IT Revolution in Learning Technology

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Introduction

The change has already begun. It is not a simple change but a ***Revolution*** in the sense of speed and its impact. It is called IT(Information Technology) revolution and has been giving great impacts on all kinds of human activities. Educational and learning support activities are not exception. Rather, I could say that the impact on them is larger than those on others. This extended abstract discusses IT revolution and its impacts on learning technology from the technical points of view together with some essence of the key IT technologies and examples.

What is IT revolution?

Let us first enumerate buzz words related to IT to see how may new technologies and concepts have been produced these days:

- Internet, web, home page, URL, metadata, HTML, XML, DTD, XML Schema, RDF, RDF schema[W3C], tags, tagging, semantic annotation, semantic web, standardization, W3C[W3C], etc.
- Java, applet, JDK, Pearl, browser, Internet explorer, Netscape, etc.
- agents, multi-agents, virtual reality, knowledge discovery, data mining, knowledge sharing, ontology, etc.
- E-commerce, EDI, CALS, SCM, virtual factory, knowledge management, corporate learning, knowledge creating company, etc.

Internet and web technology

All of the above terms have appeared very recently and are spreading everywhere with an extreme speed. The first group is the main stream of IT revolution and is related to Internet and web technology. Needless to say, Internet and web technology drive our society to the true information society. They enable us to access vast amount of information and to communicate each other through computers without any barrier about time and location. They enable us virtually form a community in the so-called cyber space where people can communicate with each other and even meet through computer technology.

HTML, XML[W3C], etc. are markup languages which make the plain information on the web into computer-understandable data. HTML makes computer-processable documents only in the sense of display structure of them on the screen, but it shows the possibility for ordinary people are willingly to make tagged documents on the web. XML and its relatives make documents whose semantic structure is understood by a computer to some extent, which makes an extraordinary difference in the value of information on the web. While tags in HTML are concerned only with structural information such as headings, fonts, itemization, etc., those in XML family are for representing any information about the document, typically some amount of its meaning such as author, topics dealt

with, etc. XML tags have two major roles: (1) explication of class(e.g., city) for each specified text(e.g., Kobe) in the document and (2) define arbitrary “data structure” for interpretation of the multiple fragments of texts. These lead us to the idea of metadata which is a data of the data(document) and are extensively used for information retrieval on the web. By using XML tags, users can explicate semantic information explicitly contained in the document as much as possible. But, they cannot produce new information which is not explicitly appearing in it such as who authored the document and when. Metadata is for representing such information that is useful for finding documents satisfying requirements on the web using it as indexes.

They have been giving a considerable influence on the concept of database in terms of data storage and access to data by making all the people a data creator and a retriever. Conventional databases have rigorous idea of managing data at the cost of flexibility. It needs a lot of cost for managing and collecting data. People have begun to view web on the Internet as a loosely structured huge database. Web documents on the Internet are different from the conventional database. Data increase automatically and they are little structured accessed by tremendous amount of users.

Knowledge processing technology

Not only Internet and web technology, but also ordinary computer technology, especially, AI(artificial intelligence) technology have made and will make substantial contributions to the information processing in the coming information era. Loosely coupled multi-agents are good to implement a large system by introducing efficient communication protocol and vocabulary. Virtual reality will open an innovative interface and virtual worlds. Among many new technologies, Ontological engineering is one of the most promising technologies for future knowledge processing and is expected to make a reasonable contribution to the coming 21st century Learning technology.

Ontological engineering

Roughly speaking, ontologies consist of **task ontology**[Mizoguchi 95] which characterizes the computational architecture of a knowledge-based system, e.g., computer-support learning and educational systems, which performs a task and **domain ontology** which characterizes the domain knowledge where the task is performed, e.g., each subject of learning. By a task, we mean a process like teaching, training, diagnosis, monitoring, scheduling, design, and so on. The idea of task ontology that serves as a theory of vocabulary/concepts used as building blocks for knowledge-based systems might provide us with an effective methodology and vocabulary for both analyzing and synthesizing knowledge-based systems. An ontology is understood to serve as a kernel theory and building blocks for content-oriented research.

Why ontology instead of knowledge? Knowledge is domain-dependent, and hence knowledge engineering which directly investigates such knowledge has been suffering from rather serious difficulties, such as domain-specificity and diversity. Further, much of the knowledge dealt with in expert systems has been heuristics domain experts have, which makes knowledge manipulation more difficult. However, in ontological engineering, we investigate knowledge in terms of its origin and elements from which knowledge is constructed. An ontology reflects what exists out there in the world of interest or represents what we should think exists there. Hierarchical structure of concepts and decomposability of knowledge enable us to identify portions of concepts sharable among people. Exploitation of such characteristics makes it possible to avoid the difficulties knowledge engineering has faced with. The following is an enumeration of the merits we can enjoy from an ontology:

1. *A common vocabulary*. The description of the target world needs a vocabulary agreed among people involved.
2. *Explication* of what has been often left implicit. In all of the human activities, we find presuppositions/assumptions which are usually left implicit. Any knowledge base built is based on a conceptualization possessed by the builder and is usually implicit. An ontology is an explication of the very implicit knowledge. Such an explicit representation of assumptions and conceptualization is more than a simple explication.

3. *Systematization* of knowledge. Knowledge systematization requires well-established vocabulary/ concepts in terms people use to describe phenomena, theories and target things under consideration. An ontology thus contributes to providing a backbone for the systematization of knowledge.
4. *Standardization.* The common vocabulary and knowledge systematization bring us more or less standardized terms/concepts.
5. *Meta-model functionality.* A model is usually built in the computer as an abstraction of the real target. And, an ontology provides us with concepts and relations among them which are used as building blocks of the model. Thus, an ontology specifies the models to build by giving guidelines and constraints which should be satisfied. This function is viewed as that at the meta-level.

E-commerce

E-commerce is roughly a new name of CALS: Commerce At the Light Speed and EDI: Electronic Data Interchange which are the activities in the industries, especially in the context of business re-engineering employing Internet technology. Industries are very flexible to adapt the rapid change of the technology and society. E-commerce is a business activity which is performed on the Internet. All information processing activities in business process including stocking, supplying, marketing, etc. is done through Internet so that decisions are made at maximum speed. It includes both activities of business to business(B2B) and business to customer(B2C). E-commerce enables us to remove the limitations about time and locations, and directly connect related activities. SCM: Supply Chain Management is a revolution in a business model. It provides innovative network-based business models to facilitate E-commerce. A virtual factory is a cluster of real factories connected through network(Internet) to virtually form an integrated factory.

What is Learning Technology?

There have been proposed a lot of teaching methodologies such as instructivism, constructivism, situated learning, etc. The topic here is not such methodologies but technology for realizing a learning support system based on them. Typical keywords related to it are:

- CAI, ICAI, ITS, Micro world, ILE, Discovery learning, exploratory learning, project-based learning, simulation-based learning, CSCL, web-based ITS, etc.

ICAI: Intelligent Computer-Aided Instruction is an advanced version of CAI, that is basically an electronic page turner of a text book with exercises with scoring functionality of the performance of the learner, with adaptive behavior using AI technology. ITS: Intelligent Tutoring Systems is similar to ICAI and it has three independent modules taking care of Tutoring/teaching knowledge, domain knowledge to teach and a learner model. These systems/technologies are based mainly on instructivism that has been attacked by constructivists who advocate that knowledge should be constructed in learner's head rather than transferred from the system. Micro world, ILE: Interactive Learning environment, Discovery learning and exploratory learning are systems based on constructivism. Features common to them include systems stay behind the learners, rather than teach them, by providing an environment in which learners perform tasks assigned taking initiative. Needless to say, no paradigm is perfect. Although such systems are good at letting learners construct knowledge by themselves, they are neither good at helping learners who get stuck nor good to summarize or generalize what learners have learned.

CSCL: Computer-Supported Collaborative Learning is a new paradigm in which learners are expected to learn through collaboration. It contrasts well to other type of systems which are within the framework of one-to-one environment. Systems of the type project-based learning and simulation-based learning are based on the idea of situated learning.

Impact of IT revolution on Learning Technology

We have overviewed thus far the current trends of IT technology and learning technology. This section discusses the impacts of these new trends on the future educational systems and activities. The keywords are as follows:

- E-learning, Web-based ITS, distance learning, virtual university, virtual school, etc.

Before discussing these keywords to see the "technology push," let us analyze the reason why we feel the change of the educational system is necessary to understand "demand pull" very well.

Why learning technology needs a big change

The causal structure around "technology push and demand pull" is not straightforward. The initial movement is done by the rapid advance of IT discussed above. It definitely drives our society into "***Information Society"***. Then, the new society produces many requirements shown below followed by meeting of the initial technology push and all the demands(requirements). Let us see what will happen in the information society:

1. Constant updating knowledge
2. Life-long learning is required
3. Huge amount of knowledge and information is accessible through computers and Internet
4. Not only knowledge but also learning capability and creativity becomes much more necessary
5. Training in industries becomes more and more important
6. Knowledge management in a company becomes critical
7. Digital divide might occur

The dominating key issue is the speed of change. In ***information society*** everything changes so rapidly that people, companies, organization and society do need something that helps them catch up with it. The rapid change, of course, includes that of knowledge. Possessing a lot of knowledge, which have meant the person is valuable before, does not always guarantee that the knowledge possessors take advantages, since it recently means some amount of the knowledge is dated. A typical example is the knowledge about computer technology. It is a well-known fact that senior persons, who were thought they have more knowledge than juniors, have a lot of trouble in using computers and Internet, while juniors are the promoters of computer technology.

The constantly changing knowledge requires constant learning, that is, life-long learning(LLL) and anytime & anywhere learning. Learning should not be a passive activity which is only done when people are in the educational institutions without knowing how the knowledge is used in the real world. It should be a continuous and active process performed under a specified goal and situation where the knowledge is really needed.

As huge amount of knowledge becomes available through Internet in the information society, it becomes possible for people to access the knowledge they need when necessary. In such a circumstance, the more important thing than having a lot of knowledge is to know how to find the knowledge, to be ready to understand and master the new knowledge and to create knowledge for future use to close the loop of knowledge production and consumption. For these reasons, the goal of education and learning should be augmented to include training of learning capability and creativity of the learners.

As we have seen in the above, the necessity of life-long learning and anytime & anywhere learning suggests that the change of institutional education a lot. Education done in schools is limited in location and time, since learners and teachers stay at the same location at the same time. Virtual schools built on the net are different. They are free from location and time which are essential properties for realizing anytime & anywhere learning as well as LLL.

The necessity of training of learning capability and creativity rather than teaching knowledge also suggest a big change. Goals of education should adapt to the new requirements.

The other major source of the necessity of constant learning is industries. Companies want to train their employees for the rapidly changing technology. Human resource management is their essential job to run the company efficiently. A huge amount of money is invested into training activities. Cutting the cost necessary for human resource management is an important issue. Recently, however, this issue has been considered within wider framework in a more positive way rather than a simple personnel management. It is **knowledge management** in the company-wide scope. In the training, knowledge transfer from the instructors to trainees is done, which is interpreted as a kind of knowledge dissemination in terms of knowledge management. But, the way of training is similar to that of conventional education which has been done in educational institutions. That is, many trainees gather a school-like place and a few instructors make series of lectures together with exercises using simulators, and test is done to evaluate the training effects. Training materials are made by instructors usually from scratch in spite of the existence a huge amount of technical documents which are potentially useful and reusable for some part of the materials. Little part of the training materials is reusable. These should be drastically improved.

Knowledge management is becoming one of the hottest topics in companies these days, since it is the technology for keeping their identity to survive in the information society. In the coming information society, the identity of each company becomes **Knowledge it has and exploits**. Learning technology and research has longer history than training. People working in learning technology should extend their interests and activities to cover what industries need. Investigation of the training of employees in the context of knowledge management will be beneficial to the future learning technology. We should notice that we have been and will have been involved in Knowledge managing in a broad sense.

The last topic here is to avoid so-called Digital divide. It is apparent that people who are low at computer literacy would lower accessibility to information on the web than those who have high computer literacy. It would cause a serious discrimination in the information society because Internet will become a major source of knowledge in the information society. Education must be responsible for avoiding this difficulty by seriously promoting education of computer literacy.

How learning technology can change

E-learning is the keyword of the change. We can learn from E-commerce to understand what change education can make and how under the name of E-learning to meet some of the above demands. Of course, we do not have to do education or learning at the light speed like CALS which stands for Commerce At the Light Speed, but the general ideas and technologies of CALS and E-commerce does make a great contribution to educational systems. E-commerce is based on a comprehensive business model in the information society. All activities are integrated through network(Internet) and computer technology. Key ideas in E-commerce include: (1) Among the three major flows in business, physical stuff flow, money flow and information flow, those of money and information are performed on the Internet to make decisions as quick as possible, (2) Direct connection of customers' needs to production, (3) modularization and standardization of parts with high reusability and global marketing and purchasing. (4) Just-in-time production, etc.

Considering the big success stories about the E-commerce, there is no reason why E-learning does not employ the similar ideas to satisfy some of the demands discussed above, since E-commerce is a trial to resolve almost the same difficulties as those education will suffer from. That is, coping with continuous change of customers' needs and business environment including rapid change of technologies.

What does just-in-time production mean in the context of learning? It is teaching/training material production. Parts correspond to parts of those materials. To enable anytime & anywhere learning,

adaptation to the learners' needs is critical. This means:

> **an E-learning system should dynamically compose a training/teaching material for each learner through interaction with him/her. To do this, just like E-commerce does the system has to identify the learner's needs, find modules necessary for the materials through Internet/intranet and then configure the modules into a material.**

Every technology should contribute to making this happen. Like user profiles, we can have learner profiles which store all the history of each learner's learning experiences which should be used for realizing adaptive behaviors of learning support systems. Learners' profile as well as parts of the material(sometimes called learning objects) on the Internet have to be standardized to some extent like CD-ROM. Metadata also has to be standardized. These activities have been done by IEEE LTSC[IEEE LTSC]

To enable anytime & anywhere learning and LLL, a computer-supported learning environment is necessary rather than institutional education. This fact forces us to seriously consider the future role of educational institutions. Some of the educational institutions could virtually exist when necessary.

> **This does not mean all the educational institutions are unnecessary. All the discussion made thus far applies only to higher educations and training in which HUMAN FACTORS and importance of face-to-face interaction are out of focus.**

To enable training learning capability and creativity of learners, educational goals should change and incorporate new evaluation schemes rather than paper-based test and one-dimensional quantitative scoring of the performance.

To incorporate training while extending the scope of learning technology to cover corporate learning and to enable E-learning, a lot of research is needed. Not only technology-level but also deeper fundamental research is required. One of the typical research topics is ontological engineering of knowledge related to training/learning activities and knowledge in general.

An example of the innovative trials and promising technology

This section is devoted to show an innovative research pursuing the direction discussed thus far and necessary technology

Ontology-based just-in-time training manual construction

The first example is dynamic training material building from technical documents. It is called IMAT: Intelligent Manuals and Training Project and is a ESPRIT project[Kabel 99]. The basic idea is rather straightforward and is to reuse existing huge amount of technical documents for constructing training material. They employ XML to make general-purpose and semantically annotated technical documents and ontology to formalize the tags used. The first three steps consists of the following:

(1) To decompose each technical document to obtain pieces of Learning objects (LO)
(2) the Indexing and
(3) retrieval of LO to configure training material

They developed several Ontologies such as Domain ontology, Fragment ontology, Instructional role ontology and Description ontology to design tags systematically. The key is the instructional ontology in the sense that it provides how to use each fragment in the training settings.

The author's group has also been conducting a very similar project for two years[Takaoka 99]. This

research is also along the line of integration of training in the corporate-wide knowledge management.

How an ontology provides us with a solution

As discussed earlier, ontological engineering does make a critical contribution to the innovative knowledge processing technology in the information society. We need to know how to treat real-world knowledge effectively. To enable just-in-time training/teaching material making does need sophisticated knowledge processing. Semantically annotated documents with semantic tags which are carefully designed in a principled manner.

First of all, an ontology provides a set of terms which should be shared among people in the community, and hence could be used as well-structured shared vocabulary. These terms enables us to share the specifications of components' functionalities, tutoring strategies and so on and to properly compare different systems.

An ontology explicitly represents the underlying conceptualization which has been kept implicit in many cases. An ontology is composed of a set of terms and relationships with formal definitions in terms of axioms. Such axioms are declarative, and hence such an ontology represents the conceptualization declaratively. Thus, an ontology is the source of intelligence of an ontology-based system.

Another role of an ontology is to act as a meta-model. A model is usually built in the computer as an abstraction of the real target. An ontology provides concepts and relationships which are used as the building blocks of the model. Axioms give semantic constraints among concepts. Thus, an ontology specifies the models to build by giving guidelines and constraints which should be satisfied. This is how the function is viewed at the meta model level. Needless to say, this characteristic is what an authoring system really needs. In fact, we can find some research based on the meta-model function of an ontology [Kin 99]

A shared ontology is a first step towards standardization. Not only informal definitions of terms/concepts but also intermediate concepts are made explicit by an ontology. The structuring usually employs *is-a* and *part-of* links to relate concepts to each other. The structure obtained in an ontology itself represents an understanding about the domain of the developer. It is usually much more informative than definition of a term. An ontology cannot instantly become a standard. An ontology designed gives a test-bed for establishing a standard.

On the basis of standardized terms and concepts, knowledge of the domain can be systematized in terms of the concepts and standardized relationships identified in the ontology. This is what we are intending to do in our ambitious plan "building an ontology of Instructional Design(ID)" which makes an authoring system "ID-theory-aware".

Conclusions

In this extended abstract, we have discussed the IT revolution in learning technology in the coming information society. E-learning will be a model of learning support systems in the 21st Century. As industries have been experiencing drastic reformation of the organizational structures and their business models, similar should happen in the educational community. We should investigate "**Educational models**" seriously to promote E-learning. We should exploit and advance the current IT for making the educational change meaningful for the bright future human life. The future of the country largely depends on Education.

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