Designing Environments for Reflection and Collaborative Learning

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ABSTRACT: This paper reports from an on-going research project that investigates the use of information technology to enhance the learning process in software engineering education. The paper discusses the use of a standard *Web-based* conference system to give students, educators and other resources the opportunity to interact as a whole unit. The aim of using such a system is that it facilitates individual reflection as well as collaborative knowledge building. The contribution of the paper is first, identification of important design principles that should be considered by educators who wish to use computer based forums to facilitate discussion and sustaining a discourse together with their students. Second, the paper describes and discusses two cases of educational activity where the conference system is integrated.

INTRODUCTION

"There's more to being a good engineer than a high level of technical competence" [1]. Engineering education came early to be based on a mixture of theoretical subjects and practical instruction. The aim with the education was to provide the students with an ability to cope with a relatively wide range of technical problems. This is not sufficient anymore, we do live in a world that demands competence in other domains than the core competence, engineering. It is important to encourage students to develop a critical, but also constructive attitude towards engineering. The students should be invited to reflect on their profession from a practical, more holistic point of view across traditional subject areas and academic disciplines. Reflection includes reasoning, the creative production of ideas, problem solving and the awareness of these activities, that is, metacognition [2]. Metacognition refers to a person's knowledge of the nature of learning, effective learning strategies, and aspects of one's own learning strengths and weaknesses. To understand complex matters students must learn to think in the large and not become blinded by the details [3]. To think in the large students need time to reflect on new knowledge. In education in technical domains, problems are generally considered only from a technical point of view. Often, it is difficult to understand and solve problems from this viewpoint only. A philosophical discussion of software engineering is an invitation to reflect upon practice. But there is very little time allotted to philosophical reflection in the education of [computing] professionals. Much of the education takes place either at schools of engineering or at business schools where philosophical reflection is viewed as a luxury.

Educators need to provide students with a learning environment viable for discussion and reflection. From a pedagogical perspective, educators have long considered discussion one of the most powerful techniques to promote learning. Electronically enhanced discussions such as group support systems, electronic meeting systems, *usenet news* etc., have been around at least since the beginning of the 80's. They have become a dynamic and lively arena for discussion and interaction for many individuals in higher education, both students and faculty. But integrating these communication and group tools in educational activities has been difficult. One reason is that in typical engineering education lecture there is little discussion [4]. Moreover, collaboration is rarely taught in traditional engineering education. Hence, this paper discusses the use of a World Wide Web (WWW) based standard conference system, for reflection and sustaining a discourse, and thereby contribute to cooperative knowledge building. There is a need to develop technology and design the use of the same to condense the discourse, sustain it through interruptions and across distances, to give discussion continuity over time [5]. This paper is formulated with software engineering as an example, but can easily be translated into other engineering disciplines.

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THEORETICAL BACKGROUND

This section gives a short background on how educational practice has changed over the last twenty years, and how educational technology has followed this change.

From Objectivistic Teaching to Collaborative Learning

The information age certainly puts new demands on education. Radical changes in what we learn as well as how we learn are required. A variety of models are used to characterize different paradigms of learning. These models are often classified as either behavioral or cognitive. The behavioral models are based on Skinner's theory about stimulus and response, whereas the cognitive models are based on cognitive information processing and more recently collaborativism.

Traditionally the model of choice in education has been, and still is, the objectivist model of learning. Basically, facts and information exist out there and the instructor acts as an intermediary who filters, selects and transmits the information to ignorant students. The dominating activities are active teachers presenting information to passive students, through lectures, and written material, such as text books. Students then provide the teacher with evidence of learning by recitation, orally or in written exams. At lectures, teachers ask questions and expect the student to provide an immediate answer, which is either right or wrong. The overall objective for the teacher is to produce, in the mind of the student, the necessary body of knowledge.

The objectivist model is criticized for stimulating surface learning [6], knowledge reproduction and knowledge telling instead of knowledge building [5]. Knowledge building is a learning theory which is based on a constructivist/social cognitive world view where knowledge is constructed as it reliably fits the individuals experience with the world [7]. Moreover, a knowledge building strategy treats the learner as an active participant, interacting with others in the group. This way the learner actively constructs knowledge by formulating ideas built on thorough reactions and responses of others to the formulation into words. Therefore, as an alternative to objectivism, a constructivist model of learning is put forward. The constructivist model stresses the crucial relationship between new experience and what is already known. Learning develops through encounters with new information that is different enough to be stimulating, but not so alien that it can not be assimilated into the learners mental structures that represent the present state of understanding [2]. Real learning must build on the students' own knowledge, needs and interest.

Writings on constructive learning have altered in their perspective over the last twenty years to include more than the mental activity of individuals in learning [2]. Social interaction among the learners is added to the constructivist model. This collaborative model of learning has frequently been used as the basis for understanding and exploring learning. The basic premise underlying this is that learning emerges through shared understandings of multiple learners [8]. The essence of the model is that active participation is critical to the learning process and that learners have knowledge valuable to other learners. Learning is sharing, and the more that is shared the more is learned. The constructive and collaborative models are combined in a, what we call, reflective model of learning. From the above, it is claimed that our conception of learning has changed from behavioral to cognitive and constructive; from individual to collaborative; and from objectivist to reflective.

In the objectivist model of learning the role of the educator is to provide or transmit knowledge. In the constructive and cooperative models, on the other hand, the educator is a facilitator and mediator of the learning process. Scaffolding is an educational term that describes this guidance and support, that the teacher provides to the learner. Clearly, teaching and learning have gone from teacher centered to learner centered. Learner centered approaches in education are getting more and more attention. Let me give a few examples. First, *problem based learning* (PBL), "people learn best when engrossed in the topic, motivated to seek out new knowledge and skills because they need them in order to solve the problem at hand. The goal is active exploration, construction and learning rather than passivity of lecture attendance and text book reading. The major theme is one of focusing around a set of realistic, intrinsically problems" [9]. Second, *learning-in-doing* were "learners are increasingly involved in the authentic practices of communities through learning conversations and activities involving expert practitioners, educators, and peers" [10]. Third, *open discovery*, where the "students have responsibility for determining what to learn, as well as when and how to learn it" [11]. Fourth, the notion of the *virtual classroom* where "computer-mediated environment supports a collaborative learning process that can exceed that of the traditional classroom, a process in which students and instructors are actively involved in creating and carrying out learning activities together" [12].

These four are examples of different reactions to the objectivist model of teaching and learning. Whereas they are different in many ways, they still share some basic assumptions. First, these approaches rely on engaged students. A central assumption is that students learn well when they are engaged in active exploration, interpretation and, construction of ideas and products with a variety of resources [13]. Second, collaborative learning is a highly interactive process with collective responsibility. Third, computing technology is viewed as an important resource in enhancing educational activities.

From Instructional Technology to Learning Environments

The use of computing technology in an educational setting will reflect, either purposely or inadvertently, a model of learning as discussed in the previous section [14, 15]. Educators have been using a diversity of technologies to make teaching better, more effective, as an instrument for rationalization or for some other reason. Over the decades, a

variety of increasingly sophisticated applications of instructional technology have been made.

The earliest attempts to apply some form of instructional technology dates back to the first quarter of this century when the first teaching machine was introduced. Later, in the 50's and 60's, commercial learning kits permitting self-instruction in basic skills in reading, writing and mathematics were available. These were also applied in other forms of training. Programmed instruction became the format of choice for many educators in the 70´s and 80´s. With the arrivals of micro computers in schools, enthusiasts adapted a vision of computers as tools for presenting programmed instruction. Computer support in objectivist model terms was to get the right information to the students. At this time, students started to use drill-and-practice software based on the principles: individual pace, small steps at a time, and immediate feedback. All in line with behavioristical conceptions of learning.

Computer-aided instruction (CAI), computer based training, or interactive learning systems are different notions of interactive instructional technique where a computer is used to present instructional material, monitor learning, and select additional instructional material in accordance with individual learner responses. Most CAI software combines tutorial material with drill-and-practice in the same way text books alternate explanations with review questions. CAI software is one of the most commonly used for three reasons according to Beekman [16]: it is easy to produce, it can be combined with traditional techniques, and it produces clear, demonstrable results. As new technologies appeared, they have been merged into the instructional sequence of the CAI paradigm with the purpose of making teaching richer and more effective. Examples of that are video, CD-rom, sound, and images. Recently the Internet was merged into the CAI paradigm as it allows these instructions to be delivered right into the office or all the way to the home of the learner.

Using computers in education has been attended by a great deal of confusion and debate. However, the use has suffered from a lack of educational perspective. Hawkins [13] stresses that computer technology has been brought into the education system in the wrong manner. It has been integrated with traditional teaching, which emphasizes active transmission and passive absorption of factual information. Research suggests that traditional teaching may not be viable for the contemporary technological environment and that new teaching approaches will be needed to fully exploit recent technological advances [8]. There are approaches moving away from CAI and towards constructive models of learning. Hypertext is one example of this, where dynamic linking of concepts or chunks of information in one document relates to concepts or chunks in other documents. The learner controls the movement throughout the written material. Later, sound and visual objects were included to form multimedia or hypermedia.

There is a shared understanding that communication technologies such as electronic mail, bulletin board services, computer conference systems, WWW, etc., have a profound effect on education as they create environments suitable for learning. Asynchronous learning network (ALN) is commonly used as a notion to integrate these technologies with an explicit pedagogical idea [4, 12]. ALN can be characterized as a support of "anytime, anyplace" education. ALN students do not necessarily meet in face to face classes. The ALN environment is a portfolio of network based support tools where *e-mail* provides a uniform mechanism for person-to-person communication. *On line course material* is provided as well as areas for submission of individual and group assignments. *Autobiographical information* about the members of the learning community and a collective diary is also common in ALNs. The key activity is *computer based discussion* which often is asynchronous. Learners connect to the ALN at the time they choose. Many ALN environments have been developed and successfully used in projects such as the Virtual Classroom at NJIT (www.njit.edu/CCCC/VC/), CSILE at University of Toronto (csile.oise.on.ca) and CoVIS at Northwestern University (www.covis.nwu.edu). Harasim et. al. [7] provide an overview of learning networks and the ALN Web (www.aln.org) is an on-line resource.

DESIGNING LEARNING ENVIRONMENTS

One of many lessons learned from the past 15 years of computing in schools is that dropping computers into classrooms and dipping teachers in a technology training workshop is simply not an effective way to get teachers and students to use technology for teaching and learning. Neither does learning come automatically just because an electronic conference is used in the course [17]. Therefore, the aim of this section is identification of critical issues for successful use of computer based conference system to facilitate reflective learning in engineering education.

A central issue in designing learning environments is facilitation of both synchronous and asynchronous collaboration and interaction. The former lends itself to brainstorming and planning, and the latter to sharing experience and, most importantly, off-line reflection [18]. Synchronous communication, such as face to face in the traditional classroom, dominates traditional student-teacher interaction. But often, the really interesting questions do not form until after the lecture, the seminar or some other activity. Asynchronous activities enable participants to continue the discussion. Asynchronous discussion enables students to compose questions, ideas, answers and refer to other material, but most importantly, to reflect on their responses. The fact that an educational process is asynchronous may result in more reflective thinking before having to answer or comment on an issue [17]. This research is mainly interested in enhancing asynchronous learning activities.

A framework based on Scardamailia and Brieter's [5] features of technology that enhance knowledge building and O'Neil's [6] principles of quality learning is the base for the design principles. The framework is outlined below as ten critical principles that should be considered by educators who wish to use computer based forums to facilitate discussion and

sustaining a discourse together with their students, in other words, to create a learning environment.

1. Learner controlled submission. Many individuals shy away from public display as they feel uncomfortable if their writing is more or less permanent. The learner must have control over her comments and the opportunity to erase or change previous comments or messages.
2. Contribution and notification. New ideas should not be trapped in folders, but presented when the participant enters the learning environment.
3. Navigation structure. Participants should be able to navigate systematically and rapidly in the material.
4. Source referencing. Linking between notes within the community as well as linking to external resources must be an option.
5. Instructor controlled submission. The educator should be able to moderate a whole discussion or parts thereof.
6. Multiple media. Different formats, text, graphs, pictures, etc., must be possible to communicate within the environment.
7. Anonymity. Being anonymous in posting notes and comments must be an option to assure that problematic and controversial issues surface.
8. Synchronous interaction. Most interaction in traditional education is synchronous. However, a proper mixture of asynchronous and synchronous interaction is crucial.
9. Computer platform independence. The learning environment should not be dependent on client software which in its turn is dependent on hardware.
10. Incentive structures. Students are economical in their use of time and other resources and will not adopt to new practices without payoff. This is certainly also true for faculty.

Several excellent conference tools are available. Best known are probably Lotus Notes, First Class, and Netscape. The learning environment was to be implemented in a Macintosh server which limited available conference systems. Of the tools evaluated, WebX (webx.lundeen.com) was found to be a feasible standard system for our purposes as it fulfilled most of the design principles above. Learning environment is from now used to describe the conference system used with a specific purpose. The next section describes the learning environment when implemented and in use.

TWO CASES

How does it look in an educational setting? Lets look at two cases—*course discourse* and *final project*. The author is part of the educator teams in the *course discourse* case. In the final project the role of the author is as an external intervener through dialogue with the responsible professor. The cases are currently on-going and therefore an extensive evaluation have not yet been performed.

Course Discourse

To students, many courses are perceived as a sequence of activities with very little explicit relations between them. The risk is that students concentrate on learning the different concepts covered as non related. The educators' effort to provide the overall picture is not always successful. The notion of *course discourse* is an effort to provide the overall picture by sustaining a discourse. The technical implementation of *course discourse* is basically a hierarchical conference structure where the teachers control and moderate the activity.

Course discourse and its implementation in the learning environment is currently being evaluated in two courses. The first course is an IT management course with a large variety of activities. Thirty students are enrolled, and individual and group projects are the core of the course. Weekly guest lecturers from the industry and regular lectures are inputs in the projects. The instructor has experienced fragmented courses where the overall picture was lacking. Therefore, the decision was to integrate the learning environment as a resource in the current course. The aim is to facilitate the ongoing discourse among the students and the guest lectures. The second course is a master program with twenty-one students enrolled. The program is strictly PBL (problem based learning) and the course discourse is used by faculty to connect and relate the different activities in the otherwise learner controlled program.

Final Project

Being dissatisfied with the quality of the master thesis', the *final project* is an effort to stimulate and support the students in improving this process. During the final semester master students engage in a project of their choice. They formulate a research question and write a master thesis. In the *final project*, however, the writing is not in focus, the emphasis is on the early part of the project and the formulation of research question. The aim is to encourage (force) students to articulate and communicate their ideas and research question early in the process of writing the thesis. The intention is to start the process of problem formulation four months earlier than previous year. The implementation is essentially that all sixty students enrolled have a section in the learning environment with host access. As hosts they have full control of the section where they present their idea to peers, faculty and industry who support the student by commenting on the ideas, which are gradually refined. For peers, it is an opportunity to early find other students with similar projects. For faculty, the matching of project with the right supervisor is made easier. For industry, it is an opportunity to head hunt students who have projects of interest to the organization. This capability of including alumni and other industrial participants would not be possible without the learning environment.

Preliminary Evaluation of Course Discourse and Final Project

Extensive or formal evaluation has yet not been performed. However, interaction with students and faculty give some indication.

1. Learner controlled submission. Posting comments in an open enviroment was new to many of the students. The

possibility to erase messages is crucial if they are to participate at all.

2. Contribution and notification. “I don’t have time to look for new messages” according to participants.
3. Navigation structure. The conference system provided a standard hierarchical structure which is found to be functional.
4. Source referencing. This is provided by the ability to link to resources outside the forum. All students will have personal Web-pages which should be used to present more comprehensive material.
5. Instructor controlled submission. In *course discourse* educators found voting, which is implemented in the conference system, to be a useful function.
6. Multiple media. Since all students have personal Web-pages, they are encouraged to use them to present more complex contributions and provide hypertext links from the discussion.
7. Anonymity. As many students feel uncomfortable in posting certain types of comments, an anonymity section is to be implemented.
8. Synchronous interaction. The notion of office hours, where the educator is available on-line on certain hours, is to be implemented.
9. Computer platform independence. Workstations, PC’s and Macs are used.
10. Incentive structures. Last on the list, but surely the most difficult and critical issue. Participation varied among the students. This was expected. However, the limited participation of faculty was not.

CONCLUDING REMARKS

In the introduction, it was suggested that engineering students are often blinded by details. It was also suggested that engineering education has very little time allotted for reflection. It is the conviction that even the smallest amount of reflection will increase the quality of education substantially and help to educate more competent practitioners.

The primary contribution of the paper is that it identifies design principles which should be considered by educators who wish to use computer based tools to facilitate asynchronous discussion. The design principles guided the implementation of two cases—*course discourse* and *final project*. The cases are on-going and no extensive evaluation has been performed. However, the preliminary evaluation of the two cases suggests that it is the method of using the technology and not the technology itself that has an effect on educational activities, as can be seen in [7,8]. Course discourse allows the educator to sustain a discussion over the whole course. All activities during the course can be explicitly linked to the discourse. Guests and other external resources can be present over time. The final project increases the time allocated to thesis writing without interfering in other activities. By exposing their ideas publicly, students are more thorough in their thinking and writing. By interacting with others, their ideas are gradually refined and finally formulated into a research question.

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