modify the existing ontology to suit ones needs than to create a new ontology. Reusing existing ontologies may also be a requirement if the system needs to interact with other applications that have already committed to particular ontologies.
- The third step is to enumerate important terms in the ontology.
- Steps 4 and 5 are closely intertwined. They entail defining the classes (concepts) and the class hierarchy (Step 4), and defining the properties of classes (Step 5).
- Step 4. A number of different approaches can be taken when determining the hierarchy of classes. One could use a top-down approach, which starts with the definition of the most general concepts in a domain and continues with more specialized concepts. Another approach is the bottom-up approach, which starts with the definition of the most specific classes (the leaves of the hierarchy), with subsequent grouping of these classes into more general concepts. From the list of terms drawn up in Step 3, those terms that describe objects that have an independent existence should be extracted as these will form the classes (concepts) of the ontology. To determine the hierarchical organization of the ontology, for each class one should ask if the instances of that class could also be instances of a more general class. If the answer is yes, then this class constitutes a subclass of the other class and, hence, is further from the root concept in the ontology.
- Step 5. Once the classes have been defined, the next step is to describe the internal structures (properties) of the concepts. Again, these should be readily available from the list produced as a result of Step 3.
- Step 6 involves attaching facets to the properties, that is, describing the value type, allowed values, the number of allowed values (cardinality) and other features that are deemed to be necessary. In this way, constraints are placed on the types of data that are allowed.

- The final step 7 in the procedure is to create instances of the classes, that is to provide examples of each of the classes.

The Development of Course Ontologies

Knowledge Engineering in Educational Technology

Knowledge engineering addresses the structuring and representation of knowledge (Sowa, 2000). Ontologies have emerged as a central technique (Daconta et al., 2003) for knowledge integration, sharing and reuse.

There is a long history of the application of knowledge engineering techniques in educational technology. More recently, ontologies have attracted widespread attention (Devedžić, 2006; Sampson et al., 2004). Ontologies help us to make the knowledge that is represented in learning content explicit. Knowledge is central in learning; learners consume content to acquire knowledge. Knowledge is also important for the content developer, as content can be an elaboration of explicitly represented knowledge, and therefore a central ingredient for the development of content. Ontologies can fill the gap between authors and content and instruction representations in authoring systems (Mizoguchi & Bourdeau, 2000).

The ontology modelling notation is of central importance for course ontology development – a number of other aspects characterising the context need also be addressed. When developing an ontology for a course subject, one needs to identify the purpose, scope and domain of the ontology as well as a source of the domain knowledge using a systematic approach. These aspects shall be addressed in the remainder of this section. Our foremost research goal in this paper is to determine the most suitable ontological modelling notation for course or subject domain ontologies. The general process model (see Figure 1 in the previous section) shall be refined and applied to a case study subject in order to investigate the research goal.

Purpose and Scope

The purpose of this study is to design and develop an ontology in an area of third-level education that could be used in the provision of an e-learning course. Here, the research questions outlined at the beginning will be addressed.

The scope (Step 1) is limited to a number of areas. The first of these is the development of a domain-specific ontology. In the context of our research aims, it was first necessary to determine if the 'Is-a' relationship, which is the only relationship found in upper ontologies, is sufficient to express the semantics of relationships between concepts. If not, then a set of relationships needs to be chosen and defined. As it would not be possible to know in advance the types of relationships that would be required, the list of relationships was developed in conjunction with the development of the ontology.

Domain and Source

Before addressing design issues, the first task was to decide upon an area to investigate as the domain of interest (Step 1). Database systems were chosen as the domain. A number of factors influenced this decision from a research perspective.

- It is a broad subject area that was likely to yield a large number of concepts and associated relationships. These could be used to test the initial hypothesis that the 'Is-a' relationship is sufficient to express the semantics.
- It is a mature discipline within computing with an agreed body of core knowledge that is readily available.

A textbook was used as the source – "Fundamentals of Database Systems" by Elmasri & Navathe (2000). There are advantages to using a textbook as the source of ontology concepts. First, coverage of the domain of interest is extensive as the purpose of an introductory-level textbook is to provide a good grounding in the subject. Second, when each new topic is introduced, new terms are explained, thus providing the basis for concept definitions.

In order to evaluate our notation in a from-scratch ontology development, we did not use any existing domain ontology (Step 2).

A Systematic Approach to Ontological Modelling

Bearing in mind the seven general ontology development steps we presented, we used the following protocol to apply the general steps 3 to 7 in the context of ontology development for the database course:

- The first task towards generating the database ontology was to compile a list of possible concepts to include in the ontology. The relevant terms were extracted from the chosen textbook on the subject (Step 3) and were discussed with domain experts.
- The next task was to decide on a structure to use, covering a number of different aspects of the ontology. It was decided to use a top-down approach, which means to start with the most general concepts and progressively include more specific concepts (Step 4), as this matched the format in which information was provided in the textbook.
- Another design decision was to model the concepts and relationships using a graphical notation similar to that used in entity-relationship (ER) diagrams. Ontologies are meant to represent a shared understanding of some domain. Using a graphical notation would make it easier for non-experts to understand the important features of the ontology. As there is no logical difference between a graphical and a textual rendition of an ontology (Daconta et al., 2003), a graphical model was considered the best option.
- Having made the decision to represent the concepts and relationships in graphical format, the next stage was to use the compiled list of possible concepts and to define each term in terms of properties and examples (Steps 4 to 7). The approach taken was to record each term in the textbook that was domain-specific, i.e., that had a specific meaning in the context of databases. For example, while the term 'add' has a generally understood meaning in English, it has a specific meaning in database terminology. It is used for instance in conjunction with the SQL command ALTER TABLE to add a column to a table.
- Finally, using a similar approach to that taken by Fischer (2000), the ontology was divided into two spaces, one for the concepts that would form the basis of the ontology (the diagrams) and the other for those concepts related to educational content. If the ontology was implemented in a computerized system, the diagrams would form the backbone of the course and would be used to determine the delivery sequence, whereas the educational-content ontology would be used to provide additional information and examples for each concept.

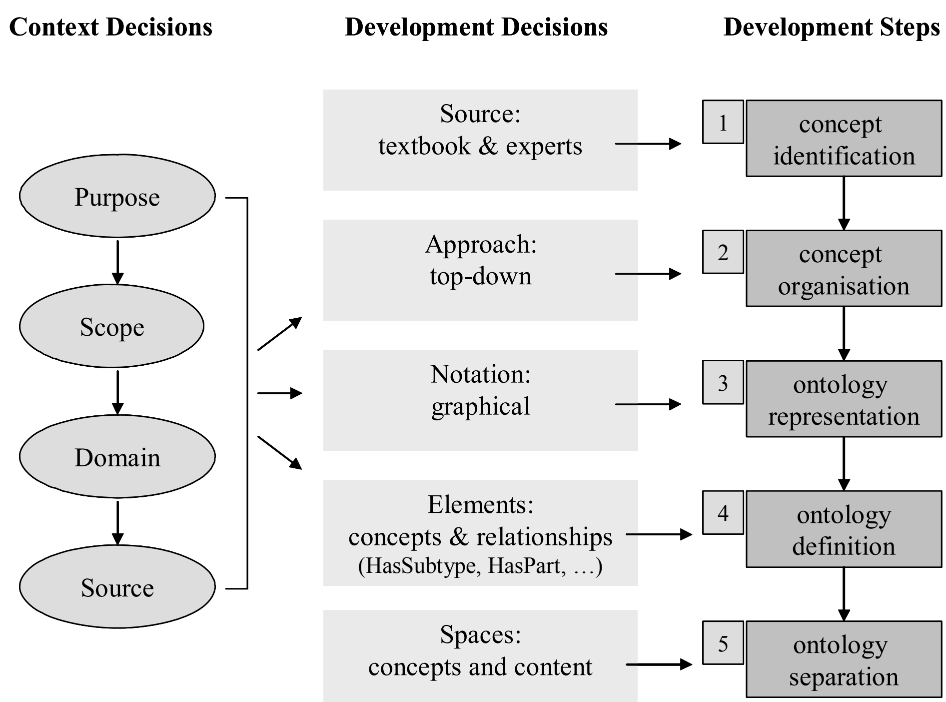

Figure 2. Summary of course development methodology.

This methodology is summarised in Figure 2. The methodology essentially consists of a number of contextual, high-level decisions that an ontology developer has to make before deciding on specific development aspects necessary to carry out a sequence of development steps.

Ontological Modelling of Domain Ontologies – a Case Study

Our research question concerns the richness of the ontological modelling support for course-subject ontologies. We address two course domains to discuss this question – the first one in a detailed content ontology case study in this section.

Concept Hierarchies – a Basic Ontology

An essential question was to determine if the ontology could be designed using the 'Is-a' relationship alone, as this is the relationship type used in most ontologies. It became apparent when creating the first part of the ontology, which covered the topic of data models in the databases domain, that while most relationships between the concepts within this data set could be catered for by the 'Is-a' relationship, there were some relationships between concepts that were not generalization/specialization relationships and therefore would be misrepresented if the 'Is-a' relationship was used (see darker diamonds representing these relationships in Figure 3). For this reason, a number of other relationship types were created and defined.

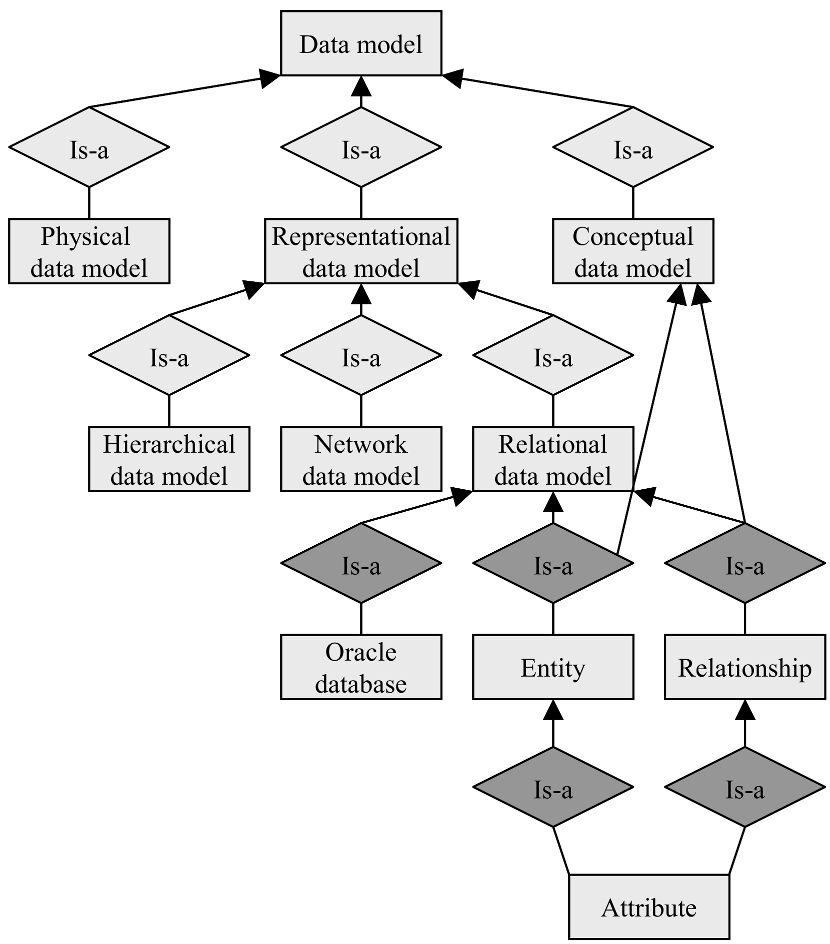

Figure 3. Data-model ontology using the 'Is-a' relationship.

A data model is a collection of concepts that can be used to describe the structure of a database. In Figure 3, the 'Is-a' relationship is used throughout. While this relationship type correctly describes most of the relationships between concepts, there are a few cases where this relation does not express the correct meaning for the relationship between the concepts. The concepts 'Relational data model' and 'Oracle database' are linked. However, as an Oracle database is an instance of a database that is built using the relational data model as its underlying model, it is incorrect to say that it is a subtype of the relational data model. The 'Is-a' relationship is also inappropriate in other cases. Entity and Relationship are not subtypes of the Relational data model. Instead, they are parts of the model. In order to rectify these misrepresentations, it was decided to define a number of other relationship types; see Figure 4, which represents the metamodel for our ontological modelling method.

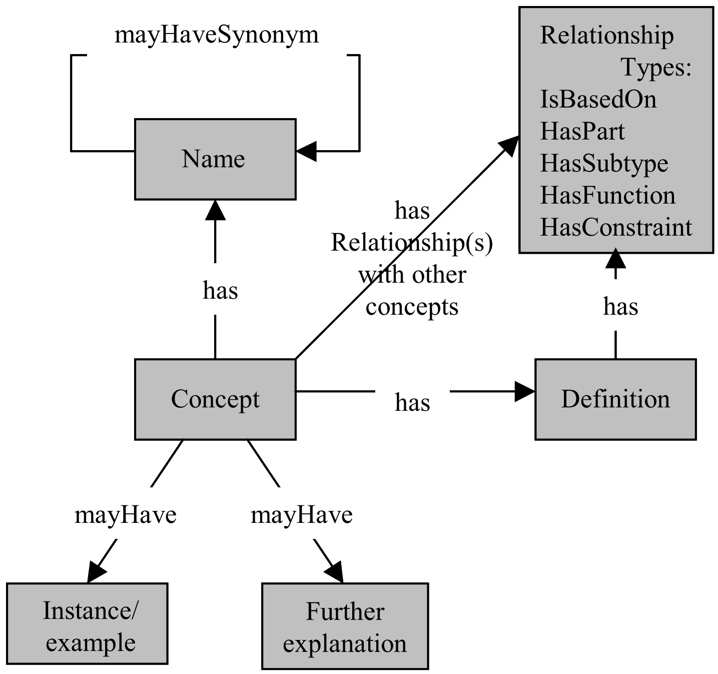

Figure 4. Overview of the relationship types.

Relationship Types – a Rich Ontology

As the ontology was being designed with delivery as a third-level educational course in mind, it was important to consider the type of information that would be required by a student that is not necessarily part of the concept ontology. For this reason, the approach used by Fischer (2001) was employed, whereby two sets of relationships were created for use in either the graphical representations (representing the concept space) or the associated content (creating the educational content space). An advantage of separating concepts from content is that content aspects in the system can be changed without affecting the overall structure or vice versa.

The objective was to create a minimal set of relationships (for both concepts and the associated educational content) that would be sufficient to represent all relationships between concepts both clearly and fully.

- General ontology relationship types for the concept space: An important relationship type is the 'Is-a' relationship. Unfortunately, use of this relationship type caused some difficulties. The correct use of the 'Is-a' relationship is to indicate a generalization/specialization relationship between two concepts. However, because of its common English usage, it often resulted in the generation of inappropriate relationships, by being used inadvertently to indicate synonyms or to associate a concept with its definition. For this reason, the 'Is-a' relationship was replaced by its inverse relation, which was called the 'HasSubtype' relation. The use of the 'HasSubtype' relationship made it much easier to avoid the pitfalls associated with the 'Is-a' relation, while remaining analogous to it. Another important relation indicates that a concept comprises a number of parts. This was called the 'HasPart' relation. Other relations used to link the concepts within the ontology were named

‘IsBasisOf’, ‘HasConstraint’ and ‘HasFunction’. These relations were included as the ‘HasSubtype’ and ‘HasPart’ relations did not always reflect the meaning of the relationship between two concepts adequately.

- Content relationship types for the educational content space: These are used to link a concept to some content. The relationship types used were ‘HasDefinition’, ‘HasSynonym’, ‘HasAsExample’ and ‘HasFurtherExplanation’. The concepts and their associated information were collated in separate tables, one for each relationship type. The ‘HasDefinition’ table contains an entry for each concept name used in the graphical representations. It also contains definitions for those domain-specific terms that are used in the definitions of concept terms. The other three relationships provide further information associated with the terms from the initial set (‘HasDefinition’).

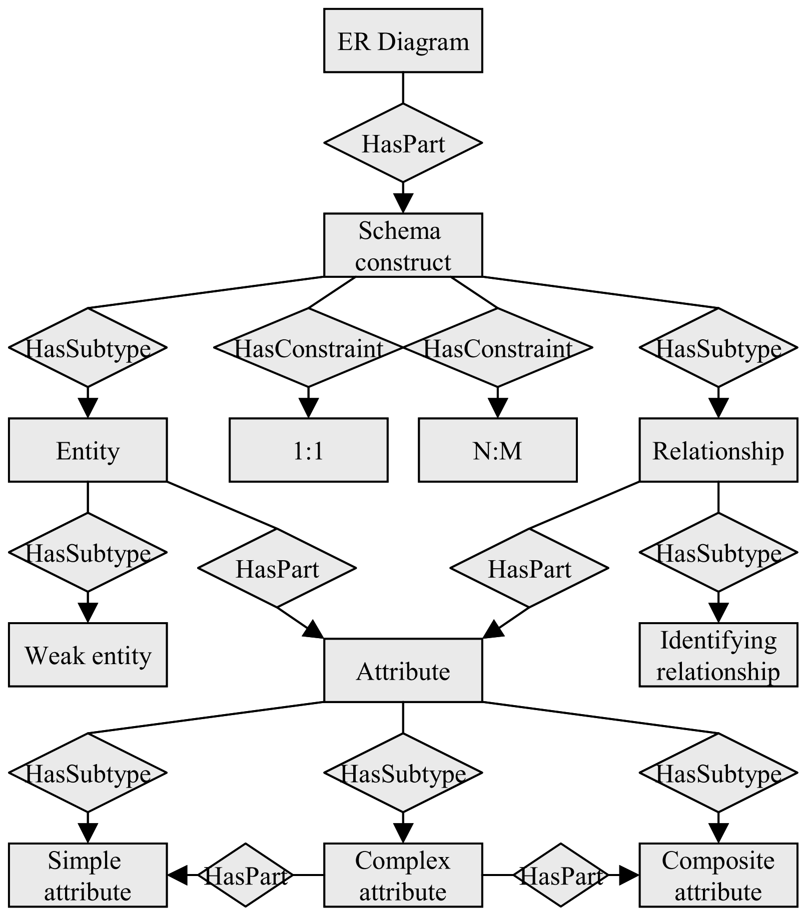

Figure 5. Excerpt of an ER-diagram ontology.

The rationale behind the choice of relationship types led to the following definitions for the two categories of relationships in the two spaces. The relations used in the concept space are as follows:

- IsBasisOf: This is the most fundamental of relationship types, expressing dependency. It is used to show that a concept in the universe of discourse forms the theoretical foundation for a second concept. This normally occurs as an unconstrained relationship between concept classes.
- HasSubtype: This is by far the most common relationship type. It is used to indicate the relationship between a general concept and all specializations (subsumptions) of that concept that are themselves simple concepts (i.e. those not comprising more than one attribute). This relation is the inverse of the ‘Is-a’ relationship type. This is a relationship that forms a hierarchy, indicating that a superconcept can have one or more subconcepts.
- HasPart: This is used to indicate that a concept comprises two or more subconcepts in a part—whole relationship (aggregation), for example chairs have the parts seat, back and legs, but legs, however, can also be

part of other objects such as tables. This is a relationship, which is not restricted to hierarchies, as HasSubtype is.

- HasConstraint: This relationship is used to describe a restriction on operations that may be performed. For example, a 1:N relationship between the concepts Company and Employee means that a single company can have several employees, but a 1:1 relationship between Company and Manager would indicate that a company could have exactly one manager.
- HasFunction: This relationship is used to indicate that a concept represents a function of its superconcept. For example, while the Relational data model is based on Set Theory, two of its main functions are to allow a user to Update or Query a database, which are not part of set theory.

HasConstraint and HasFunction are actually variants of HasSubtype and HasPart, respectively. The purpose of their explicit integration into the set of relationships is to convey specific situations in content development. While 'HasFunction' is not used here, it could be deployed in a remodelling of Figure 3, where it could be expressed that supporting queries and updates are functions of the relational data model. An example of the concept-space ontology can be found in Figure 5. It should be noted that this is an excerpt, focusing on the concept ER Diagram and its related concepts.

In the educational-content space, there are four relationship types:

- HasDefinition: This is used to indicate the link between a concept and a simple definition of that concept. There is always a 1:1 relationship between a concept instance and its definition.
- HasSynonym: This is used to indicate that a single concept may have one or more names. Here, a 1:N relationship applies, where N≥1.
- HasAsExample: This is used to indicate that the concept being linked to is an instance or example of the concept from which the link emanates. Again, this is a 1:N relationship with N≥1.
- HasFurtherExplanation: This is used as the link between a concept and further information that would be relevant to a student regarding that concept. This is a 1:1 relation, where a concept is linked to only one further explanation, which can be as long or short as required.

The example in Table 1 illustrates the content space. The different tables for the associated educational content that would normally be used are merged here for a single concept (Entity in this case).

Table 1. Example of the educational content associated with the concept 'Entity'.

Concept	Relationship	Augmentation
Entity	HasDefinition	Represents a real-world object or concept that is described in the database
Entity	HasSynonym	Object
Entity	HasAsExample	EMPLOYEE or PROJECT. Entity names are shown in block capitals
Entity	HasFurtherExplanation	A particular entity will have values for each of its attributes. The attribute values describing an entity become a major part of data stored in a database

Evaluation of the Ontological Model

Two essential aspects constitute our evaluation objective. Firstly, the correctness of the models has to be established. Domain experts such as instructors and researchers in a domain have looked at the conceptual modelling aspects; researchers in Semantic Web and ontology technology have looked at the specific issues of ontological modelling. Secondly, the adequateness of the methodology and its notation has to be analysed. Here, both domain and ontology technology experts have been involved. We look at this second aspect in our discussion in Section 5.

The conceptual and ontological correctness of the models is of central importance. This has been established through a formative evaluation consisting of discussions of the models with

- instructors and researchers in the databases and enzyme/protein chemistry domains as domain experts and potential end users to establish the correctness of the models in relation to the domains they aim to represent,
- researchers in knowledge engineering as experts in ontology engineering, in particular on methodological approaches and the ontological correctness of models in terms of internal consistency and aspects such as adequate consideration of context-independence, etc.

The presented results are a reflection of an iterative process of consultation that has provided critical evaluations. Widely used textbooks as the core sources of the ontology development are another contributor to the correctness aspect.

Discussion of the Ontological Modelling Notation

The adequacy of the proposed ontology-based knowledge modelling notation and its transferability onto different domains shall now be evaluated and discussed. We have conducted our research as a field experiment, determining the ontological modelling notation with its relationship types based on studies of particular domains and course content for these domains. We have reverse engineered course content and content sources ontologically, thereby identifying the most suitable ontology notation. We have focused on the database domain so far, but we will also address the transferability to other domains. We discuss this now in this research setting, but also in the context of related instructional design theories and models.

Modelling Knowledge for Course Content

From the examples given, it can be seen that the 'HasSubtype' relation is by far the most common. This is to be expected given that this is the only relation found in many ontologies (e.g. SUMO). The second most common relation is 'HasPart'. While this is catered for as a property of a concept in ontology editors such as Protégé (Noy & McGuinness, 2001), it is used in the database ontology to represent a part-whole relationship between concepts. This relation is analogous to the AEPart and EEPart relations used by Fischer (2001) in the Medibook ontology. Fischer also uses directed graphs in his ontology, but instead of a top-down structure, with the more general concepts towards the top of a hierarchy, the structure he uses is not hierarchical. For this reason, he has included the relationship type 'Superconcept' to indicate that one concept is a superconcept of another concept, whereas this information is available for all concepts in the database ontology by virtue of the tiered system of displaying the concepts. Fischer also has a relation called 'instanceOf', which is omitted from the database ontology as it is covered in the educational-content section by 'HasAsExample'. This had the advantage of separating subsumption (the subconcept relationship) from instantiation (the relation between concepts and their instances/examples), which is a common problem in ontology development (Guarino & Welty, 2002).

Ontologies are sharable conceptual models that enable logical reasoning about the represented knowledge in these models. Gruber's definition (Gruber, 1993) of a specification of a conceptualisation applies here. While an ontology provides a common vocabulary (a set of terms), a vocabulary cannot be said to be an ontology. The distinction between a vocabulary and an ontology is that a vocabulary deals with terms/names whereas an ontology is a theory of concepts rather than of the words used to identify the concepts (Mizoguchi, 2003; Mizoguchi, 2004). For this reason, synonyms are not an ontological issue. However, synonyms are important in a learning context. A user must be able to recognize a concept even if they know the concept by a different name. To cater for this, synonyms are included in the educational-content space.

Another interesting feature in the ER-diagram ontology is the use of reification. While reification is used in Semantic Web languages such as RDF (W3C, 2004) to enable statements to be made about statements, it is used slightly differently when structuring an ontology. An example of the use of reification is again found in the ER-diagram ontology. Concepts like 1:1, 1:N and M:N apply to both entities and relationships as they are used to restrict the number of links between instances of entities or relationships that are allowed. An example is a 1:1 relationship between a classroom and a teacher, which would mean that there could only be one teacher in a classroom, whereas there would be a 1:N relationship between a school and a classroom as a single school can have many classrooms. Instead of duplicating the concepts linked by the 'HasConstraint' relationship so that they could be linked to both 'Entity' and 'Relationship', a solution to the problem is to use the process of reification to create a concept ('Schema construct') that is more general than 'Entity' and 'Relationship' and link the concepts to that concept. Because of subsumption, the concepts linked to 'Schema construct' will apply to both 'Entity' and 'Relationship'.

An ontology of relations is not without problems, as already indicated in the subsumption/instantiation discussion earlier. While the majority of concepts in the ontology would fit into a tree structure, there are situations where this is not the case. In the ER-diagram ontology, the concept 'Attribute' has two parent concepts, 'Entity' and

‘Relationship’, which is permissible in a graph, but not in a tree structure. We have defined our hasPart relationship as graph-based, not restricted to hierarchies. This alleviates a common problem that arises if part-whole and subsumption relations are combined, where concepts – such as the legs in the semantical definition of hasPart – are unintentionally and wrongly contextualised as parts in a given subsumption (HasSubtype) relationship. Although our definition allows legs to be part of a number of concepts and their superconcepts, the general problem of unintentional misrepresentation in ontological modelling remains. Therefore, combining our methodology with a technique that ensures the ontological soundness and correctness of models such as the rules and guidelines given by (Guizzardi et al., 2004) and a more formal approach (Artale et al., 1996) would provide a comprehensive course ontology engineering framework, which is, however, beyond the scope of this investigation.

Transferability of Modelling Constructs

In order to determine if the relationship types chosen for the first ontology are domain-specific or are transferable to other domains, a second ontology was developed. However, it is not possible to answer the transferability question definitively as there is no way of knowing what ontologies will be developed in the future and what relationship types they will require. The most scientific way to try to address the question is to develop an ontology in an unrelated subject area. If the same relationship types can be applied in an ontology in a different educational domain, then it would be a strong indication that the relationship types are transferable. To ensure that the result obtained was unbiased, it was necessary to choose a subject area that was quite different from that of database systems. To this end, a subsection of biochemistry, namely enzymology, was selected (Voet & Voet, 1995; Nomenclature Committee of the International Union of Biochemistry and Molecular Biology, 1992):

- This is a narrower area of study than that of database systems.
- Like the area of databases, it is a mature area so there is consensus within the field.
- Unlike the area of databases, it is a theoretical subject and does not have a practical implementation (in the sense of applications being built to provide a service).

Enzymology is the division of biochemistry that deals with enzymes. Enzymes are biological catalysts, i.e., proteins that speed up a biochemical reaction but are not themselves used up in the process. This second ontology (see Figure 6) indicates that the defined relationships could indeed be used and are appropriate to develop an ontology in an unrelated discipline.

As can be seen from Figure 6, a subset of the relationship types created for use in the database ontology were employed. Only one relationship type was not used (‘HasFunction’). It is important to note that no additional relations were required, which supports the hypothesis that the relationship types chosen initially are sufficient to develop an ontology in diverse areas of third-level education.

Ontological Modelling and Instructional Design

Ontological modelling can be used as an instructional design technique. It can support the development of learning content. The notion of a knowledge object, similar to an ontology concept and its relationships, has already been used to identify the relationship between knowledge and content (Merrill, 1999). Merrill maps the structure of knowledge onto instruction. Based on knowledge objects, a network of elaborations that represent relationships is defined for a domain. A fine-granular classification of knowledge objects into entities, properties, activities, and processes is the basis for the modelling approach. Merrill proposes three basic relationship types: component, abstraction, and association. Relationship types are classifications of abstractions of learning activities. The notion of instructional transactions captures achieving a learning goal via a classified instructional activity. Merrill’s aim is the automation of instructional design by finding models that are not subject-specific.

The first two of Merrill’s relationship types, composition and abstraction, correspond directly to the ‘HasPart’ and ‘HasSubtype’ relationships of our concept space – although due to different aims and different basic building blocks, the resulting models would be different. Similar relationship types expressing composition and abstraction were also found, based on practical modelling in subject domains, in the Diogene Project (Diogene, 2003). Merrill’s association is a more generic relationship type, which in our context is instantiated by the other concept space relationship types. In our educational content space, we have introduced relationships such as ‘HasDefinition’, 'HasExample', and 'HasFurtherExplanation', which are also reflections of suggestions from the literature. Definitions and explanations are examples of what is called elaboration in concept learning; examples are also a central ingredient in this instructional design context.

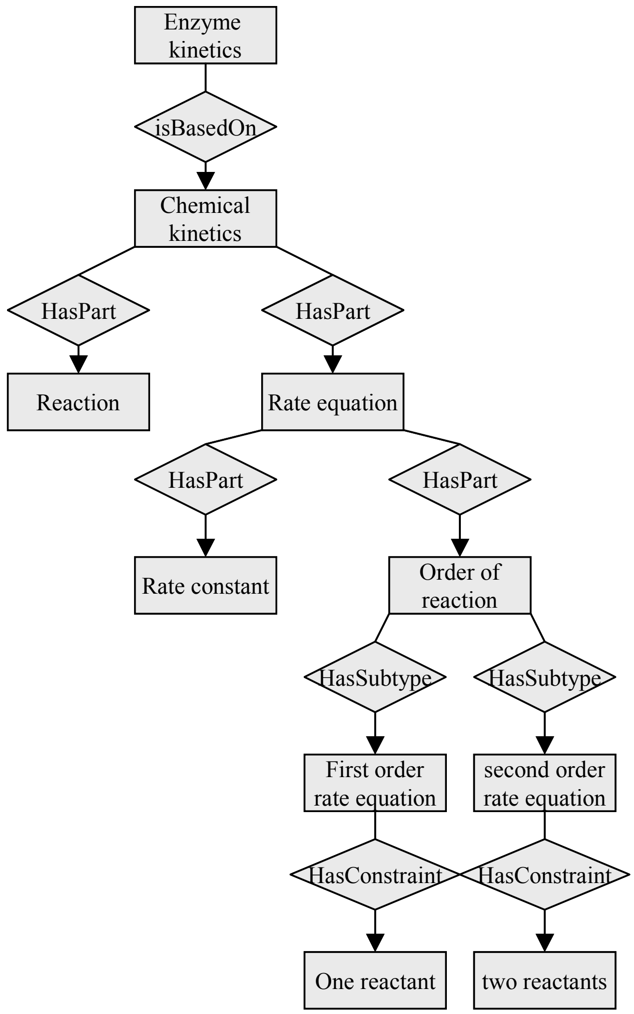

Figure 6. Enzyme-kinetics ontology.

Mizoguchi & Bourdeau (2000) reiterate Merrill's focus on modelling in the context of instructional design. Although our focus is on subject domain modelling for learning content, the link between our relationship types and, for instance, Merrill's instructional transactions is obvious. This observation regarding the elaboration of knowledge objects and concepts suggests that domain and instructional modelling can actually be linked and can be performed in sequence in content and course design. A task and instruction ontology that specifies the problem solving architecture of knowledge-based systems, as suggested by Mizoguchi and Bourdeau, can complement a domain ontology.

Ontologically represented knowledge can also be used to organise and sequence content as part of the instructional design. A concept taxonomy can provide a starting point to access content. Reigeluth (1999) argues that a course focuses on a specific type of knowledge and he provides a process model to support the organisation of a course based on specific knowledge elements. Ontological modelling can be combined with Reigeluth's elaboration theory. He defines sequencing guidelines based on the central type of knowledge:

- conceptually organized instruction – present the easiest, most familiar concepts first,
- procedurally organized instruction – present steps (activity concept) in sequential order,
- theoretically organized instruction – move from simple concepts to complex theory.

An ontology can here provide the abstract course structure in terms of the knowledge embedded in the course content in the form of concepts and their relationships.

Conclusions

Ontologies have been used in various educational-technology systems (Sampson et al., 2004). In particular, they can capture the knowledge aspects of educational content (Aroyo et al., 2002). However, ontologies for a particular subject may not exist or it might be unclear if existing ones are suitable. We have therefore addressed how content ontologies should appear with regard to their structure and quality, and how to develop content ontologies for educational technology. While most ontologies are based on the 'Is-a' relationship only, we found that rich ontologies using a variety of relationship types are most suitable for ontological content modelling. We followed an approach where the overall knowledge was divided into two spaces, the concept space and the educational content space. This structure separates the knowledge structure from the associated content, allowing more flexibility in utilizing the ontological model. The relationship types we found useful seem transferable between subjects based on our own experience and also relate to instructional design models, indicating that they could provide the basis for the development of ontologies in other areas and aid in the capture of educational knowledge and content. We have chosen two technical subjects for our investigation. In order to expand the applicability of our ontological modelling framework, a broadening of the subject base beyond technical subjects would be useful.

In conclusion, we have shown that it is possible for an individual to create a domain ontology, which bodes well for the future of ontology development. In the coming years, it is likely that, with increased development and availability of ontology tools, individuals will take up the challenge of developing ontologies in areas where they are domain experts and will make these ontologies available to the public. This will have a knock-on effect of making it easier for subsequent generations to adapt ready-made ontologies to match their needs, thus increasing the number of concepts that have associated definitions and therefore are semantically rich. This will result in increasing numbers of documents on the Web that are machine-processable, which would be a big step towards the Semantic Web (Berners-Lee et al., 2001).

An ontological model like the ones we have presented for the areas of databases and, to some extent, enzymology, can be used in a number of ways (Pahl & Holohan, 2004). The ontologies can provide an interface to the content. As we have discussed, these ontologies can guide the instruction design of a course. Learners (or instructors) can browse through the content guided by the dependencies expressed in the concept ontology, thus allowing for the delivery of a course in a way that matches the preferred learning style of the user by varying the sequentialization of content elements. A combination of a concept ontology and associated content can also be used to generate a separate content representation.

References

Aroyo, L., Dicheva, D., & Cristea, A. (2002). Ontological Support for Web Courseware Authoring. In Cerri, S.A., Gouarderes, G. & Paraguacu, F. (Eds.), *Proceedings of Intelligent Tutoring Systems*, Berlin: Springer, 270-280.

Artale, A. Franconi, E., Guarino, N., & Pazzi, L. (1996). Part-Whole Relations in Object-Centred Systems: An Overview. *Data & Knowledge Engineering*, 20, 347-383.

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). The Semantic Web. *Scientific American, 284* (5), 34-43.

Boyce, S. (2004). *Investigation of Ontology Relationships used for the Modelling and Generation of Educational Content*, M.Sc. Dissertation, School of Computing, Dublin City University.

Daconta, M. C., Obrst, L. J., & Smith, K. T. (2003). *The Semantic Web – a Guide to the Future of XML, Web Services, and Knowledge Management*, Indianapolis, USA: Wiley & Sons.

Devedžić, V. (2006). *Semantic Web and Education*, Berlin: Springer-Verlag.

Diogene. (2003). *The Diogene Project,* Retrieved June 6, 2007, from http://www.crmpa.it/diogene/.

DCMI (2003). *DCMI Metadata Terms,* Retrieved June 6, 2007, from http://www.dublincore.org/documents/dcmi-terms/.

Elmasri, R., & Navathe, S. B. (2000). *Fundamentals of Database Systems*, Reading, MA, USA: Addison-Wesley.

Fischer, S. (2001). Course and exercise sequencing using metadata in adaptive hypermedia learning systems. *Journal on Educational Resources in Computing, 1*(1), Article 5.

Guarino, N., & Welty, C. (2002). Evaluating ontological decisions with OntoClean. *Communications of the ACM, 45*(2), 61-65.

Guizzardi, G., Wagner, G., Guarino, N., & van Sinderen, M. (2004). An Ontologically Well-Founded Profile for UML Conceptual Models. In Persson, A. & Stirna, J. (Eds.), *Lecture Notes in Computer Science, 3084*, 112-126.

Gruber, T. R. (1993). *Toward principles for the design of ontologies used for knowledge sharing*, Retrieved June 7, 2007, from, http://www.cise.ufl.edu/~jhammer/classes/6930/XML-FA02/papers/gruber93ontology.pdf

Merrill, M. D. (1999). Instructional transaction theory: instructional design based on knowledge objects. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory*, Hillsdale, NJ: Lawrence Erlbaum, 397-424.

Mizoguchi, R. (2003). Tutorial on ontological engineering – Part 1: Introduction to ontological engineering. *New Generation Computing, 21*(4), 365-384.

Mizoguchi, R. (2004). Tutorial on ontological engineering – Part 2: Ontology development, tools, and languages. *New Generation Computing, 22*(1), 61-96.

Mizoguchi, R. & Bourdeau, J (2000). Using ontological engineering to overcome common AI-ED problems. *International Journal of Artificial Intelligence in Education, 11*(2), 107-121.

Nomenclature Committee of the International Union of Biochemistry and Molecular Biology (1992). *Enzyme Nomenclature. Recommendations 1992*, San Diego, USA: Academic Press.

Noy, N. F., & McGuinness, D. L. (2001). *Ontology Development 101: a guide to creating your first ontology*, Retrieved June 7, 2007, from http://www-ksl.stanford.edu/people/dlm/papers/ontology-tutorial-noy-mcguinness.pdf.

Pahl, C., & Holohan, E. (2004). Ontology Technology for the Development and Deployment of Learning Technology Systems - a Survey. In L. Cantoni & C. McLoughlin (Eds.) *Proceedings of ED-MEDIA 2004 - World Conference on Educational Multimedia, Hypermedia & Telecommunication*, Chesapeake, VA: AACE, 2077-2084.

Reigeluth, C. M. (1999). The elaboration theory: Guidance for scope and sequence decisions. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory (Vol. 2)*, Hillsdale, NJ, USA: Lawrence Erlbaum, 425-459.

Sampson, D. G., Lytras, M. D., Wagner, G., & Diaz, P. (2004). Ontologies and the Semantic Web for E-learning. *Journal of Educational Technology and Society, 7*(4), 26-142.

Sowa, J. F. (2000). *Knowledge Representation – Logical, Philosophical, and Computational Foundations*, Pacific Grove, CA, USA: Brooks/Cole.

Uschold, M., & Gruninger, M. (1996). Ontologies: principles, methods, and applications. *Knowledge Engineering Review, 11*(2), 1-63.

Voet, D., & Voet, J. G. (1995). *Biochemistry*, New York: John Wiley.

W3C (2004). *The Semantic Web Initiative,* Retrieved June 6, 2007 from http://www.w3.org/2001/sw.

Chen, C. H., Yang, J. C., Shen, S., & Jeng, M. C. (2007). A Desktop Virtual Reality Earth Motion System in Astronomy Education. *Educational Technology & Society*, 10 (3), 289-304.

A Desktop Virtual Reality Earth Motion System in Astronomy Education

Chih Hung Chen[1], Jie Chi Yang[2], Sarah Shen[3] and Ming Chang Jeng[4]
[1]Department of Mechanical Engineering, National Central University, Taiwan // spooky@mail2000.com.tw
[2]Graduate Institute of Network Learning Technology, National Central University, Taiwan // yang@cl.ncu.edu.tw
[3]Department of System Engineering, Institute for Information Industry, Taiwan // sarahshen215@hotmail.com
[4]Department of Mechanical Engineering, National Central University, Taiwan // jeng@cc.ncu.edu.tw

ABSTRACT

In this study, a desktop virtual reality earth motion system (DVREMS) is designed and developed to be applied in the classroom. The system is implemented to assist elementary school students to clarify earth motion concepts using virtual reality principles. A study was conducted to observe the influences of the proposed system in learning. Twenty-one sixth-grade students participated in the study. Statistical results show that the scores in the pre-test and post-test significantly differ and using virtual reality can assist students in understanding the concepts. Besides, four design recommendations – *information*, *spatial behavior*, *manipulation* and *concept representation* – for improving the desktop VR system in education are also presented.

Keywords

Desktop virtual reality, Earth motion, Astronomy education, Guided discovery learning

Introduction

Astronomy is an essential part of science education. However, many children have difficulty understanding some concepts in astronomy, such as: the size and shape of the Earth; the cause of day and night; the cause of seasons, and the orbits of the Earth, the Sun and the Moon (Dunlop, 2000). Some investigations have shown that the misconceptions in astronomy are found in children from various countries (Diakidoy and Kendeou, 2001; Vosniadou and Brewer, 1994). Many studies have also demonstrated that children utilize a limited number of mental models when studying astronomy (Agan, 2004a, 2004b; Baxter, 1989; Diakidoy and Kendeou, 2001; Finegold and Pundak, 1991; Ojala 1997; Vosniadou, 1991). Although understanding grows with age, some misconceptions still persist into the adulthood (Dove, 2002). Conventional teaching materials and methods represent 3D space with 2D diagrams, which are hard to interpret (Parker and Heywood, 1998).

Strategies and methods helping students correct misconceptions include lectures, web pages, substantiation, 2D diagrams, Macromedia® Flash animations, 3D models, scientific-grade telescopes, NASA space data and Virtual Reality (VR) (McKinnon and Geissinger, 2002; Pena and Quilez, 2001; NASA, 2006). VR can effectively denote spatial concepts, and can provide learners with an immersive learning environment. VR is highly promising for computer-based training and simulation. Many previous studies have revealed that VR is highly beneficial to education (Crosier et al., 2002; Byrne and Furness, 1994; Dede, 1995; Winn, 1997; Kaufmann et al., 2000; Pantelidis, 1993). Therefore, VR has already been used in many subjects, such as Biology, Chemistry, Physics, Astronomy and Medicine. The characteristics of VR – *visualization*, *interactivity*, and *immersion* – make it a useful method to stimulate learning motivation (Osberg, 1995) and help immerse learners in a learning environment.

VR has already been shown to enhance learning effectiveness, but has limitations and disadvantages in the classroom. Despite advances in VR technology, it is still inaccessible to teachers in the classroom because of complex equipments and high cost. Not every school can afford HMD, trackers and other VR-related utilities like Cave Automatic Virtual Environment (CAVE®), which is developed at the University of Illinois in Chicago. Teachers need to spend much time learning and configuring the equipments. Desktop VR is a low immersive VR that can be easily applied in the classroom by teachers without high cost. Furthermore, the low immersion of Desktop VR means that learners lack simulator sickness.

This study designed and developed a desktop VR Earth Motion System (DVREMS) aimed at teaching elementary school students Earth motion in astronomy education. The DVREMS is expected to exploit the benefits of VR to help students clarify their unclear conceptions. The DVREMS was practiced in the classroom, and an evaluation was conducted to evaluate the effectiveness of the system.

Literature review

Astronomy education

Many science curricula include astronomy topics. The National Science Education Standards (NSES) expects students in grades 5-8 to describe the motions of the solar system from a heliocentric (Sun-centered) perspective and explain phenomena including day/night, seasons, rotation/revolution and size of the Sun, Earth and Moon (Adams and Slater, 2000). NSES provide a framework to design curriculum for K-12 astronomy education (Adams and Slater, 2000). Children's understanding towards these concepts is fundamental for further conceptual development in astronomy.

Previous studies have indicated that most children do not easily understand these natural phenomena, and frequently have misconceptions. Dunlop (2000) surveyed previous studies and concluded that common astronomy misconceptions among children include the shape and size of the Earth, the cause of the day/night cycle, the cause of the seasons and the length of daytime. A study also revealed the similar observation in children and shown that children easily think those astronomy phenomena in wrong way (Bailer and Slater, 2003).

The difficulty of developing and building children's better understanding of natural phenomena has several reasons. Some researchers have found that the majority of the children used a limited number of mental models relating to observational experience (Agan, 2004a, 2004b; Baxter, 1989; Diakidoy and Kendeou, 2001; Finegold and Pundak, 1991; Ojala 1997; Vosniadou, 1991). These children tended to describe and explain the natural phenomena based on their naive notions or an alternative framework. For example, children often assert that the Earth is shaped like a flat disc (Dunlop, 2000). Older children may change their mental models to enable them to retain as many as possible of their experiential beliefs without contradicting adult teaching. Although understanding grows with age, even most undergraduate students still hold misconceptions. Studies have indicated that college students even have misconceptions in basic astronomy (Trumper, 2000).

Moreover, traditional materials such as lecture and textbooks are inadequate for teaching astronomy. Parker and Heywood (1998) indicated that 2D diagrams that attempt to represent 3D space are hard to interpret. Pena et al. (2001) also demonstrated that the images in textbooks do not always facilitate the understanding of concepts. Misleading diagrams may encourage alternative views in children (Ojala, 1997; Vosniadou, 1991). However, most teachers only adopt straightforward approaches such as images, photos, 2D animations or substantiations to teach students astronomy in the classroom. Guiding students with conventional methods is insufficient to help them understand complicated astronomical concepts. Therefore, developing an effective method to help children clarify conceptions is a significant issue in astronomy education.

Virtual reality in education

Virtual reality is defined as a real-time graphical simulation in which the user interacts with the system via analog control, within a spatial frame of reference and with user control of the viewpoint's motion and view direction (Moshell and Hughes, 2002). The definition can be extended to encompass a highly interactive, computer-based multimedia environment in which the user becomes a participant in a computer-generated world with various stimuli, including sound and tactile sense (Shin, 2002). In contrast with simulation, VR adds the specific requirements of a spatial metaphor and free viewpoint motion, providing learners with a rich set of accessible options.

Initially, VR has been mostly employed by the military and the aviation industry. The main aim of VR is to train soldiers and pilots in a safe simulated world. Modern technology allows new VR applications in different domains such as architecture design and medicine. VR also permits new learning experiences, and hence has significant potential in the education domain. VR is increasingly being applied as an educational tool in many subjects, such as Biology (Allison et al., 1997), Chemistry (Ferk et al., 2003), Physics (Dede et al., 1999), Astronomy (Barab et al., 2000; Johnson et al., 1999) and History (Maloney, 1997). These investigations have also found positive learning outcomes in VR.

Previous studies have shown that VR is a valuable tool to stimulate learning motivation (Osberg, 1995), and assisting learners to become immersed in the learning environment. VR technology enables different views of a situation, facilitates constructive learning activities (Shin, 2002), supports different types of learners, and supports spatial behavior enhancement (Durlach et al., 2000). Kalawsky (1996) also denotes nine characteristics including exploration, interaction, non real time, performance assessment, sense of scale, simulation, visualization, repeatability and abstract representation to emphasize the educational attributes of VR.

VR is often treated as an application of experience learning. According to the cone of experience theory (Dale, 1946), learners only remember 10% of what they read but remember 90% of what they say as they perform an action by seeing and doing in simulation experiences. Virtual environments allow learners to experience conditions virtually. VR has also been applied to situated learning by providing tasks within a realistic story and appealing characters and situations, empowering learners whose cognitive styles are suited to traditional linear book, helping them construct their own mental models (Moshell and Hughes, 2002). Conversely, VR also serves in discovery learning, especially guided discovery. According to Ormrod's definition (Ormrod, 1995), discovery learning is "an approach to instruction through which students interact with their environment – by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments". VR provides a virtual environment for students to investigate. During the exploration, the instructor devises a set of questions that guide the learner to make a series of discoveries leading to a single predetermined goal (Freeman, 1989). Students thus easily remember concepts that they discovery by themselves.

Desktop virtual reality systems in education

As described earlier, desktop VR is a cheap and widely available solution, and is easily adopted by teachers and students without expensive equipments. Therefore, desktop VR is a suitable educational tool in the classroom. Up to date, more and more desktop VR systems have been developed in educational domain. The authors divided desktop VR systems into three types according to their main operations. The three types are interpersonal communication, information browsing and hands-on experience. Each type can be applied to the different demands of subject domains. For example, science teachers may expect students to learn by doing whereas art teachers may expect students to watch and appreciate a lot of paintings. Therefore, functions of hands-on experience and information browsing may be suitable for these two needs, respectively. Table 1 lists some of famous desktop VR systems in education.

Table 1. Some desktop VR systems in education

System name	Type*	Instructional method	Target users
Active Worlds	I	User builds the world what they want and system provides social interaction functions	High school and college students, adults
Virtual European School (VES)	I	A 3D community that provides educational material, communication and multi-user interaction	Secondary school students
Virtual Museums, MoMA, Metropolitan Museum	II	360° virtual tours of each exhibition room and architectures of the museums	Masses
Physics Education Research (PER)	III	Provide VR labs to probe physical laws such as liner motion, circular motion and collisions	High school students
Virtual Reality Physics Simulation (VRPS)	III	Provide VR labs to probe science such as wave propagation, ray optics, relative velocity, electric machines, etc.	High school and college students
Virtual Radioactivity Laboratory	III	Provide VR labs to probe radioactivity	College students
Web Talk-I & II	I, II	An expert or an automated avatar guides users to view the exhibitions in real time. Users can discuss with the expert and other users during virtual tours	Masses
Shrine Education Experience (SEE)	I, II, III	Develop a museum virtual world, and provide socializing and manipulation in the virtual world	High school students

* **Type I**: Interpersonal communication, **Type II**: information browsing, **Type III**: hands-on experience

Systems of type I provide different communications and interactions between users to support collaborative learning activities. Some famous systems include Active Worlds (Riedl et al., 2001) and Virtual European School (VES) project (Bouras et al., 2001). This kind of VR systems build virtual societies or communities and congregate different users to have common activities such as chat, discussion, sharing, review, teaching and learning. Take Active Worlds for example, the system provides abundant materials and wide virtual worlds to assist users to build their own worlds. User can visit friends' worlds and have many social activities like developing their own organization. For that matter, teachers build the teaching environment what they need and make students interact and learn in the environment.

Systems of type II let users to navigate a replica of a real place, browse exhibitions or phenomena, and get information about exhibitions. Most VR systems such as Virtual Museums project (Lepouras et al., 2001), MoMA and Metropolitan Museum are presented in virtual museums. Users walk through the virtual environment to explore paints, statues, buildings or even animals.

VR systems of type III are applied to simulation and experiment especially in science and related domains. This kind of systems provides opportunities to users to manipulate the virtual objects. By repeated practices or simulation, users view processes in a much more detailed and controlled way such as slow motion, in a very large or small scales. Users have more freedom to choose what conditions that they want to test and understand the relationships of different factors and parameters. Physics Education Research (PER) (Demaree et al., 2005), Virtual Reality Physics Simulation (VRPS) (Kim et al., 2001) and Virtual Radioactivity Laboratory (Crosier et al., 2000) are some applications of this type.

Although three types of VR systems in education were revealed here, many new VR applications, such as Web Talk (Barbieri, 2000; Barbieri and Paolini, 2001) and Shrine Education Experience (SEE) project (Di Blas et al., 2003, 2005) tried to integrate with the characteristics of different types. In Web Talk-I and II, user can discuss with an expert and other users when visiting virtual museums. The SEE project is a manifest example that develops a museum virtual world, and provides socializing and manipulation in the virtual world.

Virtual reality systems in astronomy education

In science education, astronomy and earth science include many topics that are hard to observe and measure in real situations, making VR an appropriate method for learning these subjects. VR allows situated learning and makes learners perceive the spatial configuration. Furthermore, the 3D objects in virtual environments can denote concepts that are hard to denote using 2D diagrams.

Table 2. Some VR systems in astronomy education

System name	Learning content	Instructional method	Target users	Category
Round Earth Project	Shape of the Earth	Navigate by CAVE® and an immersadesk using collaborative learning	Elementary school students	Immersive VR
Virtual Solar System (VSS)	Solar system	Use 3D modeling software to construct models of Solar System	Undergraduate students	Desktop VR
Virtual Physics and Astronomy (VPA)	Planets' orbits relative to the ecliptic plane, cosmic facts and physical laws	Navigate in Virtual Planetarium made by VRML	Secondary school students	Desktop VR
AstroTour	Earth & Moon, Solar system, Stars, Galaxies, Universe	Wear 3D glasses in the virtual reality theatre	Elementary and secondary school students, teachers	Immersive VR

Table 2 lists some famous VR astronomy systems, including the Round Earth Project (Johnson et al., 1999), Virtual Solar System (VSS) (Barab et al., 2000; Hansen et al., 2004a, 2004b; Hay et al., 2002), Virtual Physics and Astronomy (VPA) project (Skaley and Zlender, 2000) and AstroTour (AstroTour, 2006). These VR systems provide virtual environments to teach astronomy knowledge. In the Round Earth Project, students learn the concept "the earth is round" by immersion in the CAVE® system. Collaborative learning is integrated into the instruction to improve students' understanding of concepts. However, CAVE® is too expensive for many schools. In the Virtual Solar System (VSS), students build a Solar System using 3D modeling software. Students were also found to understand and conceptualize 3D relationships well using the system. However, modeling work is too difficult for elementary school students, and most undergraduate students need time to practice using 3D modeling programs. The VSS team also studied the potential of the tools in supporting K-12 children. Virtual Physics and Astronomy (VPA) is a web-based learning platform using VRML (Virtual Reality Modeling Language) for Physics and Astronomy courses. The Virtual Planetarium is a part of VPA enabling students to explore the planets' orbits freely. It provides web-based and multimedia learning environment in the classroom and only focuses on secondary school students. In AstroTour, children wearing special 3D glasses sit in the theater to take a trip through the Universe. AstroTour teaches students about topics such as planets, pulsars, galaxies gravitational collapse, tiny meteorites and the large astronomical structures, but only provides 3D movies rather than interaction with the virtual environment.

System design and implementation

As described earlier, most VR systems are not suitable to be applied easily in the classroom. A virtual reality Earth motion system was designed and implemented with the help of science teachers. The system was built on desktop PC and can be applied easily in the classroom. Using the advantages of desktop VR overcomes the obstacles of traditional materials in astronomy education. The astronomy contents of the system focus on elementary school students. Integrated with VR and guided discovery learning assists students in clarifying unclear concepts about astronomy.

Although some VR educational environments are being used because they support collaborative learning activities and augment the emotional involvement of students, face-to-face communication is still a key feature in the classroom. It can be found that face-to-face interactions still existed even if the multi-user interactions of VR system were applied in the classroom. To decrease the complexity of the combination of face-to-face and collaborative learning in the VR environment, collaborative learning activities were not taken into account. Instead, face-to-face communication was focused in the study.

Table 3. Viewpoints

Viewpoints	Observation topics
Full view (default)	Sun-centered
From the South Pole	Midnight sun in the South zone
From the North Pole	Midnight sun in the North zone
From Taiwan	Compare daytime length with Australia; Compare day & night difference with America
From Australia	Compare daytime length with Taiwan
From America	Compare day & night difference with Taiwan
Top view at South Pole	The rotation direction
Top view at North Pole	The rotation direction
Side view of the Earth	The Earth's axis
Top view of the Solar system	The Earth's revolution

System design

The system is designed from three aspects as the following:

- *Free exploration*: Exploration is a key element of discovery learning, and is also the essential characteristic of VR. The DVREMS was designed using a student-centered approach focusing on students and their tasks. Table 3 shows some viewpoints designed to guide students to learn concepts in the virtual environment. The authors design these different viewpoints to enable students to compare astronomy phenomena in different locations. For instance, students can observe in Australia and Taiwan to understand the seasonal differences between the Southern and Northern Hemispheres, and in Taiwan and America to understand the difference between day and night. To prevent students from getting lost in the virtual world, an auxiliary map at the left down corner of the screen lets students know where they are in the map.

- *Teacher involvement*: One way of making a system useful and usable in the classroom is to ask teachers what they want and involve them throughout the development process. A teacher with a science background was involved in the design of the system, and generated a suitable lesson plan. The topics, driven questions, learning contents and discovery tasks were designed based on the teacher's teaching experience and knowledge. The teacher adjusted the difficultly of learning contents and provided interesting driven questions because he understood well what students think and how they comprehend astronomy concepts. In general, teachers' anxiety and unfamiliarity towards computer application is a huge obstacle to bring new information technology into the classroom. However, the teacher who involved in the study has to be an experienced science and computer teacher. Therefore, he made the teaching process smoothly when using the DVREMS in the classroom. He encourages students to discuss each other, share their findings, teach classmates each other, and demonstrate their operations of the system. Students got familiar with the system in a short time and participated actively. Teacher involvement is a successful factor to promote face-to-face communication in the classroom.
- *Guided discovery learning*: Guided discovery learning is an instructional strategy that exploits the merits of a learner centered approach (Spencer, 1999). Guided discovery learning has key features such as: study guides of guided discovery learning are used to facilitate and guide self directed learning; understanding is reinforced through application in task-based and problem-oriented experiences. In the DVREMS, free navigation enables exploring and learning in the virtual world. However, students easily lose and ignore what they observe. The system was expected that students have self directed learning when using the system. Students need scaffolding to guide them to discovery and learn. Guided discovery learning provides statements or questions to guide students. Therefore, the system provides driven questions to motivate them to explore, and provides hints to guide them where and how to answer the driven questions. The topics and driven questions are listed in Table 4. For example, the first driven question is, "Does the Earth rotate?" Students observe the Earth to find out the answers in the virtual environment. If they do not know how to observe the phenomena or where to find out, they can read the hints and then manipulate the system. The hint of this driven question guides them to observe from the side view of the Earth and the signs of directions show on screen to assist them to understand the rotation way of the Earth. Each driven question has similar hints and signs.

Table 4. Topics and driven questions

Main topic	Sub topic	Driven questions
Rotation	Rotation	Does the Earth rotate?
	Period	How long is the earth's rotation period?
	The Earth's axis	What's the Earth's axis?
	Direction	The Earth's rotation direction?
	Phenomenon	What would it happen, if the Earth did not rotate?
Revolution	Revolution way	How does the earth orbit?
	Period	How long is the Earth's revolution period?
	Direction	The revolution direction?
	Phenomenon	What would it happen, if the Earth did not orbit?
The Earth's axis	Tilted axis	Is the Earth's axis vertical?
	Day/night cycle	What causes the day/night cycle of the Earth?
	Four seasons	What causes the seasons of the Earth?
	Phenomenon	What would it happen, if the Earth's axis were vertical?

System implementation

The DVREMS is implemented on Microsoft® Visual C++ 6, with OpenGL as the 3D API. A Pentium 4-266 personal computer with 512 MB ram is utilized as the server. Students can use the system through the browser. ActiveX techniques are integrated to display the virtual environment in the client. The system can be downloaded to the client and can be run without Internet connection. The lowest requirement of a client's computer is a Pentium III-733 with 256MB and 8MB graphic card. The server installs ActiveX component automatically before the user executes the system with the browser.

In some other VR systems, users apply devices like tracker and HMD to interact with the virtual environment. The DVREMS employs desktop VR for use in the classroom. But the system can easily be transformed into immersive VR by using CAVE®. Teachers can select a system according to their needs or equipments. The DVREMS is also suitable for use with advanced equipments.

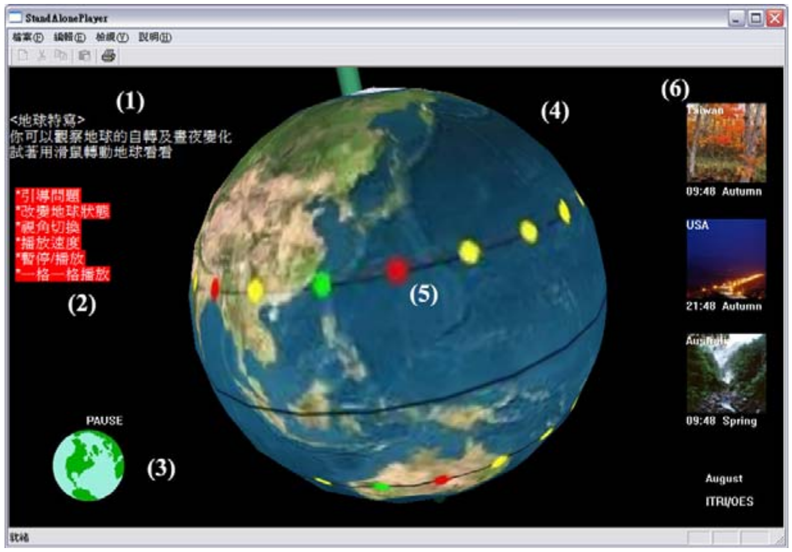

Figure 1. A screenshot of the DVREMS (from Side view of the Earth). The different areas represent as: (1) Drive questions and hints, (2) main menu, (3) auxiliary map, (4) the 3D Earth model, (5) auxiliary lines, and (6) zones information

Figure 1 shows a screenshot of the DVREMS from the viewpoint of the Earth side. Area 1 denotes the driven questions and hints. Students read the driven questions and hints to determine the learning topics and then manipulate the system. Area 2 represents the main menu enabling students to choose various contents, control speed, change viewpoints and switch auxiliary lines. The auxiliary map (area 3) depicts the location of viewpoint to prevent students from losing their way in the system. Area 4 indicates the 3D model of the Earth, and auxiliary lines (area 5) are attached to the Earth model. The colored points on the auxiliary line are used as the symbols for different time zones. Three colors are applied in the system. Green points denote specific locations (Taiwan, America and Australia). To help students count daytime length, all auxiliary lines are divided into 24 parts to denote 24 hours. Red points are located in every 3 time zones, and each yellow point represents one hour. Area 6 indicates the zones information of time, seasons, day/night times in Taiwan, America and Australia, and the real-time information changes with the rotation and revolution of the Earth.

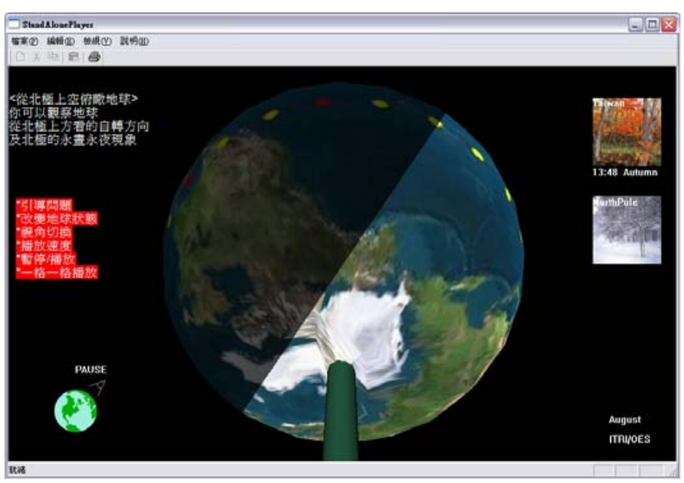

Figure 2. View from the North Pole

Figures 2-5 display screenshots of the DVREMS of different viewpoints. In Figure 2, students view the Earth from the North Pole to observe the midnight sun. In the whole view (Figure 3), students observe the Earth orbiting the Sun to understand heliocentricity. Figure 4 depicts the side view of the Earth, and students explore the half-shaded and half-lit Earth to understand the distinction between day and night. Viewing from the Earth (Figure 5) teaches the causes of star movement, sunrise and sunset.

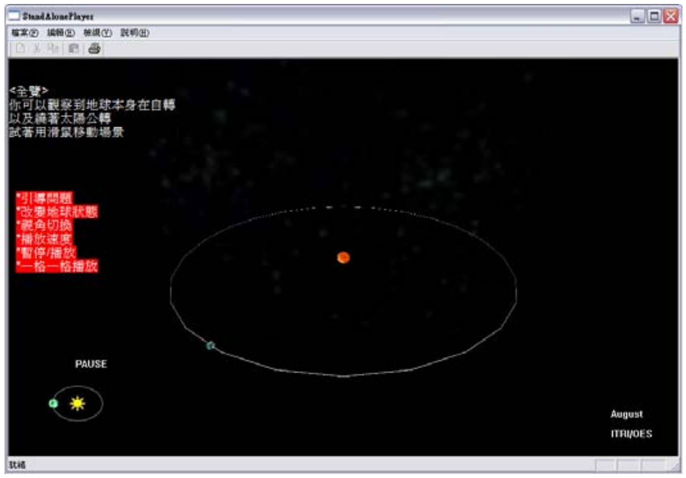

Figure 3. The whole view

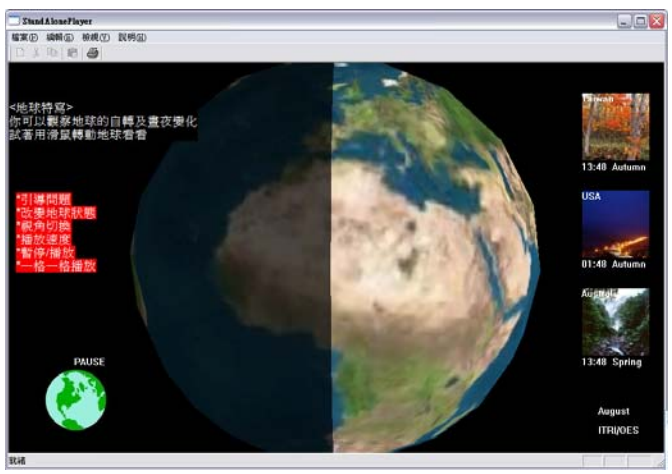

Figure 4. Half-shaded and half-lit Earth

Figure 5. View form the Earth

The study

Method

The objective of the study was to evaluate whether the DVREMS can help students to clarify unclear astronomy conceptions and observe the influence of desktop VR in the classroom. The study was performed over a four-week period in October and November, 2004. Twenty-one sixth-grade students, including seven girls and fourteen boys, participated in the study.

All students were asked to fill out a pre-test before the study, and then they attended the class for three hours every week. The study was performed in a computer room and a classroom. Students used desktop computers to run the system in the computer room, and used Tablet PCs to run it in the classroom.

During the class, the teacher first lectured important topics and then used the DVREMS to explain the concepts using the projector and the big screen in front of the classroom. The teacher asked driven questions, which can be found in the system. Students use desktop computers or Tablet PCs to explore the virtual environment and to find answers of driven questions. As well as the lectures, the teacher also provides time to enable students to use the system to explore with other driven questions by themselves. The teacher encouraged students to discuss with classmates, to share their findings and to demonstrate the operations of the system to classmates. Students' demonstrations were displayed through the projector to all students.

The post-test was conducted after the study to compare with the pre-test. The post-test, comprised the same questions as the pre-test, was modified from a survey observation of children's misconceptions (Lin, 2004). The test contained 18 items, each with two steps to answer. Each item describes at least an astronomical phenomenon. The student needs to answer "yes" or "no" to indicate whether the statement is correct or incorrect in the first step, and then select one reason from multiple options in the second step. Students need to obtain correct answers in both steps to prove that they understand the concepts. After the post-test, the interviews with students and the teacher were conducted to analyze their thoughts about the system and the items of the tests.

Results and discussion

Table 5 shows the mean score and standard deviation (SD) of the pre-test and post-test. The Wilcoxon Paired Sign Rank Test was applied to compare the difference between the pre-test and the post-test. The statistical results show a significant difference between the pre-test and the post-test scores (p=0.001 < 0.01). The average post-test score is higher than the average pre-test score.

Table 5. The mean score and SD of pre-test and post-test (n=21)

	Mean	SD	P-value
Pre-test	6.95	3.96	0.001**
Post-test	9.86	3.99	

**p<0.01

Table 6 presents the correct rate of each item in the pre-test and post-test. The Chi-square test was applied to compare the differences of items. These items are categorized in terms of the concepts, with some items containing several concepts. The correct rates in most items obtained higher scores in the post-test, but two items (items 5 and 17) obtain lower correct rates and four items (items 1, 2, 8 and 14) obtained the same scores. According to the differences of items, the influences of the system can be analyzed and categorized into four sorts – *information*, *spatial transfer*, *manipulation* and *concept representation*. The recommendations in these sorts also provided in the next paragraphs.

Information

Virtual environments typically cannot provide all information naturally, but gives users insufficient information in virtual environments, especially in the learning process. Nevertheless, text or audio can fill the information gap to build an information-rich virtual environment (Bowman et al., 1999; Bowman et al., 2003).

Results of the study reveal the importance of information representation in a virtual environment. Item 5 concerns the Earth's rotation, asking students where a certain place will locate after three hours. The correct rate for this item in the post-test (52.4%) was lower than that in the pre-test (57.1%). Many students in the post-test knew the exact phenomenon and how the Earth rotates (anticlockwise), but some were confused with the Earth's rotation period, knowing that the Earth's rotation is anticlockwise but not that it rotates by day. This was because the system does not provide sufficient information about the rotation period. However, the correct rate of item 9 is higher in the post-test (76.2%) than in the pre-test (57.1%). Item 9 states the hypothesis that the Earth takes a month to move around the Sun once. Because the system provides month information at bottom right of the screen, students easily observe the phenomena and obtain knowledge from the VR system and information at the same time.

Table 6. Items' correct rates and corresponded concepts

Main concepts	**Sub concepts**	**Item no.**	**Pre-test (%)**	**Post-test (%)**	**Change (%)**
Spatial concept	1. Direction identification	1	47.6	47.6	0
	2. Shape of the Earth (round)	3	38.1	42.9	+4.8
	3. Size of the Sun (bigger)	2	71.4	71.4	0
	4. The meaning of direct sunshine	11	47.6	66.7	+19.1
Rotation	5. Rotation (anticlockwise & one day period)	5	57.1	52.4	-4.7
	6. The relationship of Sun rises and the Earth's rotation	6	4.8	23.8	+19
	7. The cause of day / night cycle	7	52.4	76.2	+23.8
	8. The cause of nighttime	8	71.4	71.4	0
Revolution	9. The orbits (heliocentric)	4	61.9	76.2	+14.3
	10. The period of the Earth's revolution	9	57.1	76.2	+19.1
	11. The cause of seasons	15	33.3	66.7	+33.4
Earth's Axis	12. Longer daytime (summer)	12	42.9	76.2	+33.3
	13. Midnight Sun in the polar region	13	19.0	47.6	+28.6
	14. The direct sunshine on the Earth (hotter in summer)	16	28.6	52.4	+23.8
	15. The earth's tilted axis (23.5°)	10,13,15			
	16. The area receiving the sunshine	14	23.8	23.8	0
	17. The cause of seasons	10,14,15			
	18. The relationship of vertical axis and seasons	10	14.3	33.3	+19
	19. The combination of the Earth's rotation, revolution and tilt axis	12,14,17, 18	14.3	76.2	+61.9
	20. The relationship of revolution and seasons	17	9.5	4.8	-4.7

A result similar to item 5 can be found in item 6, which states students that the Earth's spinning causes sunrise and sunset. Most students knew the movement of the Sun, but were confused by the direction of sunrise and sunset. They did not obtain the direction information easily when standing on the Earth in a virtual environment. Students understand the sunrise and sunset but do not know in which direction the Sun rises and sets.

Another case of insufficient information was founded during interviewing with a student. When the examiner asked the student to draw a picture to show how the Earth and the Sun would move and show their orbits, the student drew a smaller planet moving around a bigger planet. The whole drawing was like the representation in the DVREMS. However, when the examiner asked which one is the Earth and which one is the Sun, the student said that the smaller planet was the Sun and the bigger one was the Earth. The presentation of 3D models in the VR system can tell students the circulation, but it does not tell them sufficient information about these models such as the Sun and the Earth, even though the models are common sense.

Sufficient information also means the use of accurate terms. Item 13 refers to the "midnight Sun" in the North Pole and the South Pole, but most students do not understand this term. However, the result of the interview shows that they knew that the whole day is either daytime or nighttime at the Poles. This indicates that VR system should include accurate terms during the learning process.

Spatial behavior

A study demonstrates that the low correlation coefficient between spatial reasoning and the conceptual understanding of astronomy (Nicolaou and Constandinou, 2001). A study also indicates that the understanding of directions does not influence their learning in astronomy, and that the VR technology can support the enhancement of spatial behavior (Durlach et al., 2000). However, the authors observed that spatial behavior retains an important role in the VR learning environment. Although the system tells students their locations within the auxiliary map, some students still got lost in the virtual environment, particularly in the transference between different viewpoints. In item 6, students can observe sunrise and sunset by changing viewpoint from the Earth to the sky. However, they were still lost in the virtual environment and confused the cause of sunrise with the Earth's rotation, because they did not understand the relationship between the two viewpoints. People are easily lost in a virtual environment, particularly in a huge virtual space. Therefore, providing an accurate concept of space is an important issue in developing a virtual environment.

Manipulation

In this study, the system provides functions to stop the Earth's rotation and make the tilted axis vertical. Item 18 asks students, "If the axis does not tilt, and the earth rotates itself and orbits around the Sun, then the daytime length is as long as the nighttime length in different seasons in Taiwan." The score indicates that students know what would occur if the Earth's axis were vertical. The correct rate of item 18 in the post-test (76.2%) was significantly (p=0.000) higher than that in the pre-test (14.3%). However, the system does not provide functions to stop the Earth's revolution. In item 17, the post-test rate (4.8%) was lower than the pre-test rate (9.5%), and both correct rates were very low. Item 17 states, "If the Earth rotates but does not orbit the sun, then the day time always the same in the whole year in Taiwan." Students do not know what would happen if the Earth does not orbit around the Sun.

Manipulation can be extended as a part of simulation. Simulation is another area where computer technology can support students' learning, and is also an important educational attribute of VR (Kalawsky, 1996). Bryne (1996) also figured out interactivity is an important factor in learning. Learners can repeatedly observe phenomena and perform experiments, and thus 'learn by doing'. Therefore, simulation function is a key to help learners discover the virtual environment and realize concepts. Manipulation impresses users not only in the real world but also in the virtual environment. The design of manipulation must be enhanced to assist students in learning in a virtual learning environment.

Concept presentation

Some concepts, such as daytime/nighttime length, sunshine angle and variations in the amount of Sun's energy hitting the surface, are hard to represent in the virtual environment. The system provides auxiliary lines on the Tropic of Cancer and the Tropic of Capricorn to clarify the concept of daytime/nighttime length. The auxiliary line was separated into 24 sections to indicate 24 time zones by colored points. Students can count the numbers of points to understand the daytime and nighttime length in different seasons. Item 12 relates to the phenomena and cause of longer daytime length in summer. According to the correct rates in both tests, the correct rate in the post-test (76.2%) is higher than that in the pre-test (42.9%). The difference is almost significant (p=0.058). Most students realized the phenomena and understand the area of receiving the sunshine in different seasons.

The results of items 15 and 10 show the challenge of concept presentation. Item 15 asks students, "Are there four seasons in a year?" and seeks the Earth's revolution and tilted axis as the cause of season changes. Students observed the Earth's revolution and information of month from the whole view to understand the relationship of revolution and seasons. The correct rate of post-test (66.7%) is higher than that of the pre-test (33.3%). Item 10 states that the vertical axis leads to the disappearance of the seasons. Since the system does not provide the function to stop the Earth's revolution, the season changes are hard to represent. The correct rate of item 10 was only 33.3% in the post-test. Students could not understand the relationship between the axis and seasons. A similar result was obtained in item 14, which evaluated the concept that the level of the Sun's energy in summer is higher than that in winter. The amount of the energy and the reason why the weather is hotter in summer than in winter is also difficult to represent. Hence, correct rates of item 14 maintain the same correct rate (23.8%) in both tests. Most students still do not understand the relationship between temperature and the Sun.

Previous studies (Witmer and Singer, 1998; Slater, 1999) emphasized the presence of VR. Design of some specific concepts would be considered in the virtual environment unless modern devices support sensory stimulations (temperature, force or smell). Using sensory stimulations makes learners feel presence and experience the phenomena.

As described previous, desktop VR systems in education were divided into three types: interpersonal communication, information browsing and hands-on experience. The DVREMS has the characteristics combination of Type II (information browsing) and Type III (hands-on experience). Users browsed in the virtual world and have opportunities to manipulate virtual objects. Compared with other VR systems in education, the DVREMS does not provide strong functions on building 3D worlds and socializing like Active Worlds. For students, these functions may distract them and confuse them in the classroom. For teachers, they have high flexibility in creating their teaching courses and having more activities in class with these functions if the system has a powerful authoring tool and management tool. In the study, the DVREMS is specially implemented in astronomy education. The authors expected to elaborate the characteristics of VR to assist students in clarifying their concepts effectively by information browsing and hands-on experience.

It is helpful to use the DVREMS in the classroom for the teacher and students. The teacher uses 3D visualization of the Earth to express the concepts that are hardly shown with traditional materials. The teacher does not need to use a flashlight and a ball to demonstrate day / night cycle of the Earth. The DVREMS provides manipulations such as zoom-in, zoom-out, speedup, pause, control the Earth's axis. These manipulation effects are stronger than traditional materials such as 2D animations or substantiation. Students can interpret and understand concepts easier and clearer by browsing and manipulating in the virtual environment. As an educational tool, it is suitable to use the DVREMS in the classroom. Besides, low equipment requirement and advantages of desktop VR make the DVREMS suitable for widespread use in the classroom. It is also a key factor that can stimulate teachers to use the system. Although the DVREMS does not provide multi-user interaction to support collaborative learning activities, the results of the study showed that it worked well when using the DVREMS with face-to-face communication in the classroom. The DVREMS based on guided discovery learning provides study guides to assist students in their self learning.

Conclusion

A desktop virtual reality Earth motion system (DVREMS) was designed and implemented in this study to assist in clarifying unclear concepts among students about astronomy education in the classroom. A pilot study was conducted to observe the influences of the system. The statistical results show a significant difference between the pre-test and post-test correct rates. The differences of items in the tests were analyzed to understand the influences of the system. Moreover, some design recommendations for the desktop VR leaning environment in terms of four aspects are given as follows: *information*, *spatial behavior*, *manipulation* and *concept representation*. It indicates that the designer should provide sufficient information, show spatial information, increase opportunities to manipulate objects in the VR system and try to denote inexpressible concepts to improve desktop VR systems in education. In the future, functions of multi-user interaction and collaborate learning activities will be integrated into the DVREMS. The experience of developing the DVREMS will be also applied to other subject domains.

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References

Adams, J. P., & Slater, T. F. (2000). Astronomy in the National Science Education Standards. *Journal of Geoscience Education, 48*(1), 39-45.

Agan, L. (2004a). Stellar Ideas: Exploring Students' Understanding of Stars. *Astronomy Education Review, 3*(1), 77-97.

Agan, L. (2004b). Learning about the Earth's shape and gravity: A guide for teachers and curriculum. *Astronomy Education Review, 2*(2), 90-117.

Allison, D., Wills, B., Bowman, D., Wineman, J., & Hodges, L. F. (1997). The Virtual Reality Gorilla Exhibit. *IEEE Computer Graphics and Applications, 17*(6), 30-38.

AstroTour (2006). What is an AstroTour? Retrieved June 9, 2007, from http://astronomy.swin.edu.au/astrotour/.

Bailer, J. M., & Slater, T. F. (2003). A Review of Astronomy Education Research. *Astronomy Education Review, 2*, 20-45.

Barab, S. A., Hay, K. E., Barnett, M., & Keating, T. (2000). Virtual Solar System Project: Building Understanding through Model Building. *Journal of Research in Science Teaching, 37*(7), 719-756.

Barbieri, T. (2000). Networked Virtual Environmentsfor the Web: The WebTalk-I and WebTalk-II Architectures. *Paper presented at the IEEE International Conference on Multimedia and Expo*, July 30 - August 2, 2000, New York City, NY, USA.

Barbieri, T., & Paolini, P. (2001). Reconstructing Leonardo's ideal city – from handwritten codexes to webtalk-II: a 3D collaborative virtual environment system. *Paper presented at the 2001 Conference on Virtual reality, archeology, and cultural heritage*, November 28-30, 2001, Athens, Greece.

Baxter, J. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education, 11*, 502-513.

Bouras, C., Philopoulos, A., & Tsiatsos, Th. (2001). E-Learning through distributed virtual environments. *Journal of Network and Computer Applications, 24*, 175-199.

Bowman, D., North, C., Chen, J., Polys, N., Pyla, P., & Yilmaz, U. (2003). Information-Rich Virtual Environments:Theory, Tools, and Research Agenda. *Paper presented at the 10th ACM Symposium on Virtual Reality Software and Technology*, October 1-3, 2003, Osaka, Japan.

Bowman, D., Wineman, J., & Hodges, L. (1999). The educational value of an information-rich virtual environment. *Presence: Teleoperators and Virtual Environments, 8*, 317-331.

Byrne, C., & Furness, T. (1994). Virtual reality and education. *IFIP Transactions A Computer Science and Technology, 58*, 181-189.

Crosier, J. K., Cobb, S., & Wilson, J. R. (2000). Experimental Comparison of Virtual Reality with Traditional Teaching Methods for Teaching Radioactivity. *Education and Information Technologies, 5*(4), 329-343.

Crosier, J. K., Cobb, S., & Wilson, J. R. (2002). Key lessons for the design and integration of virtual environments in secondary science. *Computers & Education, 38*(1-3), 77-94.

Dale, E. (1946). *Audio-visual methods in teaching*, New York: The Dryden Press.

Dede, C. (1995). The Evolution of Constructivist Learning Environments: Immersion in Distributed, Virtual Worlds. *Educational Technology, 35*(5), 46-52.

Dede, C., Salzman, M., Loftin, R. B., & Sprague, D. (1999). Multisensory immersion as a modeling environment for learning complex scientific concepts. In W. Feurzeig & N. Roberts (Eds), *Modeling and Simulation in Science and Mathematics Education*, New York: Springer, 282-319.

Demaree, D., Stonebraker, S., Zhao, W., & Bao, L. (2005). Virtual reality in introductory physics laboratories. *AIP Conference Proceedings*, 790, 93-96, Retrieved June 7, 2007, from http://www.physics.ohio-state.edu/~ddemar1/PERC_04_VR_DedraDemaree.pdf.

Di Blas, N., Hazan, S., & Paolini, P. (2003). The SEE experience: Edutainment in 3D virtual worlds. In D. Bearman & J. Trant (Eds.), *Museums and the Web 2003*, Toronto: Archives & Museum Informatics, 173-182.

Di Blas, N., Gobbo, E., & Paolini, P. (2005). 3D Worlds and Cultural Heritage: Realism vs. Virtual Presence. In J. Trant & D. Bearman (Eds.), *Museums and the Web 2005*, Toronto: Archives & Museum Informatics.

Diakidoy, I. N., & Kendeou, P. (2001). Facilitating conceptual change in astronomy: a comparison of the effectiveness of two instructional approaches. *Learning and Instruction, 11*, 1-20.

Dove, J. (2002). Does the man in the moon ever sleep? An analysis of student answers about simple astronomical events: a case study. *International Journal of science Education, 24*(8), 823-834.

Dunlop, J. (2000). How children observe the Universe. *Publications of the Astronomical Society of Australia, 17*, 194-206.

Durlach, N., Allen, G., Darken, R., Garnett, R. L., Loomis, J., Templeman, J., & von Wiegand, T. E. (2000). Virtual environments and the enhancement of spatial behavior: Towards a comprehensive research agenda. *Presence: Teleoperators and Virtual Environments, 9*(6), 593-615.

Ferk, V., Vrtacnik, M., Blejec, A., & Gril, A. (2003). Students' understanding of molecular structure representations. *International Journal of Science Education, 25*(10), 1227-1245.

Finegold, M. Y., & Pundak, D. (1991). A study of change in student's conceptualframeworks in astronomy. *Studies in Educational Evaluation, 17*, 151-166.

Freeman, R. (1989). *The Discovery Gallery: Discovery learning in the museum*, Toronto: Royal Ontario Museum.

Hansen, J. A., Barnett, M., & MaKinster, J. G. (2004a). The impact of three-dimensional computational modeling on student understanding of astronomy concepts: a quantitative analysis. *International Journal of Science Education, 26*(11), 1365-1378.

Hansen, J. A., Barnett, M., & MaKinster, J. G. (2004b). The impact of three-dimensional computational modeling on student understanding of astronomy concepts: a qualitative analysis. *International Journal of Science Education, 26*(13), 1555-1575.

Hay, K. E., Elliot, D., & Kim, B. (2002). Collaborative network-based virtual reality: The past, the present, and the future of the virtual solar system. In G. Stahl (Ed.), *Proceedings of the Computer Support Collaborative Learning: Foundations for a CSCL Community* (pp. 519-520), Hillsdale, NJ: Lawrence Erlbaum.

Johnson, A., Moher, T., Ohlsson, S., & Gillingham, M. (1999). The Round Earth Project – Collaborative VR for Conceptual Learning. *IEEE Computer Graphics and Applications, 19*(6), 60-69.

Kalawsky, R. S. (1996). Exploiting Virtual Reality Techniques in Education and Training: Technological Issues. *AGOCGSIMA Report Series, 26*(1), 1356-5370.

Kaufmann, H., Schmalstieg, D., & Wagner, M. (2000). Construct3D: A Virtual Reality Application for Mathematics and Geometry Education. *Education and Information Technologies, 5*(4), 263-276.

Kim, J. H., Park, S. H., Lee, H., Yuk, K. C., & Lee, H. (2001). Virtual Reality Simulations in Physics Education. *Paper presented at the Ed Media 2001 Conference*, June 25-30, 2001, Tampere, Finland.

Lepouras, G., Charitos, D., Vassilakis, C., Charissi, A., & Halatsi, L. (2001). Building a VR-Museum in a Museum. *Paper presented at the Virtual Reality International Conference 2001*, May 16-18, 2001, Laval, France.

Lin, C. J. (2004). *Teaching and Assessment integrated with IT: Test of Earth's Motion,* Unpublished thesis, Graduate Institute of Mathematics and Science Education at Nation Ping Tung Teachers College, Ping Tung, Taiwan.

Maloney, J. (1997). Fly me to the moon: A survey of American historical and contemporary simulation entertainments. *Presence: Teleoperators & Virtual Environments, 6*(5), 565-580.

McKinnon, D., & Geissinger, H. (2002). Interactive astronomy in Elementary schools. *Educational Technology & Society, 5*(1), 124-128.

Moshell, J. M., & Hughes, C. E. (2002). Virtual environments as a tool for academic learning. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 893-910). Mahwah, NJ: Lawrence Erlbaum.

NASA (2006). Student Observation Network, Retrieved June 9, 2007, from http://www.nasa.gov/audience/foreducators/son/home/index.html.

Nicolaou, C., & Constantinou, C. P. (2001). Obstacles to the development of conceptual understanding in observational astronomy: the case of spatial reasoning difficulties encountered by pre-service teachers. *Paper presented at the First International Girep seminar*, September 2–6, 2001, Udine, Italy.

Ojala, J. (1997). Lost in space? The concepts of planetary phenomena held by trainee primary school teachers. *International Research in Geographical and Environmental Education, 6*, 183-203.

Ormrod, J. (1995). *Educational psychology: Principles and applications*, Englewood Cliffs, NJ: Prentice-Hall.

Osberg, K. M. (1995) Virtual Reality and Education: Where Imagination and Experience Meet. *VR in the Schools, 1*(2), 1-3.

Pantelidis, V. S. (1993). Virtual Reality in the Classroom. *Educational Technology, 23*, 23-27.

Parker, J. & Heywood, D. (1998). The Earth and Beyond: Developing Primary Teachers' Understanding of Basic Astronomical Events. *International Journal of Science Education, 20*(5), 503-520.

Pena, E. M., & Quilez, M. J. G. (2001). The importance of images in astronomy education. *International Journal of Science Education, 23*(11), 1125-1135.

Riedl, R., Barrett, T., Rowe, J., Smith, R. & Vinson, W. (2001). Sequence Independent Structure in Distance Learning. *Paper presented at the Society for Information Technology and Teacher Education International Conference 2001*, March 5-10, 2001, Orlando, Florida.

Shin, Y. S. (2002). Virtual Reality Simulations in Web-based Science Education. *Computer Applications in Engineering Education, 10*(1), 18-25.

Skaley, D., & Zlender, U. (2000). Virtual Physics and Astronomy. *ERCIM News, 41*, Retrieved June 7, 2007, from http://www.ercim.org/publication/Ercim_News/enw41/skaley.html.

Slater, M. (1999). Measuring presence: A response to the Witmer and Singer Presence Questionnaire. *Presence: Teleoperators and Virtual Environments, 8*(5), 560-565.

Spencer, J. A. (1999). Learner centred approaches in medical education. *British Medical Journal, 318*, 1280-1283.

Trumper, R. (2000). University students' conceptions of basic astronomy concepts. *Physical Education, 35*(1), 9-16.

Vosniadou, S. (1991). Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquisition in astronomy. *Journal of Curriculum Studies, 23*(3), 219-237.

Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive Science, 18*, 123-183.

Winn, W. (1997). Global Warming: It's a Gas! A Collaborative Virtual Environment for Studying the Effects of Global Warming. *Paper presented at the AERA Conference*, March 24-28, 1997, Chicago, IL.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environment: A Presence Questionnaire. *Presence: Teleoperators and Virtual Environments, 7*(3), 225-240.

Huang, Y.-M., Chen, J.-N., & Cheng, S.-C. (2007). A Method of Cross-level Frequent Pattern Mining for Web-based Instruction. *Educational Technology & Society*, 10 (3), 305-319.

A Method of Cross-level Frequent Pattern Mining for Web-based Instruction

Yueh-Min Huang[1], Juei-Nan Chen[1] and Shu-Chen Cheng[2]
[1]Department of Engineering Science, National Cheng Kung University, Taiwan // Tel: +886-6-2757575 ext. 63336 // Fax: +886-6-2766549 // huang@mail.ncku.edu.tw // rnchen@gmail.com
[2]Department of Computer Science and Information Engineering, Southern Taiwan University of Technology, Taiwan // Tel: +886-6-2533131 ext. 3228 // kittyc@mail.stut.edu.tw

ABSTRACT

Due to the rise of e-Learning, more and more useful learning materials are open to public access. Therefore, an appropriate learning suggestion mechanism is an important tool to enable learners to work more efficiently. A smoother learning process increases the learning effect, avoiding unnecessarily difficult concepts and disorientation during learning. However, many suggestion demands come from different abstraction levels, and traditional single level frequent pattern mining is not sufficient. This paper proposes a methodology for mining frequent patterns of learners' behavior which connote a hierarchical scheme to provide cross-level learning suggestions for the next learning course. With this system, a learner can get multiple levels of abstract suggestions instead of merely single level frequent pattern mining results. Our study shows that the algorithms can mine considerable quantities of frequent patterns from real life learning data. The experimental data are collected from a Web learning system originating from National Cheng Kung University in Taiwan. The proposed methodology gives learners many suggestions to help them learn more effectively and efficiently. Finally, we collect some representative cases to realize different requirements which are extracted from a learners' access database. These cases are classified into three types; notably, type three generalized four meaningful external factors which are inferred by our observations from these cross-level frequent patterns.

Keywords

e-Learning, Cross-level frequent pattern, FP-tree, FP-growth, Data mining

1. Introduction

At the dawn of the 21st Century, the education landscape is changing, in large part due to the explosive growth of Web technology. Many of the traditional institutions of higher education - universities, colleges, and professional development centers - are now beginning to develop and deliver Web-based courses via the Internet (Chen et al., 2005b; Choi, 1999; Huang et al., 2004; Khalifa and Lam, 2002; Jeng et al., 2005; Pahl, 2003; Song et al., 2004). Therefore, groups such as SCORM (2004), IEEE LTSC (2002), IMS (2003), and AICC (2003) have undertaken significant work on learning objects schemas. A learning object is a modular data unit that encapsulates information to describe a concept, skill, operation or procedure. Accordingly, these learning objects can be easily reused and shared over the Internet.

Although numerous Web-based learning systems have been developed, the vast number of learning objects have created disorientation and cognitive overload (Berghel, 1997; Borchers et al., 1998), so that learners may find it hard to know what course to take. To increase the learning effect, many powerful assistant mechanisms have been proposed. Huang et al. (2006) proposed a sequential mining algorithm to analyze learning behaviors to discover frequent sequential patterns. By these patterns, the system can provide suggestions for learners to select their learning contents. Papanikolaou et al. (2002) presented an approach to adaptive hypermedia learning environments design and illustrated how learners' knowledge level and individual traits can be exploited to guide the adaptive dimension of a hypermedia system. Tang and Mccalla (2003) proposed an evolving Web-based learning system which can adapt itself not only to its users, but also to the open Web in response to the usage of its learning materials. Cheng et al. (2005) presented an automatic leveling system for an e-Learning examination pool using the algorithm of the decision tree. The automatic leveling system is built to automatically level each question in the examination pool according its difficulty. Thus, an e-Learning system can choose questions that are suitable for each learner according to individual background. Chen et al. (2005a) proposed a personalized e-Learning system based on IRT (Item Response Theory) providing learning paths that can be adapted to various levels of difficulty of course materials and various abilities of learners. Karampiperis and Sampson (2005) presented an alternative sequencing method, instead of generating the learning path by populating a concept sequence with available learning resources based on pre-defined adaptation rules, it first generates all possible learning paths that match the learning goal, and then selects the desired one to estimate the suitability of learning resources for a targeted learner.

Consider an e-Learning system in which various learning objects are provided for the learners via the Internet. A learner may not easily acquire suitable learning objects or may lose his/her way in this vast space. Therefore, providing suitable learning suggestions for the learners becomes an important mechanism in a comprehensive web learning system. In this study, we attempt to use the idea of Han and Fu's (1999) multiple-level hierarchy information encoded method. Following the hierarchical taxonomy, an encoded string needs fewer bits than the corresponding object-identifier. Moreover, the connotation of an encoded string and their correlations may lead to the discovery of more specific and important knowledge from the data. Relevant item taxonomies are usually predefined in real-world applications, and can be represented using hierarchy trees. Terminal nodes on the trees represent actual items appearing in transactions; internal nodes represent classes or concepts formed by lower-level nodes. Unlike Han and Fu (1999), this study attempts to find the frequent patterns with crossing-level relations rather than look for the association rules in a specific level.

Since the early work in Agrawal et al. (1993), various studies have adopted or modified the Apriori candidate set generation-and-test approach to mine association rules. Kim and Kim (2003) proposed a recommendation algorithm using multi-level association rules to predict user's preference, and then suggest items by analyzing the past preference information of users. Bonchi et al. (2003) introduced a fast algorithm for frequent pattern mining that exploits anti-monotone and monotone constraints to optimize a level-wise, Apriori-like computation. Kaya and Alhajj (2004) presented a fuzzy weighted multi-cross-level association rules mining approach which integrates several concepts, including fuzziness, cross-level mining, weighted mining and linguistic terms. However, Apriori-like candidate set generation is still costly, especially when there are many patterns and/or long patterns.

In this study, we apply a frequent pattern tree (FP-tree) structure, which is an extended prefix-tree structure for storing compressed, crucial information about frequent patterns, and employ FP-growth to mine the complete set of frequent patterns by pattern fragment growth (Han et al., 2000). The FP-growth method can get more efficient and scalable results for mining both long and short frequent patterns than the Apriori algorithm, and it is also faster than some recently reported new frequent pattern mining methods. This study provides a useful application applying data mining methodology in the e-Learning field. Our study shows that cross-level frequent pattern mining can give learners various learning suggestions. Furthermore, it succeeds in joining the methods of multiple-level hierarchy information encoded technique and frequent pattern mining, offering a new utilization in data mining field.

We ran experiments using data from an e-Learning system originating at National Cheng Kung University in Taiwan (NCKU, 2005). The data were daily collected from January 1, 2005 to December 31, 2005. Although the system is still serving, we retrieved the log data from the database and evaluated its features. At the end of 2005, the system contained 15,858 students, 528 lecturers, and 1,916 courses.

This paper has three primary research contributions:

1. Integrating multi-level hierarchy information encoded technique and frequent pattern mining method to provide learning suggestions;
2. Conducting some experiments to evaluate the proposed methodology using real-world data and realize what learners want;
3. Collecting some representative cases to understand different learning requirements.

The rest of this article is organized as follows. Section 2 shows the taxonomy of the curriculum scheme. Section 3 introduces the FP-tree construction process, and a method of cross-level frequent pattern mining is proposed in Section 4. The experimental results are presented in Section 5 and discussed in Section 6. Finally, Section 7 draws conclusions.

2. Taxonomy of the Curriculum Scheme

In the first place, the taxonomy information of the curriculum scheme should be constructed, and each position in this academic hierarchy should be given a unique encoded string which requires fewer bits than the corresponding accessing-identifier. We assume that the database contains: 1) a learning item data set which contains the description of each learning item in I in the form of (ES_i, $description_i$), where encoded string $ES_i \in I$, 2) an access database, ADB_{origin}, which consists of a set of user access data (UID_i, {ES_x, …, ES_y}), where UID_i is a user's identifier and $ES_i \in I$ (for i=x, …, y), and 3) the notation of '*' represents a class or concept in an encoded string ES_i. To clarify our discussion, an abstract example is introduced in the following sections.

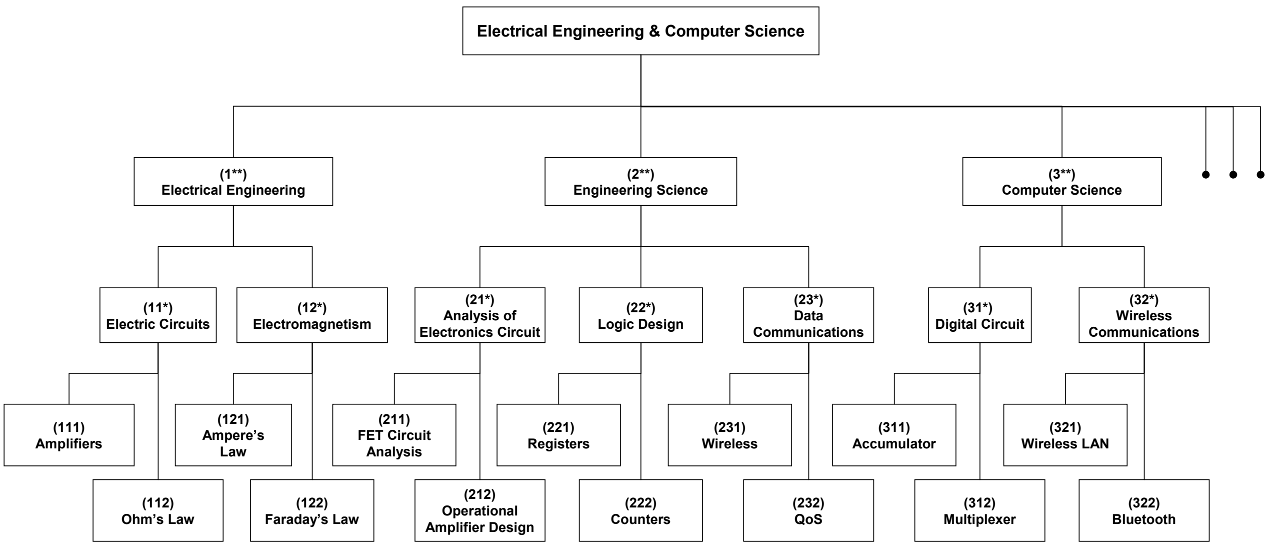

Figure 1. An example of a curriculum scheme

Example 1: For instance, the taxonomy information of the curriculum scheme is constructed as shown in Figure 1, and the encoded access database ADB_{origin} is shown in Table 1. We use a unique encoded string to represent a corresponding accessing-identifier, which is shown in the parenthesis in front of each accessing-identifier. In this example scheme, the Electrical Engineering & Computer Science curriculum is given in three layers. The first layer enumerates all the departments in this Electrical Engineering & Computer Science curriculum. The second layer lists all the courses in the corresponding departments. The third layer itemizes all the learning items including in the courses. For instance, the learning item 'Wireless' is encoded as '231' in which the first digit, '2', represent 'Engineering Science' at layer 1, the second, '3', for 'Data Communications' at layer 2, and the third, '1', for the learning item 'Wireless' at layer 3.

Table 1. An example of user access database ADB_{origin}.

UID	Items
U_1	{231, 321, 322, 312}
U_2	{111, 112, 212, 321, 322, 231}
U_3	{322, 321, 111, 212, 231}
U_4	{111, 222, 112, 212,211}
U_5	{112, 211,212, 311}
U_6	{111, 311, 212, 112, 231}
U_7	{231, 121, 321}

In this research, the frequent patterns are not restricted to the same layer (Han and Fu, 1999) but extend to the different layers. For this reason, we increase the higher-level items in the access database ADB_{origin} to be an enriched access database, $ADB_{enriched}$. Whenever the lower-level items achieve a specified portion of count, the higher-level items should be added into the enriched access database $ADB_{enriched}$ (shown in Table 2). For example, the access data U_6 in Table 2 contains the encoded items - 111, 112, 121, and 122, and these items fulfill the state we mentioned.

Therefore, the higher-level items of 11* and 12* should be added into $ADB_{enriched}$. Moreover, 1** also should be added into $ADB_{enriched}$ as a result of the 11* and 12* being satisfied with the same condition.

Table 2. An example of enriched access database $ADB_{enriched}$.

UID	Items
U_1	{231, 321, 322, 312, 32*}
U_2	{111, 112, 212, 321, 322, 231, 11*, 32*}
U_3	{322, 321, 111, 212, 231, 32*}
U_4	{111, 222, 112, 212, 211, 11*, 21*}
U_5	{112, 211,212, 311, 21*}
U_6	{111, 311, 212, 112, 231, 121, 122, 11*, 12*, 1**}
U_7	{231, 121, 321}

Definition 1: An encoded string set, *ES*, is one item ES_i or a set of conjunctive items $ES_i \cap \cdots \cap ES_j$, where $ES_i, \ldots, ES_j \in I$. The *support* of a frequent pattern *X* in a set *S*, $\rho(X / S)$, is the number of transactions (in *S*) which contain *X* versus the total number of transactions in *S*. The *confidence* of $X \rightarrow Y$ in *S*, $\delta(X \rightarrow Y / S)$, is the ratio of $\rho(X \cap Y / S)$ versus $\rho(X / S)$, i.e., the probability that pattern *Y* occurs in *S* when pattern *X* occurs in *S*.

To find relatively frequently occurring patterns and reasonably strong rule implications, a user or an expert may specify two thresholds: minimum support, *minsup*[*l*], and minimum confidence, *minconf*[*l*], where *l* specifies different level of a curriculum scheme. Notice that for finding cross-level frequent patterns, different minimum support and/or minimum confidence can be specified at different levels.

The qualification of the cross-level frequent item sets proceeds as follows. Let the minimum support at level 1, 2 and 3 be 3, 3 and 4 access data respectively (i.e., minsup[1]=3, minsup[2]=3, and minsup[3]=4). For the sake of simplicity, notice that since the total number of access data is fixed, the support is expressed as an absolute value rather than a relative percentage. In accordance with each level's minimum support threshold, the items which are lower than the minimum support should be filtered out (presented in a single deletion line), and the results are shown in Table 3. For instance, the learning item '322' occurs in U_1, U_2 and U_3, and the minimum support at level 3 is 4 (minsup[3]=4). Hence, the learning item '322' should be removed, as its occurrence is lower than its threshold level.

Table 3. A filtered example of enriched access database $ADB_{enriched}$.

UID	Items
U_1	{231, 321, ~~322~~, ~~312~~, 32*}
U_2	{111, 112, 212, 321, ~~322~~, 231, 11*, 32*}
U_3	{~~322~~, 321, 111, 212, 231, 32*}
U_4	{111, ~~222~~, 112, 212, ~~211~~, 11*, ~~21*~~}
U_5	{112, ~~211~~,212, ~~311~~, ~~21*~~}
U_6	{111, ~~311~~, 212, 112, 231, ~~121~~, ~~122~~, 11*, ~~12*~~, ~~1**~~}
U_7	{231, ~~121~~, 321}

3. FP-tree Construction

In this section, we employ the frequent pattern tree (FP-tree) structure to compress a large database into a highly condensed, much smaller data structure, which avoids costly, repeated database scans (Han et al., 2000). If two access data share a common prefix, according to some sorted order of frequent items, the shared parts can be merged using one prefix structure as long as the count is registered properly. If the frequent items are sorted in descending order of their frequency, there is a better chance that more prefix strings can be shared. Figure 2 shows the algorithm of FP-tree construction from Han et al. (2000). We use the same example from Section 2 to illustrate the FP-tree construction process.

The frequent items in each access data are listed in descending order, and shown in Table 4. Let the minimum support of a frequent pattern be 3 (i.e., minsup[FP] = 3). With these observations, one may construct a frequent pattern tree as follows. First, a scan of sorted $ADB_{enriched}$ derives a list of frequent items, (212:5), (231:5), (111:4), (112:4), (321:4), (11*:3), (32*:3), (the number after ":" indicates the support), in which items are in order of descending frequency. This ordering is important, since each path of a tree will follow this order.

Definition 2: A frequent pattern tree (or FP-tree in short) is a tree structure as defined below.

1. It consists of one root labeled as "*null*", a set of item prefix sub-trees as the children of the root, and a frequent-item header table.
2. Each node in the item prefix sub-tree consists of three fields: *item-name*, *count*, and *node-link*, where *item-name* registers which item this node represents, *count* registers the number of transactions represented by the portion of the path reaching this node, and *node-link* links to the next node in the FP-tree carrying the same item-name, or null if there is none.
3. Each entry in the frequent-item header table consists of two fields, (1) *item-name* and (2) *head of node-link*, which points to the first node in the FP-tree carrying the *item-name*.

Based on this definition, we have the following FP-tree construction algorithm.

Figure 2. The algorithm for constructing the FP-tree (Han et al., 2000)

Algorithm 1 (FP-tree construction)
Input: An enriched access database $ADB_{enriched}$ and a minimum support threshold minsup[FP].
Output: Its frequent pattern tree, FP-tree.
Method: The FP-tree is constructed in the following steps.

1. Scan the access database $ADB_{enriched}$ once. Collect the set of frequent items *F* and their supports. Sort *F* in descending order as *L*, the list of frequent items.
2. Create the root of an FP-tree, *T*, and label it as "*null*". For each access data *Acc* in $ADB_{enriched}$ do the following.
Select and sort the frequent items in *Acc* according to the order of *L*. Let the sorted frequent item list in *Acc* be [*p*|*P*], where *p* is the first element and *P* is the remaining list. Call *insert_tree*([*p*|*P*], *T*).
The function *insert_tree*([*p*|*P*], *T*) is performed as follows. If *T* has a child *N* so that *N.item-name* = *p.item-name*, then increment *N*'s count by 1; otherwise create a new node *N* and let its count be 1, its parent link be linked to *T*, and its node-link be linked to the nodes with the same *item-name* via the node-link structure. If *P* is not empty, call *insert_tree*(*P*, *N*) recursively.

Table 4. A filtered example of enriched access database $ADB_{enriched}$ with sorted items

UID	Items
U_1	{231, 321, 32*}
U_2	{212, 231, 111, 112, 321, 11*, 32*}
U_3	{212, 231, 111, 321, 32*}
U_4	{212, 111, 112, 11*}
U_5	{212, 112}
U_6	{212, 231, 111, 112, 11*}
U_7	{231, 321}

Second, one may create the root of a tree, labeled "*null*". Scan the $ADB_{enriched}$ a second time. The scan of the first access data leads to the construction of the first branch of the tree:<(231:1), (321:1), (32*:1)>. Notice that the frequent items in the access data are ordered according to the order in the list of frequent items. For the second access of the data, we construct the second branch of the tree: <(212: 1), (231:1), (111:1), (112:1), (321:1), (11*:1), (32*:1)>. For the third access of the data, since its (ordered) frequent item list <212, 231, 111, 321, 32*> shares a common prefix <212, 231, 111> with the existing path <212, 231, 111, 112, 321, 11*, 32*>, the count of each node along the prefix is increased by 1, and one new node (321:1) is created and linked as the child of (111:2) and another new node (32*:1) is created and linked as the child of (321:1). Working with the same process, we can get the data structure which is shown in Figure 3 until we have scanned all the access data in Table 4.

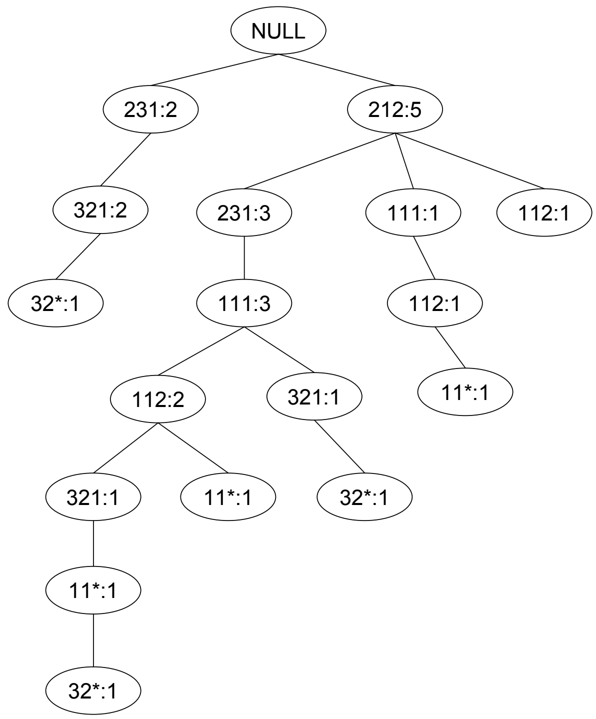

Figure 3. The FP-tree in Example 1

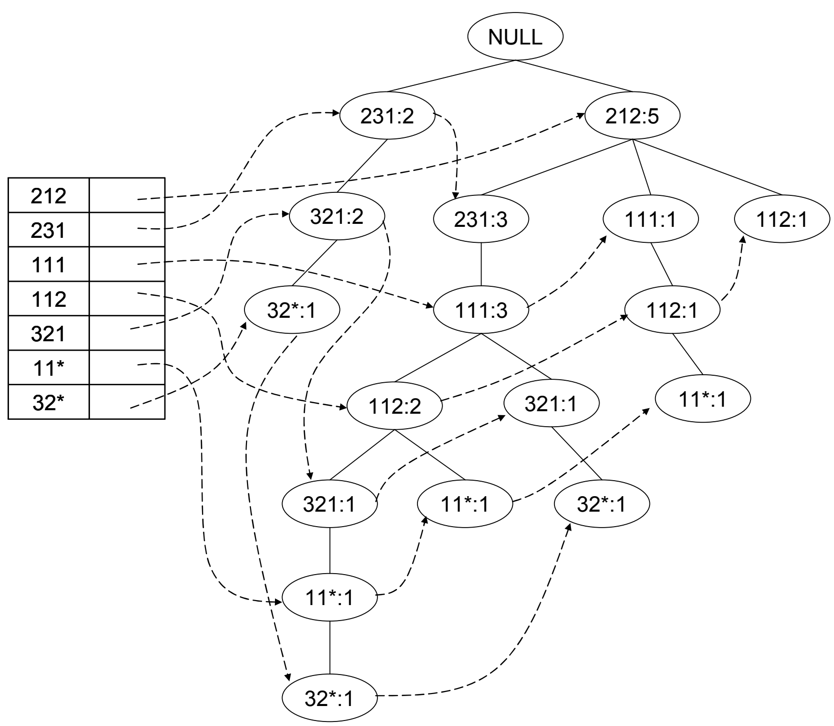

Figure 4. The FP-tree with header table in Example 1

Third, to facilitate tree traversal, an item header table is built in which each item points to its occurrence in the tree via a head of node-link. Nodes with the same item-name are linked in sequence via such node-links. After scanning all the access data, the tree with the associated node-links is shown in Figure 4.

4. Mining Association Rules using the FP-tree

In this section, we study how to explore the compact information stored in an FP-tree, mine the frequent patterns with an efficient method based on Han et al. (2000) as shown in Figure 5, and then generate the association rules from conditional frequent patterns.

$I=\{ES_1, \ldots, ES_n\}$ is a set of learning items. α and β are frequent learning items in $ADB_{enriched}$. P is a single path of the FP-tree structure. The support (or occurrence frequency) of a pattern A, which is a set of items, is the number of transactions containing A in $ADB_{enriched}$. A is a frequent pattern if A's support is no less than a predefined minimum support threshold, minsup[FP].

Algorithm 2 (FP-growth: Mining frequent patterns with FP-tree by pattern fragment growth)
Input: FP-tree constructed based on Algorithm 1, using $ADB_{enriched}$ and a minimum support threshold minsup[FP].
Output: The complete set of conditional frequent patterns.
Method: Call FP-growth (FP-tree, *null*).

Procedure FP-growth (*Tree*, α)
{
(1) **if** *Tree* contains a single path *P*
(2) **then for each** combination (denoted as β) of the nodes in the path *P* **do**
(3) generate pattern $\beta \cup \alpha$ with *support = minimum support of nodes in* β ;
(4) **else for each** ES_i in the header of *Tree* **do** {
(5) generate pattern $\beta = ES_i \cup \alpha$ with *support* = ES_i*.support* ;
(6) construct β 's conditional pattern base and then β 's conditional FP-tree $Tree_\beta$;
(7) **if** $Tree_\beta \neq \phi$
(8) **then** call FP-growth ($Tree_\beta$, β) }
}

Figure 5. The FP-growth algorithm (Han et al., 2000)

Keeping the previous example, we examine the mining process by starting from the bottom of the header table. For node 32*, it derives a frequent pattern (32*: 3) and three paths in the FP-tree: <231: 2, 321: 2, 32*: 1>, <212: 5, 231: 3, 111: 3, 112: 2, 321: 1, 11*: 1, 32*: 1> and <212: 5, 231: 3, 111: 3, 321: 1, 32*: 1>. The third path indicates that string "(212, 231, 111, 321, 32*)" appears once in the access database. Notice that although string <231, 111> appears three times and <212> itself appears five times, they only appear once together with 32*. After proceeding the remaining node of 11*, 321, 112, 111, 231 and 212, the conditional pattern bases and conditional frequent patterns can be generated and are shown in Table. 5.

Figure 6 shows the association rule generation process from conditional frequent patterns. First, the frequent access rules are generated by combining all the items in each conditional frequent pattern, and pruning the duplicate rules. Next, in each frequent access rule, all the corresponding encoded digits except the last digit should be compared. If the compared results are all equal, this rule should be pruned off; otherwise, it should be added into the pruned frequent access rule table. Finally, the pruned frequent access rules can be formed as association rules by inserting an implication relation between each gap. Furthermore, the remaining gaps of each association rule should be laid down with the interconnection relation of '∩' which ties the related items together. In Table 6, the conditional frequent patterns can be broken into many frequent access rules. If the frequent access rules already exist, the rules produced later should be omitted (presented in a single deletion line). Furthermore, since each learning item is represented by an encoded string, we can easily deduce their correlations. Since we want to provide useful recommendations to the learner, it should be omitted from the rules of great generality, especially since these items lie in the same category. Therefore, we prune the rules presented in a double deletion line.

Table 5. Mining of all-patterns by creating conditional (sub)-pattern bases

Item	Conditional pattern base	Conditional frequent pattern
32*	{(231: 1, 321:1, 32*: 1), (212: 1, 231: 1, 111: 1, 112: 1, 321: 1, 11*: 1, 32*: 1), (212: 1, 231: 1, 111: 1, 321: 1, 32*: 1)}	{(231: 3, 321: 3)}| 32*
11*	{(212: 1, 231: 1, 111: 1, 112: 1, 321: 1, 11*: 1), (212: 1, 231: 1, 111: 1, 112: 1, 11*: 1), (212: 1, 111: 1, 112: 1, 11*: 1)}	{(212: 3, 111: 3, 112: 3)}| 11*
321	{(231: 2, 321: 2), (212: 1, 231: 1, 111: 1, 112: 1, 321: 1), (212: 1, 231: 1, 111: 1, 321: 1)}	{(231: 4)}| 321
112	{(212: 2, 231: 2, 111: 2, 112: 2), (212: 1, 111: 1, 112: 1), (212: 1, 112: 1)}	{(212: 3, 111: 3)}| 112
111	{(212: 3, 231: 3, 111: 3), (212: 1, 111: 1)}	{(212: 3, 231: 3)}| 111
231	{(212: 3, 231: 3)}	{(212: 3)}| 231
212	ϕ	ϕ

Algorithm 3 (Association rule generation process from conditional frequent patterns)
Input: Conditional frequent patterns.
Output: Association rules.
Method: The association rule generation process from conditional frequent patterns is constructed in the following steps.

1. Scan the conditional frequent pattern table once. Combine all the encoded strings, *ES*, in each conditional frequent pattern to generate frequent access rules (denoted as τ). If the frequent access rule has been generated, then ignore reproduced rule.
2. **for each** τ_i **do**

   if all the corresponding encoded digits except the last one are the same **then**

   Prune τ_i;

   else add τ_i to pruned frequent access rule (denoted as ω);
3. **for each** ω_j **do**

   Insert the implication relation between each gap, and the remaining gaps lay down the interconnection relation '∩';

Figure 6. Association rule generation algorithm

5. Experimental Results

In this section, we study the learning results by varying different database parameters. All experiments are performed on a computer with a CPU clock rate of 2.8GHz and 1 GB of main memory. The program is written in Java programming language and running on Microsoft Windows XP. In this study, we change the following parameters to observe the data precision and the learning effects, which are (1) the average length of each sequential transaction,

(2) the upgrading proposition of each level, (3) confidence analysis, and (4) the accuracy between multiple support threshold and single support threshold.

Table 6. Association rules generation from conditional frequent pattern

Conditional frequent pattern	Frequent access rules	Pruned frequent access rules	Association rules
{(231: 3, 321: 3)}| 32*	231, 321 231, 32* 321, 32* 231, 321, 32*	231, 321 231, 32* ~~321, 32*~~ 231, 321, 32*	231 → 321 231 → 32* 231 → 321∩32* 231∩321 → 32*
{(212: 3, 111: 3, 112: 3)}| 11*	212, 111 212, 112 212, 11* 111, 112 111, 11* 112, 11* 212, 111, 112 212, 111, 11* 212, 112, 11* 111, 112, 11* 212, 111, 112, 11*	212, 111 212, 112 212, 11* ~~111, 112~~ ~~111, 11*~~ ~~112, 11*~~ 212, 111, 112 212, 111, 11* 212, 112, 11* ~~111, 112, 11*~~ 212, 111, 112, 11*	212 → 111 212 → 112 212 → 11* 212 → 111∩112 212∩111 → 112 212 → 111∩11* 212∩111 → 11* 212 → 112∩11* 212∩112 → 11* 212 → 111∩112∩11* 212∩111 → 112∩11* 212∩111∩112 → 11*
{(231: 4)}| 321	~~231, 321~~	ϕ	ϕ
{(212: 3, 111: 3)}| 112	~~212, 111, 112~~	ϕ	ϕ
{(212: 3, 231: 3)}| 111	212, 231 ~~212, 111~~ 231, 111 212, 231, 111	212, 231 231, 111 212, 231, 111	212 → 231 231 → 111 212 → 231∩111 212∩231 → 111
{(212: 3)}| 231	~~212, 231~~	ϕ	ϕ

The historical access data was drawn from an e-Learning system of National Cheng Kung University in Taiwan (NCKU, 2005). At the end of 2005, the system contained 15,858 students, 528 lecturers, and 1,916 courses.

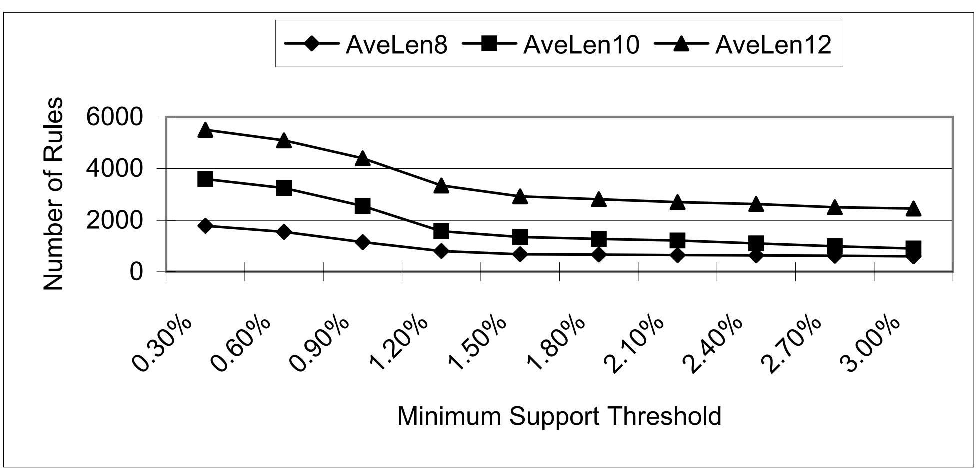

Figure 7. Average length with variant sequential transaction lengths

5.1 The Average Length of each Sequential Transaction

This experiment wants to observe the influence between the sequential transaction length and number of mining results. We fix the average data length up with 8, 10 and 12 items in a transaction. Figure 7 shows the correlation between minimum support threshold and number of rules. It is clear that the higher minimum support threshold value leads to the fewer number of rules. There is a tardy trend with the curve of AveLen8, and the visible decrease continued until the minimum support threshold reached 1.2%. Likewise, the curve of AveLen10 became gentle after the minimum support threshold also arrived at 1.2% as well. Finally, the curve of AveLen12 fell lightly after the minimum support threshold approached 1.5%.

5.2 The Upgrading Proposition of each Level

In this experiment, we want to realize each level's upgrading influence related to the number of rules. The upgrading proposition is highly correlated with the amount of higher-level items in the enriched access database $ADB_{enriched}$. Conversely, if the upgrading proposition holds great values, it will cause fewer higher-level items to exist in the enriched access database $ADB_{enriched}$. Hence, the higher learning concepts can not be extracted easily. This experiment arranges 160,000 sequential transactions which indicate the number of access data in the database. Figure 8 shows that the curve of Chapter -> Course decreases slightly since the value of the upgrading threshold is higher than 0.7. The curve of Course -> Department clearly diminishes before the upgrading threshold reaches 0.5. The curve of Department -> College decreases slowly after the upgrading threshold reaches 0.3.

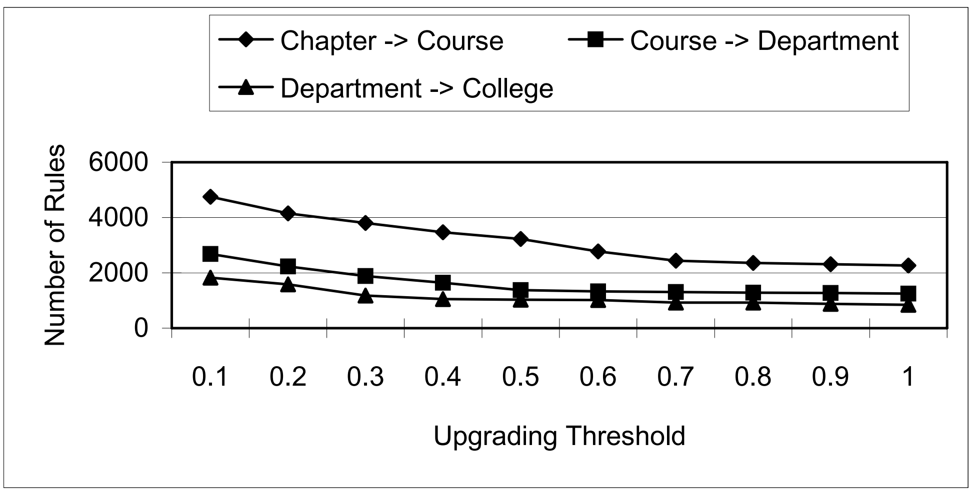

Figure 8. Upgrading threshold values with variant academic hierarchy levels

5.3 Confidence Analysis

The confidence value is the reliability of an association rule. In this experiment, we study the correlations between different confidence values and the number of rules. A higher confidence value leads to a fewer number of rules. In this experiment, when the minimum support of frequent pattern (minsup[FP]) is higher than 5%, then the number of rules decreases slightly, as shown in Figure 9. Therefore, if the system wants to provide various recommendation results, the minimum support value should not be higher than 5%. Because of the higher minimum support of a frequent pattern (minsup[FP]), more connoted rules could be filtered.

5.4 The Accuracy between Multiple Support Threshold and Single Support Threshold

We divide the data into training and testing samples to evaluate the precision and the recall of this recommendation mechanism. Precision is the number of relevant items retrieved over the total number of items retrieved. Recall is the number of relevant items retrieved over the number of relevant items in the database. In this experiment, we use different recommendation threshold (confidence) values to evaluate the accuracy of the mining results, and fix the minimum support threshold value at 0.8%. A higher precision value means that the results are more accurate for the user. In Figure 10, the precision value clearly rises after the recommendation threshold (confidence) value reaches 0.3. We can easily recognize that frequent patterns with multiple support thresholds would get better results than when every hierarchy level holds the same support value.

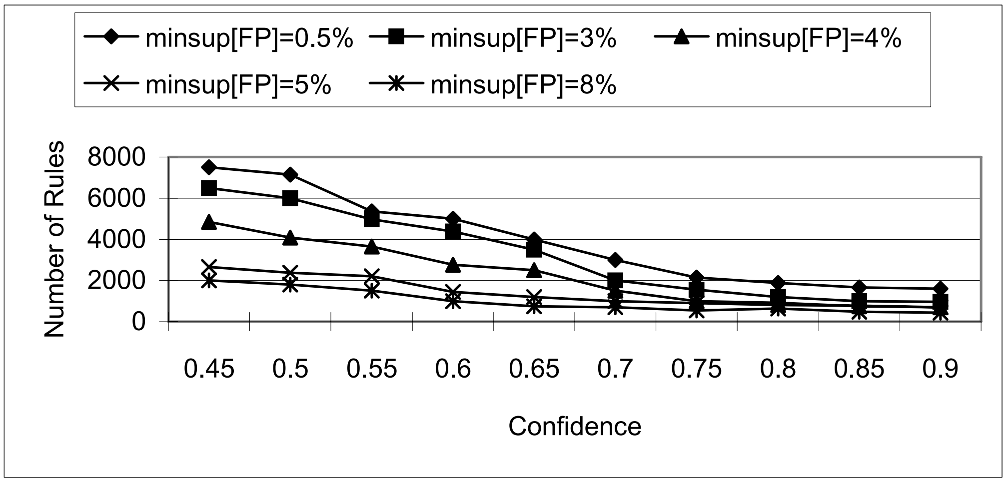

Figure 9. Confidence values with variant minimum support threshold values

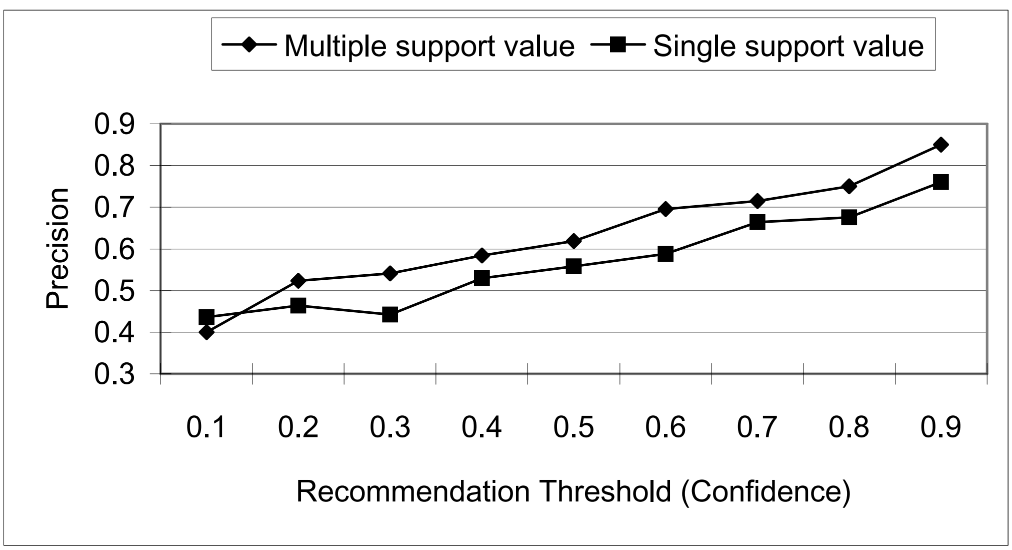

Figure 10. The precision with variant confidence values

In Figure 11, the recall is also mainly influenced on the recommendation threshold (confidence) value. The higher recommendation threshold (confidence) value means more restriction of each frequent pattern. Therefore, the higher recommendation threshold (confidence) value causes the lower recall percentage. Figure 11 shows that the recall percentage with multiple support thresholds is still 50%, since the threshold value is lower than 0.5.

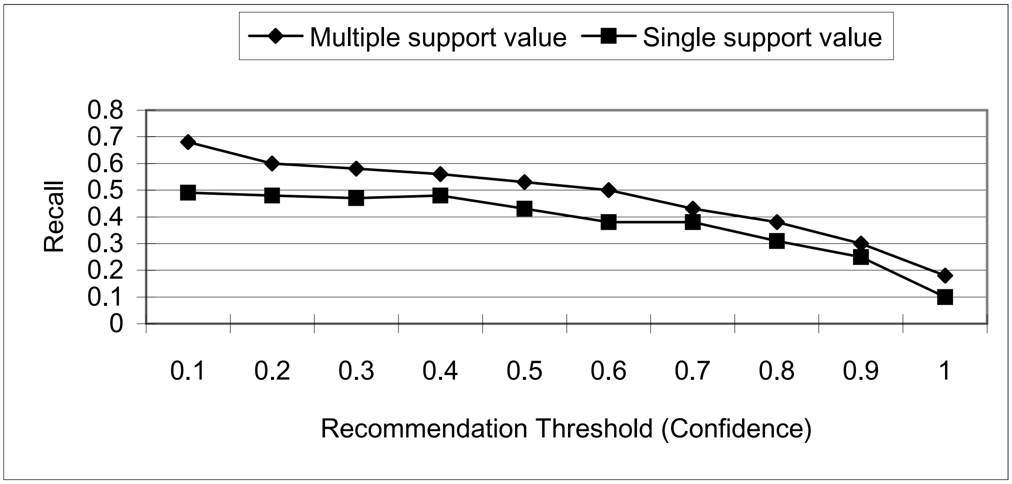

Figure 11. The recall with variant confidence values

6. Discussion

From the research results, we collect some representative cases to realize different requirements which are extracted from the learners' access database. These cross-level frequent patterns can be roughly divided into three kinds.

Type 1: High correlation between similar learning items

The meaningful type of frequent patterns is when the learning items are related to the similar concepts. This type of frequent patterns is 37% of the mining results, and is also the most important proportion of learners' behavior. The main reason is some courses contain the same learning concepts, and these learning items are explored by experienced learners. Whenever these kinds of patterns come up frequently, the mining process can easily find them from the access database. Learners can go a step further to study similar courses which involve similar learning materials as soon as they can not understand the meaning of a specific topic. For example, courses created by teachers using the authoring tool can be categorized with titles like 'Neural Networks' and 'Artificial Intelligence', etc. However, these courses involve many reduplicated concepts, but such learning items are associated with different hierarchy branches. This type of frequent pattern mainly collects the lower level relations of this academic hierarchy. This often takes place when the learner has an explicit learning target or they know what to learn, therefore, they can clearly find the related learning items to clarify and extend their learning.

Type 2: High correlation between complementary learning items

Another type of frequent pattern is learning items which have complementary relations. This kind of frequent patterns accounts for 9.3% for our experimental results. Excision is also a useful learning methodology when you want to understand a specific area of knowledge. By following an indirect approach, learners can get knowledge in a comparative way. This type of learning works best with the courses those are complementary with each other. For instance, the course of 'Solid State Physics' is theoretical, and 'Processing of Ceramics' is applied scientific knowledge. These two courses may contain the same subject matter, but presented in different ways. We think these two courses thus have a complementary relationship. Similar with type 1, the learner can also clearly identify the learning targets. Accordingly, the frequent patterns also primarily focus on the lower level relations of the academic hierarchy.

Type 3: Special frequent patterns which may imply particular factors

The greatest numbers of frequent patterns are this type. We generally categorize the remainder of rules as this type, which may not be classified into type 1 or type 2. The rules in this type may provide learners with unexpected results, and these results are not restricted to a specific level but provide level crossing relations. Unlike type 1 and type 2, most of frequent patterns in this group seem to have occurred in a haphazard way; nevertheless, some of their relations can be figured out. These relations may be connected with certain external factors in the environment. In the following, we summarize several meaningful external factors (not including all of external factors) and give illustrations to show the mining results from this group.

1) **A time-related factor**: This refers to a point in time, that is, an important occurrence may cause some learners to have the same behavior at that particular period. Therefore, in a specified time, we can collect these meaningful rules. For example, enteroviruses are small viruses that are made of ribonucleic acid (RNA) and protein, and the infections are most likely to occur during the summer. Furthermore, these viruses easily multiply in a wet and hot environment. Therefore, in summer time, a learner may study a course which is talking about the Infectious Diseases. They may associate it with environmental sanitation, and then start to survey the courses in the Department of Environmental Engineering. In this case, a cross-level frequent pattern is "Infectious Diseases (course level) → Environmental Engineering (department level)".
2) **A policy or political affairs alternation**: This type of pattern is influenced by a public policy or political affairs. For instance, in 2005, TANFB (Taiwan Area National Freeway Bureau) announced that the national highway will put the ETC (Electronic Toll Collection) system into practice by January 1, 2006 with BOT (Build-Operate-Transfer) policy. The ETC is a system which allows drivers with an OBU (On-Board Unit) installed in their vehicles to pay their tolls electronically, without having to stop at the tollgates. FETC (Far Eastern Electronic Toll Collection) company was commissioned to build the system with infrared DSRC (Dedicated Short Range Communications) standard in 2003. Based on this policy implementation, after studying the course of Data Communications, which includes the descriptions of infrared DSRC, some learners then checked the courses of Infrastructural Engineering and Management. In this case, a cross-level frequent pattern is "Data Communications (course level) → Infrastructural Engineering and Management (course level)".
3) **Natural disasters**: There have been many disasters over the years resulting from its geographical location. Taiwan has a very special geographical position, and is often threatened by natural disasters such as earthquakes, typhoons, and floods. As a result of the data collected from universities in Taiwan, we conclude that natural disasters are an important factor. For instance, the 2004 Indian Ocean earthquake, known by the scientific community as the Sumatra-Andaman earthquake, was an undersea earthquake that occurred on December 26, 2004. The earthquake was reported as 9.3 on the Richter scale. The sudden vertical rise of the seabed by several meters during the earthquake displaced massive volumes of water, resulting in a tsunami that struck the coasts of the Indian Ocean. This event may cause a learner studying the Geology course to survey the Introduction of Natural Disasters course, and then inquire into the International Perspectives on Natural Disasters course. In this case, a cross-level frequent pattern is "Geology (course level) ∩ Introduction of Natural Disasters (course level) → International Perspectives on Natural Disasters (course level)".
4) **Mass media report or daily life**: Sometimes, our thinking is deeply influenced by the mass media or our daily life. For example, Artificial Intelligence (also known as machine intelligence and often abbreviated as AI) encompasses computer science, neuroscience, philosophy, psychology, robotics, and linguistics, and is devoted to the reproduction of the methods or results of human reasoning and brain activity. There was famous science fiction film that was released in 2001, which was called A.I.: Artificial Intelligence, and directed by Steven Spielberg. This film used lots of digital image processing and took an imaginative view of AI. This may cause a learner who is taking the AI course to then study about digital image processing in Department of Industrial and Commercial Design. In this case, a cross-level frequent pattern is "Artificial Intelligence (course level) → Industrial and Commercial Design (department level)".

7. Conclusions

A method of cross-level frequent pattern mining has been described, which extends the scope of mining frequent patterns from the same level of a hierarchy to the concept of mining learning relations among a curricular taxonomy. In this study, we integrate a multi-level hierarchy information encoded technique and frequent pattern mining method to provide users with experienced learning suggestions. The FP-tree construction algorithm, FP-growth algorithm and a complete case example clarify this research idea. We also conducted some experiments to evaluate the proposed methodology using real-world data from an e-Learning system of National Cheng Kung University in Taiwan. Based on the mining results, we generalized three types of frequent patterns, and reasoned out why the patterns happen and what the learners need. Such a learning mechanism is essential in this age of Web-based instruction, where there are more and more reusable learning materials shared over the Internet. Learners can not easily take lessons in a good learning sequence, and may lose their way in this vast space. Our study initiates an innovative research direction of e-Learning field by applying data mining techniques, and gives learners many suggestions to help them learn more effectively and efficiently.

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References

Agrawal, R., Imielinski, T., & Swami, A. (1993). Mining Association Rules between Sets of Items in Large Database. *Paper presented at the 1993 ACM SIGMOD conference on management of data*, May 26-28, 1993, Washington, D.C.

AICC (2003). Aviation Industry CBT Committee, Retrieved June 7, 2007, from http://www.aicc.org/.

Berghel, H. (1997). Cyberspace 2000: Dealing with information overload. *Communications of the ACM, 40*(2), 19–24.

Bonchi, F., Giannotti, F., Mazzanti, A., & Pedreschi, D. (2003). ExAMiner: Optimized Level-wise Frequent Pattern Mining with Monotone Constraints. *Paper presented at the Third IEEE International Conference on Data Mining*, December 19-22, 2003, Melbourne, Florida, USA.

Borchers, A., Herlocker, J., Konstanand, J., & Riedl, J. (1998). Ganging up on information overload. *Computer, 31*(4), 106–108.

Chen, C. M., Lee, H. M., & Chen, Y. H. (2005a). Personalized e-learning system using Item Response Theory. *Computers & Education, 44*(3), 237–255.

Chen, J. N., Huang, Y. M., & Chu, W. C. (2005b). Applying Dynamic Fuzzy Petri Net to Web Learning System. *Interactive Learning Environments, 13*(3), 159–178.

Cheng, S. C., Huang, Y. M., Chen, J. N., & Lin, Y. T. (2005). Automatic Leveling System for E-Learning Examination Pool Using Entropy-based Decision Tree. *Lecture Notes in Computer Science, 3583*, 273–278.

Choi, J. (1999). A study on instruction strategy to improve interactivity in web-based instruction. *Journal of Educational Technology, 15*(3), 129–154.

Han, J., & Fu, Y. (1999). Mining Multiple-Level Association Rules in Large Databases. *IEEE Transactions on Knowledge and Data Engineering, 11*(5), 798–805.

Han, J., Pei, J., & Yin, Y. (2000). Mining Frequent Patterns without Candidate Generation. *Paper presented at the 2000 ACM SIGMOD International Conference on Management of Data*, May 14-19, 2000, Dallas, TX, USA.

Huang, Y. M., Chen, J. N., Cheng, S. C., & Chu, W. C. (2004). Agent-Based Web Learning System Applying Dynamic Fuzzy Petri Net. *Lecture Notes in Computer Science, 3143*, 338–345.

Huang, Y. M., Kuo, Y. H., Chen, J. N., & Jeng, Y. L. (2006). NP-miner: A Real-time Recommendation Algorithm by Using Web Usage Mining. *Knowledge-Based Systems, 19*(4), 272–286.

IEEE LTSC (2002). *IEEE Learning Technology Standards Committee*, Retrieved June 7, 2007, from http://ltsc.ieee.org/.

IMS (2003). *Content Packaging Best Practice Guide, Version 1.1.3 Final Specification*, Retrieved June 7, 2007, from http://www.imsglobal.org/content/packaging/.

Jeng, Y. L., Huang, Y. M., Kuo, Y. H., Chen, J. N., & Chu, W. C. (2005). ANTS: Agent-based Navigational Training System. *Lecture Notes in Computer Science, 3583*, 320–325.

Karampiperis, P., & Sampson, D. (2005). Adaptive Learning Resources Sequencing in Educational Hypermedia Systems. *Educational Technology & Society, 8*(4), 128–147.

Kaya, M., & Alhajj, R. (2004). Mining Multi-Cross-Level Fuzzy Weighted Association Rules. *Paper presented at the Second IEEE International Conference on Intelligent Systems*, June 22-24, 2004, Varna, Bulgaria.

Khalifa, M., & Lam, R. (2002). Web-based learning: effects on learning process and outcome. *IEEE Transactions on Education, 45*(4), 350–356.

Kim, C., & Kim, J. (2003). A Recommendation Algorithm Using Multi-Level Association Rules. *Paper presented at the IEEE/WIC International Conference on Web Intelligence*, October 13-16, 2003, Halifax, Canada.

NCKU (2005). *Web Learning System*, Retrieved June 7, 2007, from http://iteach.ncku.edu.tw/.

Pahl, C. (2003). Managing evolution and change in web-based teaching and learning environments. *Computers and Education, 40*(2), 99–114.

Papanikolaou, K. A., Grigoriadou, M., Magoulas, G. D., & Kornilakis, H. (2002). Towards new forms of knowledge communication: the adaptive dimension of a web-based learning environment. *Computers & Education, 39*, 333–360.

SCORM (2004). *Shareable Content Object Reference Model, Version 1.3*, Retrieved June 7, 2007, from http://www.adlnet.gov/scorm/index.aspx.

Song, K. S., Hu, X., Olney, A., & Graesser, A. C. (2004). A framework of synthesizing tutoring conversation capability with web-based distance education courseware. *Computers and Education, 42*(4), 375–388.

Tang, T. Y., & Mccalla, G. (2003). Smart recommendation for evolving E-learning system. *Paper presented at the 11th international conference on artificial intelligence in education, workshop on technologies for electronic documents for supporting learning*, July 20-24, Sydney, Australia.

Laborda, J. G., & Royo, T. M. (2007). Book review: How to teach English with Technology (Gavin Dudeney & Nicky Hockly). *Educational Technology & Society*, 10 (3), 320-324.

How to teach English with Technology
(Book Review)

Reviewers:
Jesús García Laborda
Associate Professor in Applied Linguistics
Polytechnic University of Valencia
E. P. S. Gandía, Valencia, Spain
jgarcial@upvnet.upv.es
Tel: +34 666 28 45 57

Teresa Magal Royo
Associate Professor in mass media communication
Polytechnic University of Valencia
E. P. S. Gandía, Valencia, Spain
tmagal@gigit.upv.es

Textbook Details:
How to teach English with Technology (with CD-Rom)
Gavin Dudeney & Nicky Hockly
Pearson - Longman
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2007, 192 pages

Overview

The volume "How to teach English with Technology" is about language and second language teaching using the devices provided by the latest computer and the Internet technology. The authors, Gavin Dudeney and Nicky Hockley, are co-directors of a language consultancy (Barcelona, Spain) specializing in online and distance learning. The book has two main goals: introducing a wide range of teaching possibilities for those teachers who are not fully aware of computer technology and Internet, and providing ideas for classroom activities. The book has 12 chapters plus four appendixes which first describe the theoretical background of each topic, followed by a description of the technical devices, software or hardware, used in the chapter and some suggestions for classroom activities. Each chapter concludes with a summary, and has some follow up activities in the first appendix. The most interesting feature of this book is the possibilities of teachers who work with a variety of types of software or hardware (or even who actually do not approach language teaching with technology) to integrate the contents into their daily teaching plans. Additionally, the book has a CD-Rom which contains practical demonstrations of the contents of each chapter, interviews with practitioner teachers and some related webliography. These interviews reflect the ways, constraints and ideas of novel and experienced teachers when working with technology.

Introduction and justification

Computers and language teaching have walked hand to hand for a long time and contributed as teaching tools in the language and second language classroom. In fact, this is not the first book of its kind. It seems that regularly, as computers evolve, applications to language teaching in form of relevant general volumes are published (Chesters, 1987; Brierley, 1991; Sabourin, 1994; Boswood, 1997; Beatty, 2003; Lee, Jor & Lai, 2005; Szendeffy, 2005; Towndrow, 2007). Besides, among a large number of recent publications, some volumes have addressed specific issues in second language acquisition (Chapelle, 2001), communication (Warschauer & Kern, 2000) or language teaching for the professions (Arnó Macià, Soler Cervera & Rueda Ramos, 2006) to only mention some.

Computers and technology are still a source of fears and insecurity for many teachers everywhere in the world despite the latest advances applicable to language teaching such as specialized websites, blogs, wikis, language teaching methodology, journals, and so. Although many countries have done institutional efforts to modernize their equipment, spent large amounts in technology, proved the positive effects of integrating computers in language learning (Tsou, Wang & Tzeng, 2006) and so, many teachers still miss the appropriate interest, strong will to learn and a challenging attitude towards teaching with computers. Most times the reasons are the lack of time for out-of-school training in combination with the natural difficulty in incorporating new working schemata within their own classrooms. Besides, institutional organizations, district and national educational boards, and even publishers are doing important institutional efforts to strengthen the presence and evolution of distance and online education. As a consequence, computers should no longer be a little more than a way to typewrite (as they are sometimes today), send messages and, when lucky, to browse out for information on the net (Johnson & Eisenberg, 2006). Therefore, one major concern that is commonly shown by both teachers and education boards is how to motivate and instruct teachers to integrate computers and ICT into their classes.

How to teach English with Technology, integrates theory and practice. In this sense, the authors intend to inform as well a propose ways in which to incorporate teaching tips, ideas and classroom plans as well as provide activities for self learning and evaluation. In fact, texts are usually followed by revision and critical thinking questions that try to make the reader process and summarize what has been said in each chapter.

Chapter Summary

Chapter 1, *Technology in the classroom*, deal with the importance of including ICT in the language curriculum. According to the authors ICT have intrinsic features that make its use a valuable source of input but, as mentioned above, sometimes teachers may distrust technology or just be reluctant to include computer activities in their classrooms.

Chapter 2, *Word processors in the classroom*, provides unique ideas for those teachers with limited expertise in teaching with technology so they can begin progressively to incorporate computer activities with texts and pictures but, in any case, in a productive and elaborate way.

Chapter 3, *Using websites*, is probably one of the most interesting chapters since the chapter gives information on how to find information for classroom activities, it makes a difference between authentic and teacher created materials, on the features to be evaluated when working with and distinguishing the best didactic websites, it also provides ideas for classroom plans and, very important, tips for disadvantaged or advanced students. The chapter is also attractive because it gives ideas for classes with different proficiency levels.

Chapter 4, *Internet-based project work*, addresses the issue of task based learning and cooperative language learning, two of the most significant issues in the last twenty years in language teaching. The authors propose a scale from the easier projects like information gather to simulations and webquests. Especially significant is the authorst combination of constructivist and behaviourist ideas and function of webquests in language learning (p. 56).

Communication asynchronous and synchronous are especially studied in chapters 5 and 6, *How to use email* and *How to use chat*. These two chapters have attracted a huge number of researchers in the last few years that have been able to see their importance in cross cultural communication and intercultural competence. Thus, the first and foreign language teachers may want to read the chapters with especial attention. These chapters include features such as proposals for keypal projects, or the educational use of chat rooms (either written or oral), chat lessons, and, overall, follow up activities for both types of communication activities.

Chapter 7, *blogs, wikis and podcasts*, deals with social software in which a variety of social actants have the opportunity to include their own contents. Among these, podcasts are significant for the language teachers because teachers find difficult to find resources for pronunciation with a variety of accents and registers to be used in the classes. Wikis and blogs incorporate a wide variety of audiovisual items that are worth incorporating in the foreign language classroom.

Chapter 8, *Online reference tools*, looks at online resources as dictionaries, thesauruses, translators, corpuses and encyclopaedias; Chapter 9, *Technology based courseware*, shows publishers' materials that teachers may want to use along with their textbooks (of which, most times they are official complimentary materials). Chapter 9 also devotes some space to interactive whiteboards that have so successfully incorporated in countries like India or Mexico, and computer assisted language testing software and online resources. This chapter is enhanced by the following, Producing electronic materials, which is a very appealing mini-course in authoring, creating and designing one own's materials with or without authoring tools like *Hot Potatoes*, *Clarity Software*, *Creative Technology* or *Quia*.

The last two chapters are exclusively devoted to the professionals' personal development. Chapter 11, *e-learning: online teaching and training*, deal with the importance of online training and tutorials, discussion lists and online groups. Chapter 12, *Preparing for the future*, may be an interesting additional extra reading. It reviews the current state of the art, and gives advice on how to keep up-to-date in such a changing world and foresees what things like web 2.0, online learning, virtual learning and m-learning may bring. This chapter is very attractive and, even for those already in the field, will certainly offer new discussion and thinking perspectives.

The book also includes a section with activities and a key for those activities just in case this book may be used for teacher training in technology courses. These activities are linked to the webliography and interviews presented in the CD-Rom. The volume also includes a jargon-free glossary with the most common entries found in the book.

Discussion

It is a pity that some teachers in first language or general teaching may be deviated by the title of this book review considering that they may not be interested in language or foreign language teaching, because this book integrates ideas and current technology and web developments that some teachers may neglect or just simple ignore but could be valuable assets in their classes. Dudeney and Hockly's work tends to be informative instead of only supporting the great benefits of including all the elements pointed in the previous section in the language classroom. Of course, they support their use in the classroom but it seems that their goal is more offering a range of possibilities to the teacher rather than directions for the implementation of *Computer Assisted Language Learning* (CALL). In this sense, the real examples provided all through the book, the huge webliography, the snapshots from websites, the demonstrations and teaching tips facilitate its reading and quick integration into most school environments. Besides, readers will feel the potential of the book and self development because they will be able to go from the simpler ideas to "dip into the chapters which seem most relevant to [their] teaching or training situation" (p. 5). In the negative sense, the book could have placed most snapshots on the CD-Rom. Also, some readers may get the feeling that the CD-Rom has been underused since many demonstrations and classroom techniques could have been video recorded like some other books in the "How to…" series have done (Harmer, 2007). One other drawback would be that the book is too descriptive and although the activities lead to personal reflexions, more possibilities for writer-reader debate and some directions to for and against forums would have been desirable for the more experienced readers. A major criticism would be the almost total lack of citations to mega websites that include many of the desirable materials (exercises, journals and more) like onestopenglish.com, Dave's ESL Café or isabelperez.com as well as mentions to journals like TESL EJ, CALL EJ, Language Learning & Technology, Internet ESL journal and many more which are open and free to be accessed by practitioner teachers.

From a content perspective, the book addresses issues that have currently attracted the interest of many teachers in any field and that have proved their value in any classroom like the educational place of webquests (Ikpeze & Boyd, 2007), the traditional use of websites as a source of information and language input (Dalvit, Murray, Mini, Terzoli & Zhao, 2005), the positive attitudes of teachers and students towards the integration of the Internet in language teaching (Yang, 2001), the use of video to provide language input and correct the student's phonological realizations (Hada Ogata, & Yano, 2002), issues in synchronous and asynchronous communication (Ingram, Hathorn & Evans, 2000), attitudes towards computer based oral (Kenyon & Malabonga, 2001) and writing (Sawaki, 2001). assessment, projects in language learning as a teaching approach for classes with different competence level and students with different teaching styles (Hollenbeck & Hollenbeck, 2004).

In general, because it can be assumed that we live with and by technology, it is time to look at ICT as an integral part of education with some limited implications in education. Thus, teachers need to use them as tools in education rather than variables of failure or success in language (or content) teaching (Felix, 2005). Of course, ICT can definitely complement textbooks, as seen in chapter 9, but it is so much more than supporting stuff (Oakes & Saunders, 2004) and, obviously, a lot less than the teacher who assumes a facilitating role that allows students to achieve new degrees and types of literacy (Molebash & Fisher, 2003).

Overall, both experienced and inexperienced practitioner teachers as well as teacher trainees will definitely learn very much from this book and its friendly reader style. They will certainly find teaching tips and strategies that may enhance and improve their teaching. Again, it can be emphasized that teachers with no experience have nothing to fear, and that the implementation of some strategies included in the book will increase confidence in technology and their esteem as teachers.

References

Arnó Macià, E., Soler Cervera, A., & Rueda Ramos, C. (2006). *Information Technology in Languages for Specific Purposes: Issues and Prospects*, Berlin: Springer.

Beatty, K. (2003). *Teaching and Researching Computer-Assisted Language Learning (Applied Linguistics in Action)*, New York: Pearson ESL.

Boswood, T. (1997). *New Ways of Using Computers in Language Teaching (New Ways in Tesol Series II)*, California: Teachers of English to Speakers of Other Languages.

Brierley, B. (1991). *Computers as a Tool in Language Teaching (Ellis Horwood Series on Computers and Their Applications)*, New York: Ellis Horwood.

Chapelle, C. A. (2001). *Computer Applications in Second Language Acquisition*, Cambridge, UK: Cambridge University Press.

Chester, S. (1987). *Use of Computers in the Teaching of Language*, Houston: Athelstan Publications.

Dalvit, L., Murray, S., Mini, B., Terzoli, A., & Zhao, X. (2005). Computers and african languages in education: An ICT tool for the promotion of multilingualism at a south African university. *Perspectives in Education, 23*(4), 123-131.

Felix, U. (2005). Analysing recent call effectiveness research--towards a common agenda. *Computer Assisted Language Learning, 18*(1-2), 1-32.

Hada, Y., Ogata, H., & Yano, Y. (2002). Supporting online video-based correction for language learning through markup-based video. *Paper presented at the Ed Media Conference*, June 24-29, 2002, Denver, Colorado, USA.

Harmer, J. (2007). *How to teach English*, Harlow, Essex: Pearson-Longman.

Hollenbeck, J. E., & Hollenbeck, D. Z. (2004). *Technology to enhance learning in the multi-lingual classroom*, East Lansing, Mi, Eric document ED490629, Retrieved June 7, 2007, from http://eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED490629.

Ingram, A. L., Hathorn, L. G., & Evans, A. (2000). Beyond chat on the internet. *Computers & Education, 35*(1), 21-35.

Ikpeze, C. H., & Boyd, F. B. (2007). Web-based inquiry learning: Facilitating thoughtful literacy with WebQuests. *Reading Teacher, 60*(7), 644-654.

Johnson, D., & Eisenberg, M. (2006). *Learning and Teaching Information Technology--Computer Skills in Context*, East Lansing, Mi, Eric document ED465377, Retrieved June 7, 2007, from http://www.ericdigests.org/2003-1/skills.htm.

Kenyon, D. M., & Malabonga, V. (2001). Comparing examinee attitudes toward computer-assisted and other oral proficiency assessments. *Language Learning & Technology, 5*(2), 60-83.

Lee, C., George Jor, G., & Lai, E. (2005). *Web-based Teaching and English Language Teaching: A Hong Kong Experience*, Hong Kong: The Chinese University Press.

Molebash, P., & Fisher, D. (2003). Teaching and learning literacy with technology. *Reading Improvement, 40*(2), 63-70.

Oakes, J., & Saunders, M. (2004). Education's most basic tools: Access to textbooks and instructional materials in California's public schools, *Teachers College Record, 106*(10), 1967-1988.

Towndrow, P. A. (2007). *Task Design, Implementation and Assessment: Integrating Information and Communication Technology in English Language Teaching and Learning*, Hong Kong: McGraw-Hill Education.

Tsou, W., Wang, W., & Tzeng, Y. (2006) Applying a Multimedia Storytelling Website in Foreign Language Learning. *Computers and Education, 47*(1), 17-28.

Sabourin, C. (1994). *Computer assisted language teaching: Teaching vocabulary, grammar, spelling, writing, composition, listening, speaking, translation, foreign languages*, Montreal, Canada: Infolingua.

Sawaki, Y. (2001). Comparability of conventional and computerized tests of reading in a second language. *Language Learning & Technology, 5*(2), 38-59.

Szendeffy, J. (2005). *A Practical Guide to Using Computers in Language Teaching*, East Lansing: University of Michigan Press/ESL.

Warschauer, M., & Kern, K. (2000). *Network-based Language Teaching: Concepts and Practice*, Cambridge: Cambridge University Press.

Yang, S. C. (2001). Language learning on the World Wide Web: An investigation of EFL learners' attitudes and perceptions, *Journal of Educational Computing Research, 24*(2), 155-181.

Holzinger, A. (2007). Book review: Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load (Ruth Colvin Clark, Frank Nguyen and John Sweller). *Educational Technology & Society*, 10 (3), 325-326.

Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load

(Book Review)

Reviewers:
Andreas Holzinger
Associate Professor of Information Processing
Medical University of Graz, Austria
andreas.holzinger@meduni-graz.at

Textbook Details:
Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load
Ruth Colvin Clark, Frank Nguyen and John Sweller
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Overview

The book "Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load" is about using the three fundamental instructional materials: visuals, written text, and audio. The book is basically intended for instructional professionals and aims at explaining how to improve learning by focusing on student attention and avoiding redundancy in the presentation of learning material. The book is based on principles of Cognitive Load Theory (CLT), which serves as the basis for all of the guidelines within this book. Real-world examples demonstrate how these guidelines may be applied in settings ranging from a typical classroom to e-learning scenarios. A supplementary CD-ROM includes sample lessons and video commentaries by the authors. The authors of the book are Ruth Colvin Clark; who holds a doctorate in Educational Psychology and Instructional Technology from the University of Southern California; Frank Nguyen, the e-Learning Technology Manager for the Intel e-Business Training group; and John Sweller, the founder of the Cognitive Load Theory (CLT, refer to Sweller (1989)), who currently teaches at the School of Education at the University of New South Wales in Australia. John Sweller's theory, which is a central theory of learning, is based on an information processing model of human cognition and emphasizes the intrinsic limitations of the working memory, i.e. the amount of information that can be processed in short-term memory at one time. Within this book, the authors use schemas as relevant building blocks for instructional materials and they discuss three conditions of cognitive load: intrinsic (contained within the learning goal), extraneous (which is the information that is the so called "nice to know, however not need to know"), and germane cognitive load (which is the information needed to support the learning goal).

Chapter Summary

This book is divided into five parts. In part one, the authors provide an introduction about the term efficiency and discuss the psychological issues of cognitive load and efficiency in learning. In part two, they present the basic guidelines for managing irrelevant cognitive load, i.e. by using visuals and audio narration to exploit working memory resources, focus attention and avoid split attention and *weeding training* to manage limited working memory capacity. Most of all, they discuss how to use segmenting, sequencing and learner pacing to impose content gradually. Finally, they discuss the transition from worked examples to practice in order to impose mental work gradually. In part three the authors present some instructional guidelines for imposing relevant cognitive load and in part four they discuss tailoring instruction to learner expertise (e.g. accommodation of differences in learning expertise and using rapid testing to adapt e-Learning to learner expertise). Finally, in part five, the authors put Cognitive Load Theory in practice. At the end of this part, John Sweller provides his personal perspective of the evolution of CLT. In the appendix, the authors provide additional information about calculating and displaying the efficiency matrix and efficiency graphs. Within the following glossary, the authors explain 69 used terms in a clear and concise manner (e.g. Weeding = an instructional design strategy in which unnecessary content or redundant content modalities are eliminated in order to minimize cognitive load). The glossary is followed by 126 references and concluded by an index. The book is supplemented by a CD-ROM, which contains asynchronous e-Learning demonstration lessons that both apply and violate the guidelines taught within this book. The examples are commented by John Sweller.

Evaluation

This book is a must read for everybody who is interested in learning and teaching. Meanwhile, it is commonly accepted that the Cognitive Load Theory has emerged as one of the most important and best researched foundations for improving the development of instructional material. Most of all, this book serves as a good example on how psychological research results can be made usable for educational practitioners. To have no background in CLT is not a problem; this book provides a sufficient introduction, anyone who is not familiar with CLT should read chapter 13, pp. 313–329 first. The presentation of the content is very well done. The chapters begin with a one page chapter outline; the chapters are well structured, the organization and style very good. At the end of each chapter there is information about the supplementing CD-ROM, a short overview about the next chapter (so called “coming next”) and well chosen recommended readings. I was extremely pleased with the “What the research says …” boxes. They contain relevant concise descriptions of corresponding research. The only shortcoming of the book is the use of much worn standard examples (i.e. Mayer, the one with the pressure pump). Readers would have liked to have new or more practical examples instead of these standard examples. A minor cosmetic problem is that the printing sometimes goes very close to the bottom of the page.

Summarizing, I can highly recommend this book to anyone who is interested in both learning and teaching and especially those who are interested in the application of the Cognitive Load Theory.

Malinski, R. (2007). Book review: The Research Student's Guide to Success (Pat Cryer). *Educational Technology & Society*, 10 (3), 327-328.

The Research Student's Guide to Success

(Book Review)

Reviewers:
Richard Malinski
Ryerson University, Canada
richard@ryerson.ca

Textbook Details:
The Research Student's Guide to Success
Third Edition
Pat Cryer
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ISBN: 0-335-22117-3
288 Pages

This is the third edition of Pat Cryer's self-help book for graduate students with specific emphasis for those research graduates in the UK. The material is a collection drawn not only from her long experience but also from students and supervisors. Keeping these two facets in mind, the book becomes a practical guide, a potpourri of hints and tips, applicable in some part to all graduate and potential graduate students.

To get a taste of this edition of the book, use your browser to explore "Resources from Pat Cryer" which is a website outlining the content of and containing many segments from this third edition of her book. On the link http://www.postgrad_resources.btinternet.co.uk/student-resources00-book.htm, note the "Resources for Graduate Students" and "See inside this book". These give access to some segments of the book and specifically to all of Chapter 1, the table of contents, and the Index. Don't miss the extra segment on 'Originality in Research' noted at the bottom of webpage.

Rather than describe the layout which is well portrayed on Pat Cryer's website, the following material considers her approach and the worthiness of the book for graduate students and also those contemplating becoming a graduate student.

This book serves as an overview of the many challenges for those considering registering or already in a graduate program. The book does focus on the research PhD process in the UK but other graduate students should find much of worth.

Potential students should note the sequence of events as noted in the first few chapters of the book but not get ahead of themselves by jumping too far too quickly. The importance of being prepared is essential groundwork for success. Getting a broad view by exploring opportunities and making the right application as indicated in chapters 2 and 3 should not get short shrift. Some readers may find the choppy style with many headings and short burst of information disconcerting. Note that this book does not provide much detail in any of the topics covered. It carries you from crest to crest and prompts you to delve into other books or the Internet and/or to ask knowledgeable people for details. You are the responsible agent who must take the material in the book and act upon it.

Once into a program, the students then must contend with managing four main streams through the process. One stream is the administrative components which include dealing with such components as complying with department or school regulations on progress reports, due dates or ethical issues as well as developing funding requests, taking on teaching assistance work , transferring to another degree stream or being a student from overseas. These are elements running through chapters 9, 11, 16 and 18. Understanding the hurdles and accomplishing these in a timely fashion is critical.

Another stream is writing or presenting your material such as, the initial research proposal, department or conference presentations, and the thesis. These are treated in chapters 4, 16, 17, 19, 20, 23, 24 and 25. Closely related to this stream are chapters 7 and 8 which focus on reading and evaluating quality of literature in the topic chosen. Cryer brings out several key facets in her writing, i.e. set and keep within boundaries, understand the departmental style for reports/theses, stay open minded to recognize originality and creativity, and remember that writing takes longer than you think. One eddy that really should be strong current through the work is the mention of when to start a thesis. Six lines on page 176 suggest that reports written during the years of study often form parts of the thesis. This reviewer would rephrase that to say that all reports should be seen as being part of or chapters in the final thesis. There should be more emphasis on having students plan ahead, choose a thesis topic and focus all work on that topic. However, Cryer does take the more realistic approach in stating that the students should begin the thesis at the earliest possible time.

A third stream that the book introduces is that of personal development which flows through chapters 10, 12, 13, 14, 21 and the Appendix. While the thesis is the ultimate tangible product of the graduate program, personal growth is the greatest intangible and most worthwhile facet in this reviewer's opinion. Cryer makes it clear that students must take control of their own development by understanding their skills and abilities such as emotional traits, working style, learning style, planning abilities and computer skills. Cryer mentions clearly that students do not often know themselves well enough to engage in activities that support their learning and work styles or foster a positive emotional state. Contacting the institutional learning centre or student support facility to seek help to assess emotional intelligence, learning style or preferred working environments is very important. Cryer also stresses the need for personal development planning (PDP) which, developed by the Quality Assurance Agency, is an important activity in UK graduate schools. This PDP approach prompts students to reflect on their learning and performance in order to structure their personal, educational and career development. In the Appendix there is a valuable list of specific skills that graduate students should study and aim to develop where appropriate. Cryer is correct to emphasize this because students do not do enough self-reflection in today's fast paced educational environment.

A fourth stream is that of personal interaction which Pat Cryer covers in parts of chapters 5, 6, 10 and 15. Cryer emphasizes the importance of dealing with others while in the graduate program. The most important person is the supervisor because having a respectful relationship here can mean help in complying with administrative rules, in refining the research work and successfully preparing and defending the thesis. Cryer's various suggestions on how the student should develop an appropriate relationship here are extremely important to the student's success and should not be underestimated. Cryer also comments that networking and team playing are also important not only in assisting the student through the stages of the program but also as well as in coping with isolation and stress. Becoming familiar with the 'community' be it academic staff, fellow students or local resource people provides the student with many opportunities to gather useful information, to understand administrative processes and also to resolve issues that might otherwise stall progress.

This book requires close reading. It is easy to miss important points because the staccato writing style of so much material in so many headings promotes skipping. Because of this style, a detailed index would prove a useful tool in finding and referring back to the information. Cryer has many illustrative examples separated from the text in numbered boxes. She also has other boxes for 'Suggestions' and 'Points to Ponder' which prompt the students to reflect on the text or begin a related activity. Having these noted in the index would facilitate finding them again. The references to books and websites are most useful as is the introduction of the many UK agencies such as the Quality Assurance Agency and the UK Council for Graduate Education but product placement of Microsoft Office products seems to be out of place!

There are many useful points in Cryer's book that any graduate student would be well advised to take to heart. Of the many points there are several crucial personal issues touched upon and of which graduate students should be especially mindful. These four important survival or success factors are

- self-awareness as embodied in emotional intelligence (page 120), in learning style (page 151), and alluded to in Chapter 2 and in Chapter 21;
- commitment as introduced in Chapter 2 and again in Chapter 21;
- supervisor relationships as noted primarily in Chapter 6; and
- community support as noted in Chapters 5, 10 and 14.

Cryer's book, for those looking for an overview of challenges facing them in a graduate research program, would serve well as a first guide.

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