An integrated approach to individual and collaborative learning in a web-based learning environment

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Abstract: In this paper we will discuss the design of a web based interactive learning environment. We will focus on the cognitive and collaborative tools that we are developing for students learning at a distance. We have adopted a constructivist, problem based approach for our design. An essential element of making this approach work is to integrate the individual and collaborative learning as well as the affordances and scaffolding provided by the different tools. We will discuss the design principles, the tools and the framework for integrating individual and collaborative learning.

Keywords: scaffolding, problem-based learning, constructivism, cognitive tools, collaborative spaces, individual and collaborative learning.

Introduction

With the availability of inexpensive and powerful computers and advances in technology, the World Wide Web has become one of the major technologies in distance education. Distance learning via the World Wide Web (WWW) presents some unique challenges because learning in such an environment is a truly distributed event, where learners are physically removed from one another. Feelings of isolation, of not being part of a community and, lack of motivation are known to have been reported by students (Wegerif, 1998). Moreover, students' perception of the usefulness of a course offered on the WWW is dependent on how fruitful and productive their collaborative interactions have been.

Most web-based courses provide formal and informal discussion forums, in the form of chat rooms and discussion seminars respectively. However, discussions are not necessarily integrated with other activities that students undertake. One of the reasons for this is that there is often a lack of a sound conceptual framework guiding the design of the courses. In order to develop collaborative spaces that maximize educational benefits, the design of the entire course (or program) needs to be taken into account so that individual and social learning opportunities complement each other. The learning environment needs to integrate collaborative learning with activities that students can undertake on their own. To achieve this, we are developing an interactive web-based learning environment based on a constructivist, problem-based approach. It not only integrates individual and collaborative learning opportunities, but also provides scaffolding at three levels: cognitive, collaborative and metacognitive.

In this paper, we will discuss the conceptual framework guiding the design of the learning environment. We will describe the cognitive tools and the collaborative spaces we are designing, the different levels of scaffolding we are building into the tools and discuss how we are integrating the tools as well as the levels of scaffolding. We will then discuss the context in which we are using the web-based environment and some preliminary results.

Conceptual framework guiding our design

We are using a constructivist, problem-based approach to designing an interactive web-based learning environment (WBILE). Constructivists believe that learning is constructing knowledge from one's experiences rather than directly receiving information from the outside world (e.g. Collins & Green, 1992; Resnick, 1987; Brown, Collins & Duguid, 1989; Collins, Brown & Newman, 1989). The basic tenets of constructivism are (a) learners construct their own understanding; (b) new learning depends on current understanding; (c) learning is facilitated by social interactions and (d) meaningful learning occurs within authentic learning tasks. Solving authentic problems is one such constructivist approach (e.g., Barrows, 1985; Barrows & Kelson, 1995). Problem-solving environments are richest when drawn from the world of practice, from real world learning situations. As students work on solutions to complex problems, they have the opportunity to construct and generate rich meanings (Piaget, 1954; Perkins, 1986). In addition, students need to reflect on their ideas and solutions, provide explanations and justifications, all of which can augment their understanding of the domain knowledge. Our design of the web-based interactive learning environment (WBILE) is being guided by the following principles.

Solving complex problems affords rich opportunities for learning

Problem solving has long been regarded as a generative activity that could promote deep learning (e.g., Barrows, 1985). Recent research shows that, indeed, students learn content knowledge deeply by solving relatively complex, real world problems that can have multiple solutions (Barrows & Kelson, 1995). Koschmann (1994) has put forth six principles for effective learning – multiplicity, activeness, adaptation, authenticity, articulation and termlessness and has emphasized that solving complex ill structured problems provides students with ample opportunities to engage in all of these. Real world problems have several features that make them ideal for promoting learning and vehicles for connecting theoretical knowledge to issues in the outside world. (1) They are complex and ill structured and have multiple solutions or methods of solving them (Jonassen, 1997). (2) They are generally underspecified, thus requiring the learner to generate multiple hypotheses, and explore for more information in order to refine these hypotheses to move towards a solution. (3) They are complex and therefore require the learner to acquire knowledge and skills to resolve them (Barrows, 1985). (4) Ill-structured problems come from the world of practice and therefore help learners to make the connections between the theories they are learning and their application in the real world. (5) They provide opportunities for collaborative learning in which learners can engage in collective meaning making.

Thus one way to encourage deep learning is to have students engage in solving complex, ill-structured problems. Our approach to designing a web-based interactive learning environment for distance learning seeks to do just that. Our aim is to develop problems in the content area of a given course, and cognitive tools to support student learning as they solve the problems. Each of the different problem solving experiences in the distance courses that we are developing becomes a rich "case" available to students as they engage in later problem solving. Case-based reasoning (Kolodner, 1993) explains that the extent to which an experience is useful to later learning depends on the richness of analysis the reasoner has undertaken. An experience anchored in a rich context will provide ample opportunities for analysis. Such an experience will also provide more opportunities for the learning to transfer to novel situations. If learning is a process of acquiring the culture of a professional community as described by Lave and Wenger

(1991), distance learning via an interactive environment should offer numerous possibilities for electronic apprenticeship.

Collaborative learning promotes reflection, articulation and knowledge building

Researchers have demonstrated the importance of reflection as being important to enhance learning. For example, Pirolli and Recker (1994) suggested that reflection on problem solutions that focuses on understanding the abstract relationships between problems is related to improved learning. Collins and Brown (1988) used abstracted replay in which the learners' solution procedure was reified to help learners examine their solution trees. Research on self-explanations (Chi, 1989; Bielaczyc, 1994) suggested that students learn better when they generate explanations thereby monitoring their understanding. Another way that reflection can be enhanced is through articulation in collaborative discourse. Reflection is not a solitary process (Schon, 1983, 1987). Collaboration provides students with opportunities to reflect on and articulate what they are learning.

The importance of the social context in supporting an individual’s understanding of her own learning (i.e., metacognition) was emphasized by Brown & Palincsar (1987). Working in groups provides many opportunities for exploration, reflection and articulation. Collaborative work allows students to successfully tackle problems more complex than what any group member could do alone (Hmelo, Narayanan, Newstetter & Kolodner, 1995). Researchers have emphasized the importance of collaborative discourse not only to support learning but also build a community. For example, Brown and Campione (1990) proposed communities of learners and thinkers, while Scardamalia and Berierter (1994) proposed restructuring classrooms into knowledge building communities.

Although collaboration is known to promote reflection and articulation, outcomes of collaborative learning are influenced by several factors. Some of these are the composition of the pairs or groups (Whitelock, Taylor, O’Shea, Scanlon, Clark, & O’Malley, 1993), the nature of the task (Puntambekar, 1996) and the nature of the environment itself (Crook, 1994). These factors, either singly or in combination, lead to different interactions among the learners; the types of interactions heavily influence the learning outcomes. In addition, learning outcomes in a computer based environment are also influenced by the instructional roles that the tools support and **when** the tools are used in the learning process (Koschmann, 1996). Collaboration has also been found to be more fruitful and resulting in better learning outcomes if it is **anchored**, i.e. students have a purpose to collaborate, such as reviewing or critiquing or answering a question (Guzdial, 1998).

This is especially true in a distance learning situation on the WWW because learners are geographically removed from each other. They cannot thus take advantages offered by face-to-face interactions. Furthermore, the support that learners can provide one another is crucial to the building of a community of learners. Therefore, the individual and social learning opportunities in a distance learning environment need to be integrated in such a way as to maximize the learning benefits. In order to achieve this, the type of support afforded by each tool needs to be carefully considered so that the tools complement each other.

Scaffolding is critical to help students learn within an ill-structured problem space

An important aspect of making a constructivist, problem-based approach work is the scaffolding that students require in order to learn within an ill-structured problem space. Scaffolding in a complex environment such as problem solving needs to be **distributed** among many agents (Puntambekar & Kolodner, 1998). This is because complex problem solving involves many stages and any one agent of scaffolding, such as peer interactions or the software cannot provide students with the support and adaptability that scaffolding in such an environment requires. Moreover, both individual and collaborative learning opportunities need to be integrated so that students are supported during the entire problem solving process. The cognitive and collaborative tools that we are building serve as vehicles for three levels of scaffolding – cognitive, social and metacognitive. An essential aspect of the tools we are building is that it integrates the scaffolding across both individual and collaborative tools.

Tools to support individual and collaborative learning

We are building tools that provide opportunities for collaboration as well as help students reflect on their own before and after they engage in group discussions. The tools are – 1. reflective notebooks that will help students flesh out their ideas before discussing them with other students, 2. discussion tools for small and large group discussions and 3. collaborative concept maps.

Reflective notebooks

The 'reflective notebook' enables learners to analyze ideas, explore, articulate and reflect on solutions to problems. This is an 'individual' tool which is a repository of students' thoughts and ideas and helps them to think about the issues before they participate in electronic discussions.

The notebooks serve many functions. Based on the notion that "making covert, abstract processes visible, public and manipulable, serves as a necessary catalyst for reflective metacognitive activity" (Derry, Tookey & Chiffy, 1994), the notebooks serve as a **vehicle for providing hints**. They make thinking visible and record students' journey through the problem solving process. They also provide prompts to help students decide how to move forward. The reflective notebooks provide guidance for students both in **carrying** out activities such as exploring the problem space and coming up with ideas, etc. and also **reflecting** on them in order to learn from them. We are developing two types of prompts for each stage in the problem solving process – generic prompts and specific prompts. The generic prompts are common to all problems and help students with the process – for example, thinking about the major issues in a problem. The specific prompts are unique to each problem and will encourage students to think about issues in that problem. These prompts can be customized by the instructor. This is very important in learning via the WWW because it allows the instructor to modify prompts based on the electronic discussions that students participated in.

Students can note their responses, append or edit what they had written earlier. Each entry is date stamped and is saved in a database. Thus it is an excellent source of assessment that enables students as well as the instructor and designers to understand students progression in (1) a problem and (2) across problems.

In addition, the notebooks also serve the purpose of evaluation at the end of each module as students individually write their **reflective essays**. At the end of each module, students write essays justifying their solution and drawing connections between the concepts they are learning.

Discussions

Small group

We are planning on using two types of discussion forums. One is meant for small groups of students working on problem solutions. These are accessible to the group members who can mentor each other and offer suggestions regarding the problem solution. These will serve the purpose of informal discussions in which students can ask each other questions and support each other. This is especially important in a distance learning situation because students are geographically removed from each other.

Whole class

Whole class discussion (with the instructor as the facilitator) are included in the course. The discussions are not ad hoc, but are built into the problem solving process in such a way that they support knowledge building during particular phases in the process. For example, the first discussion is designed to occur after students have individually (in their notebooks) generated ideas for solving the problem and have had an opportunity to discuss their ideas within their group. The discussion will focus on identifying the major issues in a problem and the initial ideas that students have about solving the problem. A second discussion takes place when students have done some information gathering which will help them to resolve the problem, based on the theories they are learning.

Thus by using a constructivist, problem-based approach, we are also aiming to make the discussions more productive so that the social context (in this case asynchronous) can be used to augment the cognitive affordances provided by the problem-based approach. Learning in such an environment is therefore a result of both individual and social processes (Driver, Asoko, Leach, Mortimer, and Scott, 1994).

Collaborative Concept maps

An additional feature that we will be integrating is 'collaborative concept maps'. Students collaboratively construct and edit concept maps that summarize the main concepts and show connections between theories they are learning. This activity is designed to be undertaken in small groups. It is expected that the maps will increase in richness and complexity as students complete modules in a given course. Concept maps provide students with an opportunity to integrate their content knowledge and see connections rather than viewing topics as isolated. As they progress through the course, students will be provided with opportunities to critique or add to concept maps drawn by other groups.

Levels of scaffolding provided by the tools

Each of the tools discussed above provides scaffolding that is unique to that tool. The scaffolding is distributed across the tools and is integrated in such a way that the educational benefits are maximized.

Cognitive level

The reflective notebooks

The reflective notebooks provide students with scaffolding at the cognitive level. Based on the Vygotskian notion of making abstract processes more visible, the scaffolding in the reflective notebooks provides students with support for the processes or steps in problem solving. This involves helping students to restate the problem, identifying the major issues in solving the problem, generating ideas about how they might solve the problem, etc.

Concept maps

Student generated concept maps will serve as scaffolds in the form of the conceptual representation of the theories and concepts that they need to solve the problem. Concept maps will also allow students to see the connections between the theories that they are learning so that they get an integrated picture of the topics as opposed to studying isolated facts. As students progress through the course they will be provided with more opportunities to work on building a conceptual representation of the domain.

Collaborative level

Scaffolding at the social level comes from the electronic discussions that students engage in. Learners can play an important role in supporting each other in the process of learning. They can post ideas, critique each others' ideas and reshape their own, ask questions and provide explanations. Thus numerous ways to reflect and articulate can be built into the environment which enables learners to construct meaning. This also has an additional advantage of building a community of learners. Because of the remote nature of the medium, students often feel isolated for not being part of a community. By engaging them in meaningful discussions that are also part of the scaffolding, we believe that their interactions will not only be more meaningful, but will also help them in building a sense of community. We are designing discussions to serve as scaffolds during at least three stages in problem solving: initial brainstorming, generating ideas to solve the problem (both initial ideas and after they researched or read about the issues), and for explanations and justifications. The instructor plays the role of a facilitator during these discussions. The instructor will post questions to start the discussions. Student responses in the notebooks will be taken into account while posting questions.

Metacognitive level

An important aspect of both these levels is that metacognitive prompts to encourage reflection are embedded in them. Thus, for example, students are provided with prompts that will encourage them to explain any problem from multiple perspectives, thereby providing them with an opportunity for generating richer understanding and integration of the domain knowledge. The concept maps also help them in gaining a deeper conceptual understanding as well as monitoring their own understanding of the domain.

Integrating multiple levels of scaffolding into individual and collaborative learning

In order for students to take advantage of the scaffolding afforded by the individual and collaborative tools, and to seamlessly integrate the collaborative aspects of learning with individual reflection, we have developed a framework that will allow students to learn on their own as well as collaborate in small groups and with the whole class. Although we have described three different levels of scaffolding, they are not mutually exclusive and we need to align all the affordances so that they are well-integrated and taken advantage of. We are integrating the levels in such a way that that the individual and collaborative learning opportunities are seamlessly integrated, as described in Table. The scaffolding provided by the tools best supports the process at that time. Individual and social learning is integrated throughout the problem solving process. This is especially important in a web-based distance learning situation where students are on their own and do not have the kind of instructor and peer support as in face to face instruction. Table 1 shows the stages in the problem solving process and the type of scaffolding provided by the tools for that stage. In addition, it also describes the activity that the tool supports, and the type of learning benefit that is expected as a result of the scaffolding.

Type of learning	Supporting tool (Scaffolding)	Activity supported	Learning benefit
Individual	Reflective notebooks providing scaffolding	Phases in the problem solving process such as problem understanding, generating ideas, identifying major issues etc.	Prepares students for collaboration in small groups and whole class. Also helps reflect on their own.
Collaborative	Concept maps providing scaffolding	Generating an integrated understanding of the domain	Collaboration in small groups
Collaborative	Small group discussion – Scaffolding in the form of collaborative discourse	Solving the problem in a small team, collectively figure out the issues, conduct research and generate a solution.	Team work to help each other in solving the problem as well as mentoring each other.
Collaborative	Whole class discussions – Scaffolding in the form of collaborative discourse	Discussions during at least three stages in problem solving: initial brainstorming, generating ideas to solve the problem (both initial ideas and after they researched or read about the issues), and for explanations and justifications.	Interactive discussion to facilitate understanding of domain knowledge.
Individual	Reflective notebooks	Reflective essays	End of module reflection by individual students. Draws on discussions in small groups as well as whole class.

Table 1: Stages in the problem solving process and tool support

Implementation and context of use

Implementation of the web-based environment is being undertaken in stages. The first prototype of the environment consists of the reflective notebook, and the collaboration tool. We have not yet implemented the collaborative concept maps in the web-based environment. We are presently using the web-based environment to teach a graduate course in learning theories. The main objective of the course is to provide students with an overview of the important theories of learning and help them understand the educational implications of the theories. Students are presented with cases or problems from the real world. The course comprises of eight cases that broadly cover the major theories of learning such as Behaviorism, Cognitivism, Developmental theories, Situated learning etc. They use the individual and the collaborative tools provided to explain each case or solve the problems presented in the case. The course is being taught as a web-based course, with only three face-to-face meeting in the semester long course.

Evaluation of the learning environment

Our evaluation plan addresses usability and usefulness as well as user and instructor satisfaction surveys of the course. A three-tier evaluation plan is currently being implemented.

Tier I - Usability testing

The integration of the physical layout of the program and the way in which navigation is conceptualized and implemented is an important aspect of learning in a WWW environment (Jones and Faquhar, 1996). The specific questions during this phase relate to the design features of the learning environment, including the interface, links and usability of the tools.

Tier II – Usefulness testing

Recent research shows that it is important to address the needs of a population of users who are also learners (Jackson, Krajcik & Soloway, 1998; Soloway et al. 1996). It is therefore important to evaluate whether the system supports learners, as they develop their understanding over time. Although the usability of the tools is an important factor, the usefulness of the tools to support learning is crucial for the success of the learning environment. Hence, during this stage we will evaluate successive designs of the curriculum, engaging in a process of iterative redesign. The main objectives of this phase is to understand whether the tools that we have designed are helping students in what we intend for them to accomplish. The questions during this phase relate to the problems or cases that we have developed, as well as cognitive tools.

Tier III - Studies for student satisfaction and delivery of the course

Student satisfaction and delivery of the course are important aspects of a web based distance learning environment. During this phase of our formative evaluation, we will use the WBILE with larger samples of students (15-20, the number of students enrolled in the course). The main objective of this phase is to gather data regarding user satisfaction and attitudes about the course, about technical problems and experiences of the instructor during delivery and about the experiences of the instructor.

Evaluation of student learning

At present we are offering the course in Learning Theories to twenty five students. Pre and post survey to understand how comfortable students are with using the tools are being conducted. In addition, student learning is being evaluated in terms of their responses in the collaborative discourse and their reflective notebook entries. Preliminary results show that there have been an average of fifteen postings per day on the discussion area. Preliminary analysis of student comments show that students are not only explaining the case presented in terms of the learning theory, but are also actively interacting with each other. In addition, students have also been solving any technical problems that other students may have had. The reflective notebook entries show that the collaborative interactions are making the students' summative essays richer. Thus the integration of the individual and the collaborative learning is working in the sense that both the tools are complementing each other and together they are contributing to a more complete understanding of the domain.

Conclusion

Our early findings from the first course being offered in an interactive web-based format seem promising. Our aim is to integrate the collaborative concept maps in the next version of the web-based environment.

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