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ABSTRACT

There is an obvious growth in the use of distributed and online learning environments. There is some evidence to believe that collaborative learning environments can be effective, especially when using advanced technology to support learning in and about complex domains. There is also an extensive body of research literature in the areas of situated cognition and problem-based learning that provides a theoretical perspective for the design of such learning environments. What is lacking are intelligent support tools to make it possible for subject experts (teacher-designers) to be more intimately involved in the design and implementation of collaborative distance learning environments. This paper describes such design tools, explicitly drawing on a socially-situated view of problem-based learning in technology-mediated environments. It concludes with an illustration of the tools as applied by teachers to the domain of environmental education. (Contains 31 references.) (Author/AEF)

Teachers as Designers of Collaborative Distance Learning

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Abstract: This paper describes a theoretically based approach to the design of collaborative distance learning environments by subject experts. There is an obvious growth in the use of distributed and online learning environments. There is some evidence to believe that collaborative learning environments can be effective, especially when using advanced technology to support learning in and about complex domains. There is also an extensive body of research literature in the areas of situated cognition and problem-based learning that provides a theoretical perspective for the design of such learning environments. What is lacking are intelligent support tools to make it possible for subject experts (teacher-designers) to be more intimately involved in the design and implementation of collaborative distance learning environments. I provide a description of such design tools, explicitly drawing on a socially-situated view of problem-based learning in technology-mediated environments. I conclude with an illustration of the tools as applied by teachers to the domain of environmental education.

Introduction

Technology-based learning environments are growing in number and prevalence at an unprecedented rate in spite of continuing debates in the academic literature with regard to their learning-effectiveness, impacts on organizations, and overall utility to society (see, for example, Carter 1997; Clark 1994; Kozma 1994). As a consequence, there are many investigations into how people learn using new technologies, and these studies are, in turn, causing much discussion with regard to foundational issues in learning theory and instructional design. One challenge we face is to make sense of some of these changes so that we can make effective use of new technologies to support learning and instruction. It is my hope in this paper to move this discussion forward by providing an easily accessible design framework for technology-mediated learning environments. I intend this framework to be well-founded in learning theory and to have strong implications for designing learning environments for what I regard as a challenging domain: learning in and about complex systems. Moreover, I shall emphasize the need to empower teachers to become designers of such environments. I proceed by briefly identifying and reviewing relevant learning theories and current tools. I shall then establish a unifying perspective with clear design and evaluation implications. This unifying perspective will then become the basis for the use of tools. I conclude with an illustration of this framework and indicate other instances close in kind and spirit to what I present here.

Theoretical Perspective

How do people come to acquire complex skills and knowledge? I ask this question in order to identify relevant assumptions and highlight its complexity. First, much learning research proceeds on the following assumptions: (1) learning is a natural, human activity; (2) the unit of analysis for learning effectiveness is an individual human learner; and, (3) learners are rational. An additional assumption prevalent in the educational research community is that instructional design is primarily a prescriptive enterprise forming a bridge between descriptive learning research and practical development of learning environments (Reigeluth 1983).

There is practical value in adopting this research perspective. By varying the instructional methods used in certain conditions, one can measure outcomes and study the effects of those methods on learning outcomes. If enough data is collected, one then hopes to be able to establish a strong argument for the desirability of a particular method given certain learning conditions, thus prescribing how one ought to design instruction to achieve desired outcomes. In this perspective, learning is a natural process, and it is theoretically possible to identify how various types of learners engage in this process and take those differences into account in the design of instruction. Learners are rational in the sense that they are goal-driven, purposeful agents with the ability to identify and select reasonably

efficient means to achieve goals. Typically, conditions are held constant and various interventions (instructional methods instantiated in particular learning environments) are investigated. Learning outcomes or effects are then measured on individuals.

Such a research paradigm has produced many useful findings, so it should not be discounted. For example, by emphasizing the rationality of learners, designers are able to facilitate the identification of learning goals and support activities likely to satisfy the achievement of those goals. This line of research emphasizes intentional learning, and generally ignores incidental learning, to which it is more difficult to apply the conditions-methods-outcomes model. Since it is assumed that learners will want to achieve goals efficiently, designers can then specify how and when to provide learners with informative feedback on progress towards those goals.

I shall refer to this as the atomistic perspective because it is characterized by an atomistic view of learning, both in terms of units of learning (very specific and discrete conditions, methods, and outcomes) and in terms of learners (typically focusing evaluation on individual learners, even when the setting involves cooperative learning). The atomistic perspective can be contrasted with what I shall call the integrated perspective (Spector 1994, 1995). The integrated perspective begins with a view of a person as a member of a society or language community. The overall goal of a society or language community typically involves a strong survival element, although this is quite often not made explicit. Living consists of working and learning, which are viewed as essentially collaborative efforts to achieve commonly held goals. From this perspective, individuals might manage to acquire extremely high levels of performance at particular tasks while the larger social group consistently falters. This would not count as effective learning from an integrated perspective.

There are comparisons to a team perspective when thinking of learning from an integrated perspective. A team may have several outstanding players, leading the league in certain categories, while the team is in last place. This is not a satisfactory situation, especially from the team's point of view. One can further imagine a team locked into poor overall performance by paying one star player a very high salary. This might prevent the team from paying higher salaries to others, and it may also foster jealousy and resentment within the team. While the star player may draw in large crowds and the team's owners may prosper, the team's poor performance may further decline, even when a second star player is added. One should be careful not to carry the sports analogy too far, however. Learning organizations and societies are not necessarily competitive with other such organizations. Moreover, membership criteria and reward mechanisms are entirely different. The point is to suggest the need to consider a more integrated, holistic view of learning, especially with regard to learning in and about complex domains.

Complex Domains

From a research perspective, complex domains present significant challenges, both for designing effective learning environments and for determining factors which contribute to learning. From a social perspective, these domains present significant challenges for the future well-being of our species on this planet. We have serious problems to confront if we are to survive, including worsening global environmental problems, persisting regional and ethnic conflicts, and wildly fluctuating economic conditions. Can we become better prepared to meet these challenges? How? Complex systems can be depicted as a collection of inter-related items, which are characterized by internal feedback mechanisms, nonlinearities, delays, and uncertainties (Sterman 1994). These systems typically exhibit dynamic behavior, especially in the sense that how they behave has an effect on internal relationships (the structure of the system), perhaps strengthening one of the feedback mechanisms (e.g., the owners' proceeds due to acquiring a star player reinforces that mode of response to declining profits, as opposed, for example to improving overall performance.). This change in internal structure in turn has consequences for how the system will behave in the future; for example, the team may perform even more poorly as existing players resent the special treatment and salary given the star (Davidsen 1996).

Our inability to dealing effectively with complex systems is well documented (see, for example, Dörner 1996). Deep understanding of complex systems, characterized by effective decision making across a wide variety of changing conditions, takes years to acquire, and appears not to be easily acquired in spite of concentrated education and training efforts (Dreyfus & Dreyfus 1986). Why have we failed to improve our thinking skills in complex domains in spite of persistent and serious efforts? In part, we have not fully understood relevant psychological and sociological factors. In part, we have not fully integrated relevant principles about human learning into design praxis. We should have learned that humans have difficulty in estimating the effects of accumulation over time, in predicting the effects of delays, and in calculating nonlinear outcomes (Sterman 1994). We should have learned that even well-intentioned persons tend to focus on local problems as opposed to whole systems (even when told that a holistic understanding is essential for solving particular problems), that people may become cynical and overlook possible solutions when their first attempts fail, that people do not communicate effectively in crisis situations, and

that inferring underlying system structures from externally viewed system behaviors is not an easy task (Dörner 1996).

In short, instructional scientists have not fully understood the socially-situated learning perspective and its implications for human learning in and about complex systems. There is a great deal of discussion about situated, problem-based, and collaborative learning, but we are missing critical pieces of a design framework. We lack a well-articulated design framework with sufficient detail to take us from a socially-situated, problem-based, collaborative learning perspective to the design of a particular learning environment for a particular subject domain. The closest such approach I find is cognitive apprenticeship (Collins 1991). I regard this work as an extension to that approach.

Theoretical Foundations

The theoretical foundations for this effort come primarily from a socially-situated learning perspective, drawing heavily on the views of Bruner (1985), Lave (1988), Piaget (1970), and Vygotsky (1978). Within this perspective, learning is viewed as an active process of knowledge construction in which learners are typically involved with other learners in authentic, problem-solving situations. The need to learn created by a realistic problem provides motivation, and interaction with other similarly immersed learners provides facilitation. I am favorably inclined to Sfard's (1998) view that emphasizes the need to take into account both an acquisition (static knowledge objects with learners acquiring expertise) and a participation metaphor (dynamic knowledge objects with learners as active apprentices). Much higher order learning relies on knowledge and associated learning activities that might best be supported within the acquisition view. However, to progress beyond competent performance and become a proficient expert (Dreyfus & Dreyfus 1986), I believe that the participation metaphor with its emphasis on active learner participation in socially-situated and problem-oriented settings is crucial.

Vygotsky's Cultural-historical Theory and Activity Theory

For Vygotsky (1978), human mental functions appear first as inter-individual and later as intra-individual. This process involves the use of socially developed tools. The unit of analysis for human activity and for human learning is the mediated action of an individual. This broadens the unit of analysis identified earlier from just the individual to include an artifact with which an individual interacts. Leontiev (1975) expanded Vygotsky's cultural-historical theory to an activity theory approach to human interaction. From this perspective, reality consists of mediated, social activities, among other aspects. For Leontiev, the unit of analysis was extended to include the notion of a collective activity, something done by a community with a purpose (which need not be consciously recognized). This motive or purpose is composed of individual actions were directed toward a common goal. An individual's mediated actions could still be analysed, but there was now a necessary social dimension (being part of a collective activity) which was used to understand individual activity. Davydov (1988) applied Leontiev's activity-theoretical approach to the learning process and developed a psychological theory of learning activity which focused on purposeful and joint activities of teacher and learner in the social context of development. From this perspective, the aim of a learning activity is to teach study skills that enable learners to think on their own. Margolis (1993) suggests that within this perspective the computer can have one of two roles: as a tool for the acquisition of knowledge and empirical facts, or as tools for the development of children's thinking (i.e., as tools for reflection or metacognition). I think both roles are possible, even within the same learning environment, but I do agree with Sfard (1998), Dörner (1996), and others that when the computer is used to support higher order learning in complex domains that supporting active participation and reflection are especially important.

Socio-cultural theories of learning and teaching, as inspired by Vygotsky, have addressed the instructional use of computers. Some of these include cognitive apprenticeship, cognitive artifacts, distributed cognition, learning by expanding, scaffolding, situated learning, and so on. In short, the theoretical heritage for collaborative online learning and distance learning is quite rich.

Collaborative Learning

Collaborative learning is a collection of perspectives that emphasize the following (Fjuk 1995):

1. Joint construction of knowledge (e.g., joint problem-solving by mutual refinement).
2. Joint negotiation of alternatives through argumentation, debate and other means.
3. Student reliance on both fellow students as well as teachers as learning resources.

Collaborative learning is based on the notions of 'socially shared cognition' (Resnick, Levine & Teasley 1991), of 'distributed cognition' (Salomon 1993), and of 'jointly accomplished performance' (Pea 1993). The majority of research into collaborative learning has focused on collaboration between physically present actors and has generally focused on whether and under what circumstances collaborative learning was more effective than individual learning (Dillenbourg, Baker, Blaye & O'Malley 1996). More recent efforts, however, have been directed towards a more process-oriented account of collaboration where the focus is on the role that variables such as group

size, group composition, and communication media play in mediating interaction. Again, this is a clear indication that the unit of analysis has been appropriately enlarged far beyond the individual learner.

I have now collected several design principles which form key features of a design framework, and I have shown their linkage to learning theory. These principles might be summarized as follows:

- Provide support for the joint construction of knowledge objects and for the joint construction of problem solutions. This can be accomplished by providing learner-extensible databases, by providing learner-modifiable simulation models, by supporting learner-learner and learner-tutor collaboration in making changes and extensions to existing knowledge objects, and by supporting learner-learner and learner-tutor reflection on outcomes of those modifications.
- Provide tools to support joint negotiation of alternatives. Commenting tools are a beginning. Allowing changes to be tested when appropriate is also important. It is especially important to allow learners to try out alternative simulation models, to observe results, and to support learner-learner and learner-tutor discussion and analysis of those results.
- Provide both public and private feedback support mechanisms for learners while emphasizing to those intelligent agents providing feedback that it is important for learners to gradually improve their own ability to monitor and assess progress toward desired goals.

In short, this framework aims to support both individual work and collaborative activities, and it especially aims to support the development of collaborative learning communities.

Computer Supported Collaborative Learning (CSCL)

The important implications for CSCL that emerge from these theoretical foundations include the view that the computer is a mediating tool that needs to be seen in the context of the entire learning environment within which it will be used. That context includes the instructional setting, the presence or absence of a teacher, the role of teachers and tutors, the role of the learner and other learners, the curriculum, the organizational setting, etc.). Contemporary theories for the instructional use of computers need to address not only the role of the teacher in the classroom, but also the role of the computer, the design and choice of instructional software, and interactions between the teacher, student and computer. In short, one must describe both the content of the microworld as well as the organization of various learning activities. The microworld represents the content to be learned (i.e., a practical skill or theoretical concept) which is a concrete school subject to be mastered. Dörner (1996) and Sterman (1994) have a broad view of the microworld, viewing it as a facilitating means to help learn about a broader subject matter. The interaction modes needing organization and control by designers include supporting student interactions with the computer and interactions between the teacher(s)-computer(s)-student(s).

Distance Learning

Distance learning evolved from a need to ensure equal access to education for all students (Bourdeau & Bates 1997). The most obvious feature of distance learning is that students and professors do not all meet at the same place and time. Individual learning, individual tutoring and asynchronous communication are typical features of distance learning, requiring careful instructional design, and a strong student support system. These features, however, do not necessarily dominate in the design of an effective distance learning environment. Many variations of *telepresence* needed to be taken into consideration, including the sense of telepresence in a virtual meeting, the sense of telepresence in interactions with rich multimedia environments, and the sense of telepresence in extensive human collaborations with online knowledge objects and virtual worlds (e.g., online microworlds).

Coordination Theory

Salomon's work on CSCL (Salomon 1992, 1993) provides the most complete approach to the study of CSCL. Salomon's focus is on mediation in CSCL, which is a key issue in collaborative distance learning. In his view, collaboration involves interdependencies, sharing, responsibility, and involvement. Genuine interdependence is characterized by Salomon (1992) as follows:

- the necessity to share information, meanings, conceptions and conclusions;
- a division of labor where roles of team members complement one another in a joint endeavor and the end product requires this pooling of different roles; and,
- the need for joint thinking in explicit terms that can be examined, changed, and elaborated upon by peers.

Salomon's emphasis on genuine interdependence between team members raises the following question: How can such interdependencies be specified and supported in a collaborative distance learning situation?

Malone and Crowston (1994) describe coordination theory as focused on the interdisciplinary study of how coordination can occur in diverse systems. Coordination theory provides a means for specifying (inter)dependencies between, and among, actors, tasks, and resources by identifying a *dependency type* (e.g., shared resource) and a

coordination process (e.g., group decision making) for managing the dependency. In their work, coordination is defined *as managing dependencies between activities* (Malone & Crowston, 1994), hence they have focused on dependence between activities. Drawing on ideas about activity coordination in complex systems from disciplines as varied as computer science, linguistics, psychology, economics, operations research and organization theory, they present an analysis that characterizes the basic processes involved in coordination (Wasson & Bourdeau 1998).

A Design Framework for Collaborative Learning Environments

A relevant starting point for the design of these learning environments can be found in the computer supported collaborative learning (CSCL) literature. The CSCL perspective focuses on the use of information and communications technology as a mediating tool within a collaborative learning framework of learning. CSCL emphasizes an understanding of language, culture and other aspects of the social setting (Scott, Cole & Engel 1992) and can be traced in part to a socially-situated perspective of learning (Lave 1988; Vygotsky 1978), as I have already indicated. The common and unifying notion of situated and shared cognition emphasizes the larger environment within which learning takes place. Learning is viewed in part as entering into a "community of practice" with a shared language and understanding. The problem of establishing such a community in distance settings is a critical design aspect that has been poorly understood and not especially well implemented in practice.

An example of an approach which aims in this direction can be found in the VIRTUE Program, a collaboration of three universities in the domain of marine biology and environmental education (see the following web address:). One interesting line of research involves public school children from the Baltimore area. Children are brought to the University of Maryland research facilities in the summer and offered an opportunity to help construct a database for bio-diversity in Cheseapeake Bay. The students learn about specific aspects of bio-diversity, how to collect data, how to interpret data, and how the data is inserted into the database and used by professional environmental engineers. These students become members of the community of practice by collecting and interpreting data and then by helping build the database. They become contributors to and partial owners of an important environmental database.

This design methodology is based on cognitive apprenticeship (Collins 1991). The overall learning approach is collaborative in nature. The specific view of collaboration is that tasks and activities should be realistically arranged and mediated in ways that naturally involve and recognize particular interests and skills of learners (Salomon 1993). In the marine bio-diversity example, students work in small groups of two and three and rely heavily on the assistance of graduate assistants and teachers to check their work. Students understand the significance of the activities in which they are engaged and recognize their contributions as valued and significant.

Distance learning environments can and should be designed so as to support these interdependencies. The fluid mediation of such collaborative learning activities is a major challenge for online learning environments. Mechanisms to support synchronization, exchange of information and documents, and access to tools and services, all need to be as transparent as possible so as to minimize the cognitive overload associated with new tools and technologies. Viewing learning environments from a coordination theory (Malone & Crowston 1994) perspective offers a means of understanding the inter-relationships between actors and entities and how these relationships can and should be supported. I argue that such a model should inform: (1) the instructional design of learning scenarios; (2) the specification of the design of the online learning environment; and, when possible and appropriate; and, (3) the design of intelligent agents to mediate and co-ordinate learning activities between and among learners and tutors.

Concluding Remarks

I have tried to identify useful and theoretically grounded design principles for the creation of distance learning environments for complex domains. I have suggested the following initial principles:

- Provide support for the collaborative construction of knowledge objects, for the collaboration construction and analysis of problem solutions;
- Provide tools to support negotiation of alternatives;
- Provide both public and private feedback support mechanisms;
- Provide mechanisms to share and exchange information, objects, views, etc.;
- Facilitate a meaningful division of labor;
- Support joint, online thinking, commentary, etc.;
- Include meaningful learning scenarios;
- Design authentic problems and legitimate cases as the basis for learning activities;

- Take into account the entire learning environment;
- Support mediation among all the participants; and,
- Foster a sense of a collaborative learning community.

It is premature to argue that such a framework will produce significant and long-lasting learning effects. Based on existing data collected on teacher-designed learning environments and from data reported on some of those which adopt similar approaches, I believe that there is great promise in designing distance learning environments from a socially-situated learning perspective with heavy emphasis on collaborative learner participation in the creation and modification of knowledge objects and artifacts. Furthermore, I am convinced that teachers can participate much more actively in the design and implementation of such learning environments.

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