Can Quality Graduate Software Engineering Courses *Really* Be Delivered Asynchronously On-line?

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ABSTRACT
This article briefly presents a case study in on-line asynchronous course delivery. It sketches the design of a graduate computer science course entitled "Software Design and Quality," illustrating an effective approach to distance learning that accommodates learning by doing, team collaboration, and critical thinking. It also shows that there are effective alternatives to "canned" streaming media presentations that achieve quality on-line education.

Keywords
Distance and distributed learning, asynchronous learning networks, video conferencing, multimedia course materials

1 INTRODUCTION

With the growing influence of the World Wide Web and on-line communication tools on distance learning, more universities are considering the pragmatics of on-line course delivery. At the same time, many educators feel that there is no substitute for a more traditional face-to-face educational experience [2]. Others believe that although self-paced, web course delivery may be OK for introductory material or lecture-based content, it is inappropriate for higher-level courses where more advanced capabilities, such as design, are taught. After all, it is hard enough to teach such skills face to face.

While there are valid reasons to be concerned about the appropriateness of any delivery mechanism with respect to a course's learning objectives, the key is choosing mechanisms that complement the intended learning activities and help reinforce the learning goals. Through careful choices and instructional design, one can create an engaging and effective on-line learning environment. This is true even when teaching higher-level skills, such as design, where effective learning traditionally relies on creating, reflecting, analyzing, and constant interaction.

This demonstration presents the course materials and design of a graduate software engineering course entitled "Software Design and Quality." This course, including its presentation method, is notable because it:

- Illustrates an effective approach to distance learning that goes beyond streaming video presentations and canned multimedia lectures.
- Encourages students to learn by doing, learn from each other, learn by observation, and critically analyze.
- Provides multiple interaction paths between the student and the instructor, between the student and the course material, and among peers.
- Supports collaborative teamwork and group learning activities in a distributed setting.
- Provides effective access to and navigation through the on-line materials used in the course.
- Serves as a model course delivery strategy for additional distance learning courses at Virginia Tech.

This article briefly sketches the background and instructional design of the "Software Design and Quality" course in Sections 2 and 3. Section 4 details the learning activities used in the course, and Section 5 outlines the on-line presentation and delivery of materials that support these activities. The article concludes with some preliminary evaluation results and future directions.

2 COURSE BACKGROUND

The course outlined in this article is CS 5744: Software Design and Quality, a new graduate course offered by the Department of Computer Science at Virginia Tech. The catalog description serves as a simple overview:

> This course focuses on critical aspects of the software lifecycle that have significant influence on the overall quality of the software system

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including techniques and approaches to software design, quantitative measurement and assessment of the system during implementation, testing, and maintenance, and the role of verification and validation in assuring software quality.

5744 takes students who have already been introduced to the basic concepts of software engineering, and pursues more advanced techniques in software design and project management aimed at producing high-quality results.

The audience for 5744 includes a broad mix of students, some with little or no work experience and others who are employed full time. Students at multiple geographic locations may participate; the initial offering involved three separate locations. Students who work full-time have limited time for completing out-of-class assignments and limited patience for assignments they perceive as "busy work," or that lack clear field-related learning relevance. Further, "any time, any where" access to course materials is necessary, so materials can be accessed at home or work on the student's own schedule.

In response to the needs of this student audience and to reduce course management effort, 5744 was designed to be entirely "paperless." All written communication in the course was transmitted electronically. All course notes and handouts were delivered on-line, all graded work was submitted on-line, all grades and comments were delivered on-line, and all exams were submitted and graded on-line.

3 COURSE DESIGN STRATEGY

The content in 5744 covers software design as well as quality assessment techniques. While traditional lecture techniques are appropriate for some of the content, design and assessment skills seem to be best acquired through a variety of active learning techniques. It is essential for students to practice creating designs. Learning by observation is also important—by studying the designs of others or watching "over the shoulder" as a design problem is solved. Finally, opportunities to analyze existing designs and discuss them with other students are important to support reflection and assimilation of basic principles. Similar techniques apply to learning assessment skills.

At the same time, on-line students must take more initiative in their own education. To promote this, it is necessary to focus on learning activities that engage the student, give the student some "ownership" over class assignments, and promote interaction among classmates [1, 5].

With this in mind, 5744 is centered on group learning activities that promote student interaction, discussion, and critical analysis of the techniques and sample systems presented in the course material. The core activity in 5744 is a small team design project (3-4 weeks long). Student teams self-select the subject of their designs and typically become personally invested in the project. Other individual and group assignments build on the group designs produced by classmates, encouraging interaction and promoting critical but constructive analysis of realistic examples.

This classroom strategy results in learning activities that are closer to those in a literature class than a physics class, with students studying selected works, analyzing and discussing relevant issues as a group, and producing new works of their own. This classroom concept also borrows on medical and law school class techniques, where students review case studies individually, and then discuss each case as a group, guided by specific issues or questions presented by the instructor. The textbook for 5744 [4] was chosen in part to support this technique; it includes brief case studies of a number of software designs. These designs each highlight different design choices that are appropriate for addressing different application concerns.

Learning Objectives

For any course, a clear, well-articulated set of learning goals forms the foundation of the instructional design [3]. Different institutions have varying expectations in how learning goals are to be phrased, but the end result is the same. Learning goals define the desired outcome for students who successfully complete a course.

The learning goals for 5744 state that, upon successful completion of the course, a student will be able to:

- Read and write basic UML design notation.
- Review and critique software designs for quality.
- Collect and interpret OO code metrics.
- Plan and manage integration and system tests.
- Apply some design patterns.
- Explain software process and project metrics.
- Assess software quality through metrics.
- Discuss verification and validation activities throughout the software lifecycle.
- Discuss methods for managing traceability.

Supporting Student Interaction

Given a set of learning goals, the instructor designs materials, delivery mechanism(s), and activities aimed at achieving these goals. In the context of distance learning or on-line delivery, it is important to remember the various interactions that contribute to a student's learning [3]:

- Students interact with the instructor.
- Students interact with the course materials.
- Students interact with their peers.

In a traditional classroom setting, it is common for class meetings and office hours to act as the primary mechanism for student-instructor interaction, along with e-mail or listserv messages. Students interact with typical course materials, a textbook and packet of course notes, by individual reading, studying, and note taking. Peer-to-peer interaction occurs during class discussions, as well as outside of class in informal study groups.

In the context of alternative course delivery mechanisms, however, it is important to support effective interactions of all three types for students. Further, the absence of face-to-face interaction with the instructor may increase the need for effective interactions with other information sources.

4 LEARNING ACTIVITIES FOR STUDENTS

As stated in Section 3, the learning activities in 5744 are designed to provide opportunities for learning by doing, learning by observation, and critically analyzing. More importantly, however, multimedia presentation of lecture materials was not the focus of 5744 course development. Instead, it was crucial to choose class assignments that encourage students to stay engaged in the class week-to-week and that drive student interaction [5]. As a result, the 5744 classroom philosophy involves studying background material, and then focusing on student-produced designs, assessing and being assessed, and building off of the work of other students in the course.

While much of the preparatory work for these activities can be done asynchronously, the final step often involves group participation. In some instances this can be accomplished on-line asynchronously, but in other cases it requires synchronous group presence, with participants on-line simultaneously. The design of the course materials aims to maximize asynchronous, self-paced delivery of lecture and reference material, maximize use of asynchronous discussion techniques, and reserve synchronous on-line meetings for those class activities that require it.

The graded work in 5744 can be roughly divided into five categories: reading assignments, class participation, individual homework assignments, group projects, and a final examination.

Reading Assignments

5744 students are expected to read course material individually on a regular basis. Reading assignments are typically taken from the course text or from supplemental reading materials provided electronically on the course web site, such as relevant journal articles. Reading assignments are given weekly, along with a small set of questions. The questions are open-ended and designed to promote critical thinking about the content of the reading. Students submit their answers on-line.

Class Participation

After completing readings, students are expected to participate in class discussions and contribute their own thoughts and insights. In the initial offering of 5744, this was accomplished by two-way video conferencing meetings. The video from these meetings was recorded to use in enhancing the course materials provided on-line. Similar topical discussions can also be carried out on-line synchronously using chat rooms or other tools, or asynchronously using discussion boards, listservs, or other mechanisms.

Homework Assignments

5744 includes two substantial individual assignments. These assignments are termed "homework" to differentiate them from group tasks. The assignments are writing intensive, and designed to promote reflection and critical application of course concepts. The first individual assignment involves assessing and critiquing one of the case studies presented in the textbook. The second involves assessing and critiquing a group software design produced by other students in the class. Design critiques include detailing the strengths and weaknesses of the design, identification of any open design issues, and suggestions for improvement. Submissions are anonymously presented on the course web site for the benefit of others and for use in later assignments.

Group Project Assignments

5744 also includes two substantial small group projects, completed by teams of 3-4 students working collaboratively. To simplify logistics, group members are all collocated at the same site. They may choose to meet face-to-face in performing assigned work, but sufficient on-line support is provided so that all out-of-class collaboration can be completed electronically if desired.

The first group assignment is developing a high-level software design for a realistic application. Groups are allowed to self-select design topics, and many choose systems related in some way to group members' work activities. Each group is responsible for sketching its project's requirements, identifying the critical design issues, and devising an architectural design. Classmates review the group designs in an individual homework assignment.

The second group project involves selecting the design produced by some other student group and devising and organizing a test plan for it. This includes planning out integration builds, identifying the collection of test cases needed to properly exercise each build, and devising system-level validation tests.

Final Examination

The final examination for the course is a written, take-home exam delivered to the class electronically. Students are allowed complete access to the text, any course materials, and any other printed or electronic resources in completing the exam. Students have approximately one week to submit their exam answers, and are honor-bound to complete it without the assistance of other individuals inside or outside of class.

5 ON-LINE DELIVERY

The 5744 course strategy focuses on supporting the three forms of interaction described in Section 3 by applying typical mechanisms associated with on-line course delivery and Asynchronous Learning Networks (ALN).

Student Interaction with the Instructor
Interaction with the instructor is supported asynchronously through e-mail and through a class-wide discussion board on the course web site. Synchronous interaction with the instructor is provided through on-line office hours or Q&A sessions using chat rooms. In the future, we may experiment with two-way audio-only or two-way audio/one-way video office hours, although current classroom experience indicates that the existing support for student-instructor interaction meets students' needs well.

Student Interaction with Course Materials
Course material presentation was designed with three principles in mind: the student should always be in control of navigation, exploration should be encouraged, and the large and small topics covered should remain "visible" so that students will not have to remember what is available or where it is located. The effects of these principles are evident in the course web site.

PowerPoint lecture materials were automatically converted to text in HTML (not screen capture images). In the initial offering of the course, live lectures were videotaped and later digitized. Small, focused audio or video/audio clips on specific topics were extracted and attached to individual lecture content pages. These multimedia clips provide more thorough exploration of the material than the course notes, and also provide access to comments or questions raised by other students. This presentation style is distinctly different from delivering a lengthy video lecture in its entirety via streaming media techniques.

For navigation support, the site provides an "at a glance" site map and a comprehensive book-like index to the body of lecture materials on a page-by-page basis. From the index, students can quickly access the corresponding sections of the lecture notes, in-class presentation video segments, or in-class audio segments. The index is searchable, as are most web indices, but it is also browsable. Students can view the list of keywords alone, or browse through the complete alphabetical index and see the page titles associated with each content keyword. Such an index supports free association, exploratory navigation, and active engagement of the course content more effectively than a search engine interface. The index is automatically generated from the lecture materials.

Student-to-Student Interaction
Asynchronous peer interaction is supported through a hypermail-archived listserv and discussion boards hosted on the course web site. There is one discussion area open to the entire class, and separate "private" discussion boards for each team of students working on a project. Synchronous interaction among students is provided through chat-rooms. As with the discussion boards, there is one chat area with 6 separate rooms open to the entire class. In addition, each student team has a similarly structured "private" chat area that can be used for student-scheduled team meetings or discussions. In the initial offering of the course, periodic two-way videoconference meetings among all involved student sites were also used for discussions and class-wide dissemination.

6 CONCLUSIONS

Preliminary evaluation of 5744 indicates students enjoy the course and consider it a valuable experience. In the initial offering, students were given an on-line survey early in the semester and again at the end of the semester using questions from the Flashlight inventory. This formative evaluation was intended to assess the course delivery techniques and point out areas needing improvement. Student responses indicated they enjoyed studying for the course, felt better able to communicate their ideas, and felt they could understand the material better than in other (more traditional) courses. These results parallel those from other studies [6]. Student performance on graded work also indicated the students learned course concepts well.

As a result of this effort, the basic delivery strategy and course design issues will be reused in additional graduate courses at Virginia Tech that are being designed or redesigned for on-line delivery. Additional evaluation of such courses is an integral part of assessing how well they achieve their intended learning goals.

ACKNOWLEDGEMENTS

This research and instructional development is supported in part by Virginia Tech's Center for Innovation in Learning. Sherri Turner and Tom Corbett of Virginia Tech's Institute for Distance and Distributed Learning aided in this work. Their contribution is gratefully acknowledged.

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