PEDAGOGICAL FRAMEWORKS AND TECHNOLOGIES FOR ONLINE NETWORK LABORATORY INSTRUCTION

Research issues in matching technology to pedagogical processes

Shyamala Sivakumar
Computing and Information Systems, Saint Mary's University, Halifax, NS, Canada

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Abstract: We investigate the technological issues involved in designing an electronic learning system that adapts pedagogical approaches and best practice instructional strategies to model, design and implement a blended virtual learning space. We discuss technology issues that are challenging in the design and implementation of a modular integrated web environment (IWE) used to deliver online network laboratory learning. We show that the IWE must incorporate an online laboratory tutorial system for guided practice to elicit performance from the learner. Also, the learning space must be designed to match the quality of service (QoS) requirements to the interaction taking place in the learning space and the characteristics of the delivery media must be matched to learning process. This approach promotes good student interaction & infrastructure management.

1 INTRODUCTION

The developer of an e-education system faces several challenges in designing frameworks for an online learning environment that ensures strong effective interaction that best replaces the onsite face-to-face interaction taking place in labs like those employed in Internetworking (INWK) and Information Systems (IS) courses which extensively use networking hardware and computer/simulation software tools. In addition to a clear understanding of the knowledge domain requirements, the challenge is in supporting good pedagogy and learning practices given technical constraints with regard to bandwidth, quality of service, real time interactions, and multiple users. The e-learning design framework must include an effective, accessible and responsive multi-user online environment, employ interactive hands-on laboratories, and incorporate effective instructional strategies to impart knowledge and meet instructional outcomes. The paper is organized as follows: in section 2 we review literature. Section 3 presents the online pedagogical framework. Section 4 discusses online network lab learning technical design and implementation issues.

2 LITERATURE REVIEW

Issues in e-learning include: 1) student interaction 2) adapting pedagogy to the online environment 3) develop knowledge repositories based on sound instructional design practices 4) infrastructure management for delivering learning material and 5) student performance tracking. Pedagogical models, learning and instruction theories in active, collaborative and learner-centric instruction proposed by Bandura, Gagne, Hiltz, Kolb, Skinner, and others (Bandura, 1986, Gagne, 1992, Hiltz et al., 2000, Kolb, 1985, Skinner, 1968). These are examined to see how they can be adapted to model the interactions between student and learn-ware resources, lab equipment and online tutoring systems. Learn-ware employing multimedia (MM) enabled learning tools such as simulators, interactive hands-on laboratories and online laboratory tutorials (OLT) help create an environment that fosters skill building and enhances problem-solving skills. Two pedagogical environments that correlate with the onsite lab teaching include the constructive and collaborative approaches (Gagne, 1992, Hiltz et al., 2000). Authentic lab based activities help construct knowledge. Group interaction increases student engagement resulting in better learning. Also, situated learning can be employed to present

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academic knowledge in a practical context to teach students problem solving skills (Bandura, 1986). Studies indicate that effective pedagogy begins with a classification of student learning styles, such as the the Kolb's learning style inventory (KLSI). KLSI has a specific focus on the learning process and thus enables online pedagogical design to address specific instructional objectives (Kolb, 1985). KLSI classifies learners into activist, reflectors, theorists and pragmatists. Activists learn by doing. Reflectors research the subject by analyzing data. Theorists model systems and theories. Pragmatists implement what they have learnt. Typically, abstract learning is favoured by theorists and pragmatists, while concrete learning is favoured by activist and reflectors. Hartman matched KLSI learning styles to pedagogical strategies consisting of four distinct segments, namely activities that are rooted in concrete experiences (CE) e.g., use lab, field work, observations; theorizing that involves abstract conceptualization (AC) e.g., use lectures, papers and analogies; reflective observations (RO) e.g., use of logs, journals or brainstorming; and learning through active experimentation (AE) e.g., use simulations, case studies and assignments (Hartman, 1995). In particular the four quadrant pedagogical and learning style model suggests how an online learning system should be designed and specifically, suggests ways in which the knowledge repository must be structured, interfaces designed, and the online learning environment implemented for optimal learner support. Successful learning requires that the activities in a remote lab implement the nine instructional strategies as outlined in (Gagne, 1992). These include: (i) gain attention, (ii) inform learners of objectives, (iii) recall prior learning, (iv) present stimuli, (v) provide guidance, (vi) elicit performance, (vii) provide feedback, (viii) assess student performance, and (ix) enhancing retention (Gagne, 1992). What we have not seen in literature and plan on addressing in this paper are the unique challenges of online lab-based learning such as the need for students to interact with lab resources synchronously and asynchronously, limitations in lab resource system response, given bandwidth and real-time response constraints, in the context of multi-user support.

3 IWE ONLINE PEDAGOGICAL FRAMEWORK DESIGN

We propose that the pedagogical framework employed in an online laboratory must incorporate all the segments of a KLSI learning cycle. Ideally, the online laboratory space must provide maximal opportunities for the active experimentation (AE) of the learning cycle based on concrete experiences (CE) and intellectual stimulation based on understanding abstract concepts (AC) with ample scope for reflective observations (RO) using online collaboration. Also, social presence can be achieved by established an online community of learning and cognitive presence by forming a community of enquiry in which instructors/online tutorial systems help students construct and confirm knowledge through online interaction. Teaching presence is defined as the facilitation and direction of cognitive and social process for the realization of learning outcomes. An important research issue is how to increase teaching presence in the online environment. We propose that teaching presence can be achieved by incorporating 1) instructional strategies that direct student learning processes when interacting online with hardware/software 2) online laboratory tutoring (OLT) systems that monitor and guide the learning process 3) competent online facilitation by a facilitator and 4) appropriate intervention by the system/facilitator when learning objectives are not meet. Studies indicate that student learning process can be directed by incorporating Gagne's instructional strategies and a research issue is how to implement these in an online lab. We propose that the online lab themes be based on concrete real world INWK/IS applications that help students learn by employing networking equipment, simulations and software tools to comprehend, analyze, and evaluate abstract INWK/IS theories/concepts. This pedagogical model increases comprehension, synthesis of new knowledge by evaluating the lab results through reflective observation and helps convert the explicit content-specific learning material into implicit knowledge. The proposed online pedagogic process threads all of the dimensions of Kolb's cognitive learning levels into the learning cycle.

4 ONLINE LAB LEARNING: DESIGN & IMPLEMENTATION

Functional implementation issues of a lab rich virtual learning space that is scalable, accessible, interactive, and modular are now considered.

4.1 Learning space & online educational material design

Learning environments can be classified as synchronous or asynchronous or blended (Picciano, 2002). The design and implementation of laboratory interaction using a Web-based environment can present challenges, e.g., too much interaction can be perceived as busywork, while too little interaction leads to perceptions of isolation. Research issues include designing virtual LS to enable the following interactions - 1) one-on-one asynchronous interaction between student and learning resources 2) a scalable learning environment that can support several group-based lab activities simultaneously 3) a collaborative environment for simultaneously inter-team interaction 4) an environment for discussions in news groups, and 5) one-to-one/many synchronous interaction between student and facilitator/instructor (Shang et al., 2001).

We propose a LS that incorporates 1) an online laboratory tutoring (OLT) system for asynchronous learning 2) virtual lab space that supports multiple real-time interactions with actual hardware, simulators and software for synchronous learning and 3) facilitation by facilitators for blended (a)synchronous learning employing streaming multi-media at a minimum and 4) asynchronous many-to-many web based communication (WBC) using bulletin board, e-mail and chat for discussions and evaluation of all online laboratory activities. In addition, performance support such as HELP system and advice will be included as part of LS system design.

The characteristics of media used in communication can be assessed using media synchronicity theory (MST) that proposes that learning performance will be improved when learning needs are matched to a medium's ability to convey information. MST suggests face-to-face communication supports low one-to-one synchronous interactions but facilitates feedback (Dennis and Valacich, 1999). Similarly, text based communication supports one-to-many asynchronous interactions with low ambiguity and has good editing features. Thus any one media is not capable of providing all features. An important research issue is to explore how multi-media (MM) and streaming MM may be applied to the problem of online learning to match the characteristics of media to learning processes in a remote lab. Issues include exploring which MM (or combination) are good for i) interaction with equipment ii) guidance iii) demonstration of lab techniques iv) troubleshooting networks v) result analysis and vi) feedback.

4.2 Instructional strategy and online laboratory tutoring (OLT) system

Tools that incorporate virtual routers have been proposed (Baumgartner et. al., 2003). We intend to employ virtual switches, packet sniffers and LAN/WAN analyzers in addition to routers. By employing virtual equipment (whose response is typically text based) along with talking heads and video/audio clips in the OLT environment, the system can help guide a novice student through basic lab instruction including the use of correct commands, proper configuration and use of actual equipment. Research issues in OLT design include usability of the interface, content presentation in several formats, atomizing information so as not to overwhelm student, eliciting performance, organize learning content in a way logical to the student, and providing context dependent information.

Web usability posits that content should account for 60-80% of a page's design. We propose that the OEM is well labelled, documented and organized and navigation information includes current location of student and links to additional content such as Java applets, sound/video clips and graphics. The additional content enhances student comprehension by presenting information in a variety of formats (listening, viewing and answering). Skinner posits that for successful learning, it must be accomplished gradually in incremental steps (Skinner, 1968) and hence, the OEM must be designed to atomize information. Research issues include how to overcome limitations of existing approaches in the use of hypermedia (HM) and MM in course material through the provision of the features including: i) ability to individualize and annotate MM and HM OEM lab material in a way similar to making notes ii) browsing and navigation through the OEM according to individual annotations, iii) providing situation- and context-sensitive interaction between learners and OEM (Weaver, 2004) (e.g., while troubleshooting communication networks the technical support information needs to be organized or navigated based on task). Another important research issue is how to design the OLT so as to elicit learning performance from the learner and may be used i) to assess learning outcomes ii) provide direction, feedback and iii) guide student learning thus incorporating steps 5-8 of Gagne's instructional strategies. We propose that performance is elicited from students by designing the OLT so that students practice under the guidance of the OLT and also provide corrective feedback as it is an effective teaching strategy that enhances learning and long-term retention.

4.3 Interaction and QoS requirements

Keeping in mind the different interactions types in the IWE, an important research issue is to design, develop and test an innovative instructional tool that integrates various communications technologies including MM/SMM IM, e-mail and chat in an integrated web environment that pays careful attention to quality of service (QoS) requirements including the bandwidth, delay, jitter, security, and error rate required when supporting 1) person-to-person(s) interactions 2) interaction with learning content, 3) virtual collaboration, and 4) discussions in news groups and chat rooms. We intend to incorporate an interaction aware QoS manager that is part of the IWE architecture.

4.4 IWE architecture design issues

While WebCT and other remote education tools enable educational OEM web-page development, administrative tools to assist with course administration, and tools for communication; typically, there are no dedicated tools for collaboration, and QoS management. The INWK/IS lab consists of PCs and servers, networking devices, and network simulation software. In our previous research (Sivakumar et al., 2004) we have addressed design and implementation of a synchronous remote site INWK lab. The online IWE lab architecture must be designed to provide both synchronous and asynchronous access to the remote lab equipment, the OLT and lab OEM. We propose that the IWE architecture include a data base (DB), a data base manager, a course editor (CE), a collaboration manager (CM), and a QoS manager. The DB will contain all OEM (including all multi-media files and slides). A DB server will manage the database administration. The CE enables the import of hypertext, MM, SMM and text files. The remote student can use an Internet-browser to access the lab, OLT and to display the MM/SMM lab OEM content. Connections between the client and the DB/Terminal server can be established via TCP/IP. Collaborative content handling must support joint discussion, viewing and editing of task material, and submitting joint solutions can be done by the collaboration manager (CM).

5 CONCLUSION

The novelty of the proposed integrated web engine for online networking laboratory instruction lies in designing an e-system by adapting pedagogical approaches and best practice instructional strategies to model, design and implement a blended virtual learning space. The IWE must incorporate an online laboratory tutorial system for guided practice that is designed to elicit performance from the learner. The learning space must match the quality of service (QoS) requirements to the interaction taking place in the learning space and the characteristics of the delivery media to learning processes. This approach will promote good student interaction, infrastructure management, and provides an ideal virtual learning environment that is available anywhere and at anytime.

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