Enhancing the Classroom Learning Experience with Web Lectures: A Quasi-Experiment

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Abstract. In this paper, we present continuing research into the use of web lectures to enhance the classroom learning experience. By using web lectures to present lecture material in advance of class, more in-class time can be spent engaging students with authentic learning activities; our goal is to use class time for more learning by doing, less learning by listening. A longitudinal quasi-experiment was conducted during the Spring 2005 semester with two sections of the same course: one using web lectures and one using traditional lectures. The web lecture section's grades were significantly higher than the lecture section, and web lecture students reported increasingly strong positive attitudes about the intervention. We also present multiple threads of future work motivated by these positive results.

Keywords: Web lectures, constructivist learning, educational technology, educational intervention

INTRODUCTION

Learning sciences research tells us that students learn much better "by doing" rather than "by listening." Thus, passive learning – the traditional lecture – is being replaced in our classrooms by more active learning that emphasize student problem solving, discussion, presentation, and other authentic learning-by-doing activities. At the same time, students continue to need information – facts, concepts and context – to meaningfully engage in these activities. In the past, students have acquired this information via readings and the traditional lecture. But, with more class time used for active learning as a way for students to convert information into knowledge, there is less time for in-class lectures.

We are exploring the use of web lectures (combination of audio/video/PowerPoint materials created with Microsoft Producer) as a way to present the information in advance and outside of class, to prepare students for the more meaningful in-class activities. Our web lectures are studio-recorded condensed lectures; they are usually 20-30 minutes long, and cover the same amount of material as 40-50 minutes of classroom lecture. Our exploration encompasses both pedagogy and technology.

We seek *pedagogical techniques* that motivate students to watch the lectures in advance (the same challenge as motivating students to read material before coming to class). One such technique is to have students prepare an in-class presentation based on material covered in a web lecture. Another is to have students complete a homework assignment that depends on the web lecture. We are also exploring what types of in-class activities work best in conjunction with web lectures.

We also seek *technological support* for the pedagogical techniques, to imbed in the web lecture viewing mechanism technological capabilities that will engage students in activities that relate to their subsequent classroom participation. For instance, to encourage students to ask questions about a web lecture, a convenient way to ask the question in the context of a particular lecture slide could be provided – such as typing a question with the slide, and making the question available to the instructor. Some questions can be answered by email; those that would foment class discussion can be held for the next class meeting.

The research is being conducted in the context of an introductory course on Human-Computer Interaction (HCI). The class itself is heavily project-based, with student teams doing a semester-long requirements analysis / design / implementation / evaluation project. Web lectures and other material are made available to the students via the Georgia Tech Human-Centered Computing Education Digital Library (http://hcc.cc.gatech.edu).

Our previous pilot studies into the use of web lectures has concentrated on achieving optimal levels of web lecture production quality, the mechanics of a course format where much more class time is available for activities other than lecture, and soliciting students' subjective attitudes about web lectures and the in-class activities made possible by them [1, 2]. Encouraging findings in this past research motivated a more controlled investigation that would allow us to evaluate the web lecture intervention not only in terms of students' opinion, but also in terms of educational outcomes. Thus, our hypothesis going into this quasi-experimental study was that a course taught using our web lecture / in-class activities format would be as or more educationally effective and enjoyable than a traditional lecture-based course, as measured by grades and students' self-reported attitudes.

EDUCATIONAL THEORY INSPIRATIONS

Web lectures can be used to augment, not replace, the classroom learning experience. The traditional one-to-many lecture still prevalent in classrooms today all but ignores accepted contemporary learning theory. Much of this is due to the inherent lack of learner engagement in such lecture settings [3]. Often, the problem is not that the instructor does not desire to foster learner engagement; rather, the instructor does not have time to do so while also covering all the required course material. Our goal, therefore, is to take advantage of the opportunities and technological affordances [4] of web lectures in order to decrease the in-class time spent on information transfer and increase the in-class time available for more active learning.

Edgar Dale's Cone of Learning [5] suggests the least effective learning method involves learning through passive information presented through verbal symbols (i.e., listening to spoken words - lectures), while the most effective learning method involves the student actively participating in "hands-on" learning activities. Dale's category for "Movies/Videos" fell in the middle of retention cone. Additional research based on Dale's findings, conducted by the National Training Laboratories, produced the Learning Pyramid [6]. The Learning Pyramid illustrates the average retention rates for different teaching methods, where lecture was found to provide the least retention (5%), audio-visual and demonstration were placed in the a higher retention range (20-30%), and more active methods such as practice by doing and teaching others were found to provide the most retention (75-90%).

This suggests that students viewing web lectures should retain at least as much as students listening to traditional lectures. Because web lectures allow the viewer to pause and review a web lecture, one could argue that they fall in a learning effectiveness category significantly above traditional classroom lectures. More to the point, when a large portion of the lecture material is covered before class, much more in-class time is available to engage learners in the more authentic learning activities that Dale and other subsequent educational researchers suggest are the most effective.

Contemporary educational theories suggest that active learning environments are the most effective way to increase motivation and learning. Duffy & Cunningham argue that constructivist learning theory and educational approaches based on constructivist principles are more effective than traditional methods [7]. Constructivist theory suggests that learning is best achieved by active construction of knowledge in meaningful contexts. Also important in the process of learning and cognition is the critical role of social interaction in such knowledge construction activities [8]. These forms of learning environments often involve learners participating in somewhat open-ended, learner-centered activities that include some collaborative problem solving, results sharing, and public/personal articulation and reflection.

As noted previously, with more in-class time made available by having students watch web lectures, more opportunities arise to integrate constructivist-inspired learning activities into a course. Many educational approaches and activities based on constructivist principles can be implemented into the classroom: project-based learning [9], problem-based learning [10], inquiry-based learning [11], cognitive apprenticeship (reciprocal teaching) [12], and role-playing activities [13], to name a few.

Previous research suggests that using pre-recorded lectures in the distance learning context produces "no significant difference" [14] in learning effectiveness. Although we do not intend to use web lectures as they have been used for distance learning, this result and the previously noted Cone of Learning and Pyramid of Learning support our use of web lectures as a means of information dissemination. We believe that the most beneficial way to use web lectures will be when they are used *in addition* to normal classroom time and reading assignments, as a way to *supplement* the classroom experience, not to replace it. This is in marked contrast to the distance learning approach of using web lectures to replace the classroom experience, and is more in the spirit of "blended e-learning."

When students come to class with a baseline of knowledge, they can truly engage with the material [15]. Students can collaborate more effectively when coming into class equipped with the knowledge necessary to support higher-level application. The extra in-class time available as a result of using web lectures can be used to answer questions, discuss difficult subject material, and engage in constructivist-inspired learning activities.

RELATED WORK

Research into the use of recorded video material in the classroom dates back to the 1970s. One seminal study is the Tutored Video Instruction study conducted by Gibbons at Stanford University. This research found that when remote students watched recordings of lectures in small (3-10 person) groups with a facilitator (tutor) present to periodically pause and prompt discussion, they typically outperformed the students who attended the live lectures [16].

Since that time, technological developments, especially the rapid growth of the internet, have brought exciting new opportunities to guide and enhance learning, and new ways to apply Gibbons' results. Furthermore, advancements in the field of learning sciences and cognitive psychology have increased our understanding of the principles of learning and transfer [17]. Using web lectures streamed over the web, especially in the context we intend to use, is still largely unexplored. This is mainly due to relatively recent technological advances in audio/video compression, web portability, network bandwidth, and authoring software. With these recent advancements, research on the application of internet technologies in education is rapidly accelerating.

Research with studio-recorded web lectures was conducted at the University of Wisconsin with a large-enrollment computer science course for engineering students [18]. There, two scheduled large lectures per week were dropped and replaced by web lectures, and the minimal class meetings were entirely dedicated to discussion. Although this format required more self-discipline, Moses *et al* found that the majority of the students enjoyed and learned as much or more using the new course format.

Research by Oliver and others stresses the need for internet-based learning environments to make better use of technological affordances in order to create more active learning opportunities [19]. Although their end goal is similar to ours – to create a more active learning environment – their focus is on primarily internet-based learning environments, whereas we intend to facilitate more active learning through the combined use of internet and in-class learning environments.

At Georgia Tech, the eClass project [20] captured audio and video from live in-class lectures, aggregated with presentation slides, the instructor's annotations, and visited websites. eClass made recorded live lectures available via the web that were primarily used for exam review, whereas we are recording condensed lectures in a studio for use before class. Students made heavy use of eClass in over 60 classes and reported positive attitudes, although performance as measured by grades was not affected.

In a different vein at Georgia Tech, Collard *et al* have found encouraging results in studying the effect of decreasing the amount of class time spent on information transfer in order to increase the time available to illustrate concepts and approaches to problem solving [15]. To accomplish this, they use online pre-lecture assignments (called "HWebs") that ask questions about material covered in the assigned reading. These ensure that students will have already had exposure to and critically thought about the material to be expanded upon during class or lab sessions.

TECHNOLOGY AND COURSE DESCRIPTION

In this section, we discuss the technology we use to create web lectures and the context within which we evaluated the web lecture intervention.

Web Lectures

Web lectures are authored using Microsoft Producer [21], a plug-in for Microsoft PowerPoint 2003. Microsoft Producer facilitates seamless integration of one video feed, two audio feeds, Microsoft PowerPoint slides, and web pages. All of these components can then make use of many different presentation layouts, which can include a real-time navigable table of contents. For recording, we set up a small studio with a laptop, digital video camera, microphone, and appropriate lighting and background, at a total cost of less than $3000US. Recorded web lectures are published to the web in both streaming and downloadable formats for easy viewing anytime, anywhere.

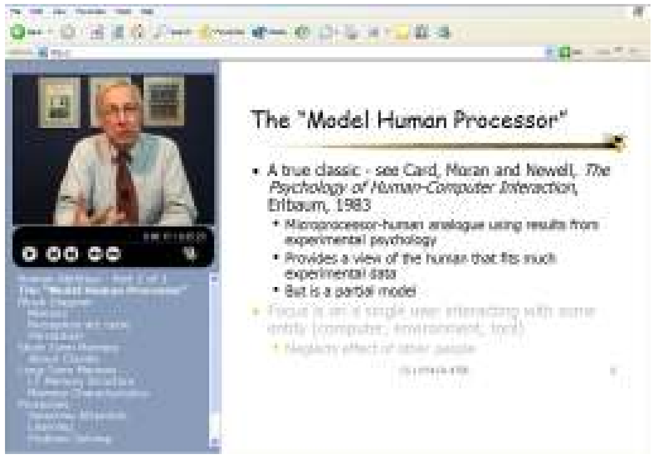


Figure 1 Web Lecture Playback in a Web Browser

Figure 1 shows an example web lecture viewed in a Microsoft Internet Explorer browser window, which is in this case divided into three panes. The upper left pane is the streamed video image, displayed by the Windows Media Player. The lower left pane is the Table of Contents (TOC), a list of links that correspond to slides at the right of the screen. They also contain an anchor point in the video stream; users can skip around in the web lecture by clicking on the TOC entries. The right pane is the current PowerPoint slide. To help focus viewers' attention, bullet points on each slide change from light gray to black as they are discussed by the lecturer.

CS4750 User Interface Design

CS4750 User Interface Design is an introductory HCI course for senior-level undergraduate students. Although the majority of student who take the course are computer science students, the course is cross-listed with the psychology department, so students from a range of other disciplines (i.e. psychology, instructional design, etc.) enroll as well. Enrollment is typically 25 to 35 per class. The curriculum schedules 30 bi-weekly class meetings of 80 minutes each. Students engage in a semester-long design project, complete several short homework assignments, and are assigned weekly readings. When taught traditionally, 25 of the 30 class meetings are lecture; the other five are reserved for project presentations and a mid-term exam. Assessment is based on the homeworks, the semester design project, and mid-term and final exams.

RESEARCH DESIGN

This section discusses the setup of our quasi-experiment with two sections of CS4750, including the differences between each section and the methods used to control as many factors as possible.

The Experimental Section

The experimental section of the course was re-designed to integrate the web lecture intervention. The same topics were covered in approximately the same order, with all but three in-class lectures replaced by web lectures. Time spent watching web lectures (27 web lectures for a total viewing time of 6 hours) was deducted from the scheduled amount of in-class time, equating to seven cancelled class meetings. Class attendance was required.

Our previous research on the use of web lectures [1, 2] indicated that students need and want some form of explicit motivation to watch web lectures. Similar to the HWebs [15] used by Collard *et al*, we implemented lecture homeworks (LHWs). LHWs are short – usually three to five question – assignments designed to promote synthesis of material covered in a web lecture (or series of web lectures) and live lectures. Fifteen LHWs were assigned throughout the semester, each worth 1% of the final course grade; when a web lecture(s) was assigned, the associated LHW was due at the start of the next class meeting. The LHWs not only served as the desired explicit motivation to watch web lectures, but also, and arguably just as importantly, as a stimulus for discussion and informed question asking during subsequent class meetings.

After discussing the web lecture(s) and LHW(s) assigned, each class meeting used the remaining time for various active learning activities. These activities included project-related presentations, small breakout group discussions and presentations, re-design sessions, and design critiques.

The Control Section

The control section of the course was taught in the traditional manner, with 25 class meetings for lecture, five for project presentations and the mid-term exam. The only exception was that the same LHWs used for the experimental section were also added to the control section curriculum. In the control section's case, students would attend a lecture, and the associated LHW would be due at the beginning of the next class meeting. For both sections, assessment was based on LHWs (15%), homeworks (10%), the semester project (40%), and mid-term (15%) and final exams (20%).

Attendance was also required in the control section. Students in both sections were allowed two missed class meetings, and each missed class after that would result in a 1% grade reduction. For the experimental section, attendance was extremely important because of the already fewer class meetings necessitated to control time on task; for the control section, this was one way we controlled for the possibility of control students watching web lectures instead of coming to class. Neither attendance nor control students watching web lectures turned out to be a problem – no students grades were reduced due to attendance, and server logs on the machine that hosted the web lectures did not indicate any significant viewing from the control section.

Methods

When researching educational interventions in the classroom as opposed to the laboratory, there are inherent trade-offs of naturalism and experimental control [22] . Although our desire to study web lectures *in situ* over an entire semester necessitated giving up some experimental control, we strived to maintain control in all ways still available to us. We matched the two sections on all possible factors so that we could later compare the educational effectiveness and enjoyment of a traditional course to one augmented using web lectures. The two sections were matched across the following factors:

- Instructor teaching the course
- Topics covered
- Lecture slides used in class or integrated into web lectures
- Assigned reading
- LHWs, homeworks, and semester project
- Mid-term and final exams
- Time on task:
  - Control section: time spent in class
  - Experimental section: time spent in class plus total running time of assigned web lectures

In addition to these control measures, all grading for the two sections was counterbalanced and blind. To ensure that any difference in section grades was not due to differences in the two T.A.'s grading styles, each assignment and test from both sections was graded by one or the other TA, with all names removed. The semester design project could not be graded blind, but each phase was graded by both TAs together using the same grading criteria.

LHWs were matched not only by having the same questions, but also by allotting the same amount of time between a lecture or web lecture and when the associated LHW was due. Because students in the experimental section could watch (or review) web lectures as many times as necessary to complete an LHW, the control students were given time to review the lecture slides and their personal notes. Additionally, LHW questions were blind to the instructor until the day a particular LHW was due. If the instructor knew the questions on the LHWs, he may have inadvertently lectured more on those topics in the control section's live lecture. Since all web lectures were recorded before LHWs were written, this would have been an unfair advantage to the control section.

Finally, we did not want any difference in performance to be attributable to more "required" time on task. As noted above, to compensate for this the total running time for assigned web lectures was subtracted from in-class time in the form of cancelled class meetings. Again, our motivation is to increase the amount of in-class time available for active learning, not to cancel classes; we only cancelled classes in this experiment to ensure a more valid comparison of educational outcomes. Also, given the technological affordances offered by web lectures (pause, rewind, etc.), it should be noted that total running time may or may not be equivalent to the actual time spent watching web lectures.

In spite of our best efforts to control or match the two conditions on as many factors as possible, there were still a number of factors for which this was not possible in a naturalistic classroom study:

- IQ / GPA
- Prior HCI knowledge

- Learning styles
- Personality type [23]
- Hawthorne effect (students knowing they were in the control or experimental section) [24]
- Possibility of control students viewing web lectures
- Any differences the class meeting time may have introduced
- Possible differences in enthusiasm or attitude by the instructor

Research Participants

A total of 46 students participated in our study for 16 weeks. The experimental section, which met on Tuesdays and Thursdays from 12:05-1:25pm, had 28 students, and the control section, which met Tuesdays and Thursday from 3:05-4:25pm, had 18 students. All students gave informed consented to participating in the study; students in the experimental section were given the opportunity to transfer into the control section, although none opted to do so.

As mentioned above, we could not control for students' GPAs coming into each section. Although there was some degree of randomness in that participants did not know they were going to be a part of an experiment when they signed up for the course, we could not randomly assign students to conditions or match participants across conditions based on GPA. In order to make a valid comparison of grades between sections, we needed to verify that the GPAs of each section coming into the course were not significantly different. We obtained the cumulative GPAs of all 46 students coming into the Spring 2005 semester: the average GPA for students in the control section was 2.76 and the average for the experimental section was 2.85. The experimental section's GPA was slightly higher, but the difference was not statistically significant ($p=0.30$).

RESULTS

In this section, we discuss the results of our quasi-experimental study in terms of educational outcomes and students' subjective attitudes.

Educational Outcomes

The experimental section clearly outperformed the control section. On *every* assignment and test, the experimental section's average grades were higher than the control section, as shown in Table 1.

	Control Section	**Experimental Section**
Homework	76	88
Lecture Homework	67	86.12
Project	80.55	87.25
Exams	82.8	86.75
Final Course Grade	79.95	88.23

Table 1 Control and experimental section average grades.

Homework

There were three graded homeworks throughout the semester. One homework asked students to do a keystroke analysis of their cell phones, and the other two involved writing critiques of two other groups' project progress reports. All homeworks were assigned and due at the same times for both sections. On all three homeworks, the experimental group averages were higher than the control group. (have a graph for this, but not real important)

Lecture Homework

Lecture homeworks produced the largest difference in performance between the two sections. Even though LHW questions were based on the exact same set of slides used in the corresponding web lecture or live lecture and each section had the same amount of time to complete them, the experimental section scored significantly higher than the control section. The difference between the averages across all LHWs was statistically significant ($p<0.01$). Figure X below illustrates each section's average LHW grades throughout the semester; data for LHW 7 and 8 had to be excluded because of grading miscommunication between the TAs.

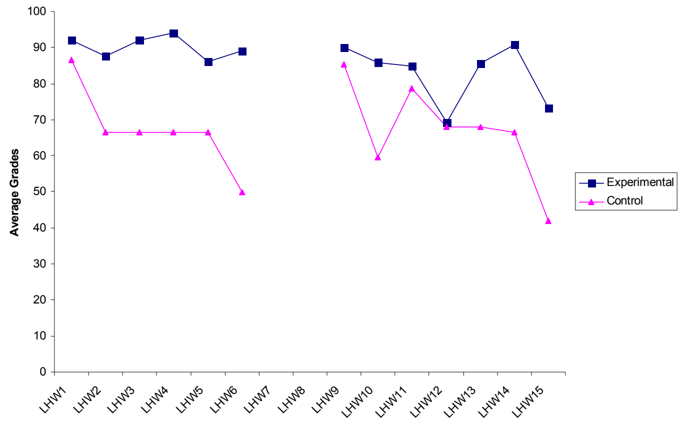


Figure 2 Average LHW grades throughout the semester.

Project

The semester project was divided into four phases throughout the semester. The experimental section's average project phase grades were higher than the control section for all four phases; the difference was statistically significant for phase one ($p<0.01$). Average project phase grades for each section are shown in Fig. 3 below.

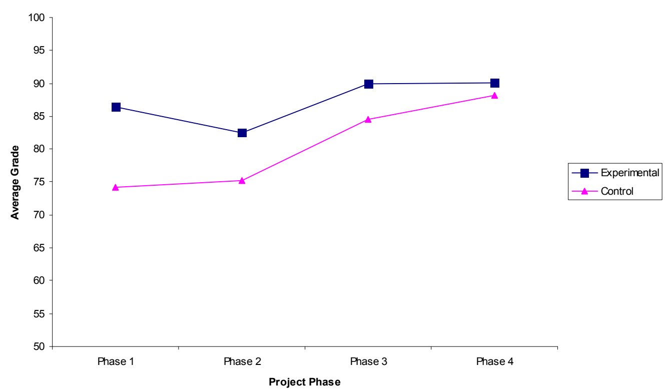


Figure 3 Average project grades for each section.

Exams

On both the midterm and final exams, the experimental section's average grades were higher than the control section. Table 2 below shows each section's grades on the exams and the associated p-values.

	Control Section	**Experimental Section**	**p-value**
Midterm	82	86	0.10
Final	83.6	87.5	0.055

Table 2 Average exam grades.

Final Course Grades

Considering the experimental section's higher grades on all assignments and tests, it is not surprising that their final course grades were higher than the control section. The experimental section average final grade was 88.23, while the control section was 79.95; the more than 8-point difference is statistically significant ($p<0.01$). Because the semester project could not be graded blind like all other assignments, we also compared the final course grades of each section without including project grades. Again, the experimental section's 53.14 average was statistically significantly ($p<0.01$) higher than the control section's 47.70. With or without projects included, the experimental group scored about 10% above the control group. A simple ANOVA of student incoming GPAs and final course grades was insignificant ($F(36,3)=1.791$, $p=0.354$), verifying that the experimental section's insignificantly higher GPA coming into the course was not related to the strongly significant increase in grades.

Subjective Student Attitudes

Subjective data was collected four times throughout the semester with surveys:

- Entrance Survey – administered the first class meeting
- Interim Survey – administered three weeks into the course
- Midway Survey – administered eight weeks into the course
- Exit Survey – administered at the final exam, fifteen weeks into the course

Surveys were given to both the control and experimental sections. The control surveys had questions soliciting students' attitudes toward the course in general and about effectiveness of the LHWs; the experimental section had all the same questions as the control survey, plus questions regarding the web lectures and the new course format. Surveys were primarily 5-point Likert scale questions, with a few open-ended questions. Overall, responses indicated that students in the experimental section were more positive about the course in general, and with successive surveys, they reported increasingly positive attitudes about various dimensions of the web lecture / in-class activities course format.

Attitudes about Web Lectures

In the experimental section, we measured students' perceived usefulness of web lectures from three perspectives: as a way to study for exams, as a way to provide class time for other activities by viewing in advance of class, and as a tool for education in general. Figure 4 shows students' perceived usefulness of web lectures for education in general and for freeing up class time for activities were both positive midway through the semester, and became even more positive by the end of the course. Also, note that the rated usefulness of web lectures to study for exams was somewhat positive midway through, but ended as slightly negative. We saw this same decreasing trend in an earlier study [1]; responses to open questions and focus groups indicated that the decrease was because students felt the web lectures were better to introduce new material than for review.

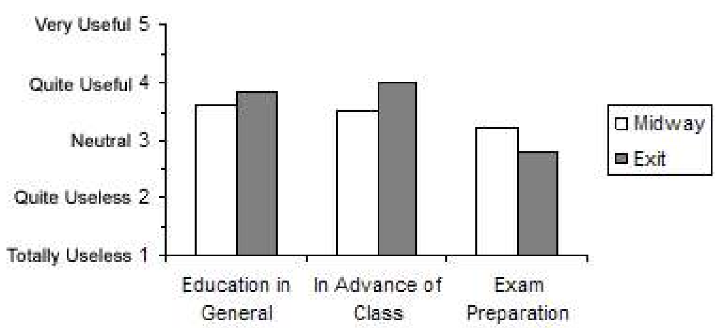


Figure 4 Students' perceived usefulness of web lectures.

We were also interested in perceived usefulness of web lectures in comparison to the other major pedagogical elements of the course. To get at this, we asked students to rank in-class lectures, web lectures, in-class activities, and readings in order of usefulness, where 1 was the most useful and 4 was the least useful. As Figure 5 shows, students ranked web lectures the most useful, in-class activities were second, in-class lectures third, and reading was ranked as the least useful.

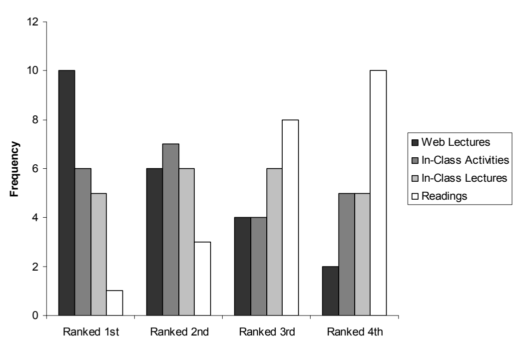


Figure 5 Ranked usefulness of four pedagogical elements.

Attitudes about the New Course Format

Two questions were used to understand students' attitudes about the new web lectures / in-class activities course format. The first question asked students to rate their attitude (scale 1-Very Negative to 5-Very Positive) toward the new course format in comparison to other courses they had taken, and the second question similarly asked students to rate the new course format in comparison to the traditional lecture format (scale 1-Much Worse to 5-Much Better). Figure 6 clearly represents students' increasingly positive attitudes towards our web lecture format; the increase from interim to exit surveys for both questions was statistically significant ($p<0.05$).

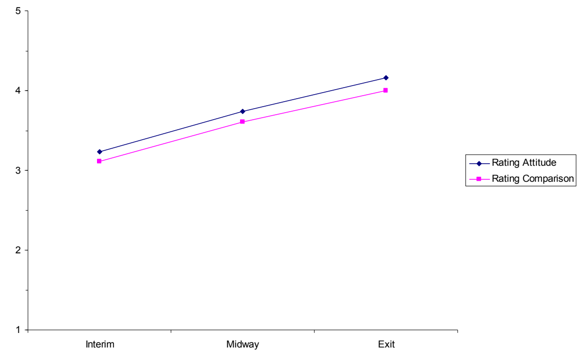
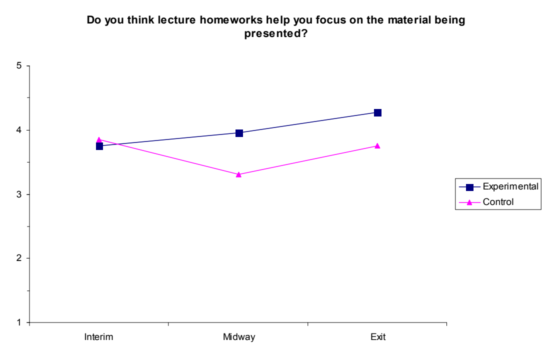
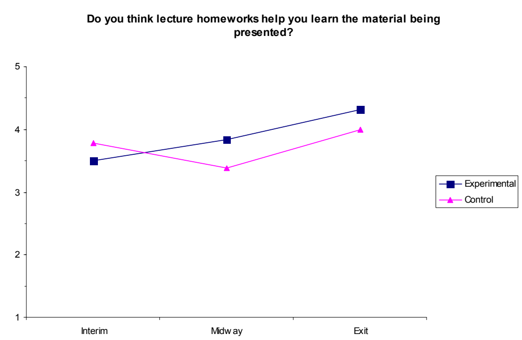


Figure 6 Students' attitudes about the new course format.

Attitudes about Lecture Homeworks

Both sections were asked questions about the effectiveness of the LHWs. We were interested in whether students felt the LHWs helped them *focus* on the material being covered (either in live or web lecture), and whether the LHWs helped them *learn* the material being covered. Interestingly, both sections strongly reported that LHWs helped them focus and learn the material. The control section's attitudes fluctuated throughout the semester, but always stayed positive. The experimental section reported increasingly positive attitudes as the semester progressed; the increases from the interim survey to the exit survey for both focus and learning were statistically significant ($p<0.05$).





Self-reported Learning

On the exit survey, we also asked both sections to compare how much they learned in this course as compared to other courses they had taken (scale 1-Much Less to 5-Much More). On average, both sections reported learning more from this course than other courses. The experimental section, however, reported more positively (Avg: 3.8) than the control section (Avg: 3.4).

Discussion

Students taught using our web lectures / in-class activities format earned significantly higher grades than the traditional lecture format class and reported increasingly strong subjective approval of web lectures, lecture homeworks, and the new course format. At least in the context of a CS4750 course, we believe this quasi-experiment adequately validates our hypothesis that a course taught using web lectures before class in order to free up in-class time for engaging learning activities is as or more educationally effective and enjoyable than a traditional lecture-based course.

FUTURE WORK

The strong positive results encourage further investigation into the idea of using web lectures as a means to free up class time. In this section, we will discuss a few veins of future work, including improvements to the web lecture playback mechanism, investigation of web lecture learning in a controlled lab environment, and further classroom studies in courses other than CS4750.

Web Lecture Playback Mechanism

The ability to stop, fast forward, or rewind playback and to navigate to any point in a web lecture using the table of contents navigation bar are simple examples of technological affordances already provided by our web lecture delivery software, Microsoft Producer [21]. Other related research projects, online communities, and web forums make use of a variety of technological affordances to support collaboration, engagement, and understanding. Examples include discussion forums, links to external resources, integrated interactive activities, and presence indication. We plan to explore which, if any, of these technological affordances may be beneficial additions to the web lecture playback mechanism.

Initially, additions that we think will be particularly beneficial include integrating the LHWs into the actual web lecture (as opposed to paper homeworks), and adding a facility that supports submitting a question during a web lecture. For the latter enhancement, we envision a facility that allows students to simply click a "Submit Question" button at any point during web lecture playback. When the button is clicked, playback will be automatically stopped, and a question submission window will appear with a timestamp automatically recorded. The student could then write their question, and when submitted – either by email or posted to a webpage – the question would have all the information needed for the professor, TA, or other class members viewing the web lecture to address it adequately. With this functionality, the professor could view questions before holding class and be prepared to spend the first part of class addressing them. We also plan to explore integrated discussion forums; various approaches to remote, synchronous web lecture viewing; and the ability to adjust the web lecture playback speed.

Laboratory Experiments

As mentioned above, naturalistic classroom studies like the one we have presented here preclude a certain amount of experimental control. Now that we have seen evidence of the effectiveness of web lectures in the classroom, we are interested in exploring exactly what it is that makes them effective in a more controlled environment. Prior work has suggested that simultaneous presentation across multiple modalities, as compared to presentation with one modality, can improve learning [25, 26]. Could this be one explanation for the improved performance of students using web lectures? We would like to compare learning of participants studying carefully matched, variously "moded" materials. For instance, a short web lecture, just the sound alone of the same web lecture, a passage of reading covering the same topic, etc. We suspect that web lectures are taking advantage of learners' ability to process parallel information channels, while not overloading any one of the processing channels. Audio or reading alone, on the other hand, may saturate a single channel, making such single-modality activities less effective.

Web Lectures in Other Contexts

All of our classroom studies of web lecture use have been situated in one course. A natural next step is to investigate whether or not the web lecture intervention would be as successful in another course as it has been in CS4750. Currently, we are talking with other professors in the College of Computing about recording their own web lectures and at least partially integrating them into their courses. At this time, we have begun planning such an integration into the graduate-level course in information visualization, CS7450. In the future, we hope to also study the effectiveness of web lectures in courses of disciplines other than computer science, and eventually outside of an engineering school.

CONCLUSION

In this paper, we have presented our continuing research into the use of web lectures to enhance the classroom learning experience. Encouraging results from multiple pilot studies motivated a more controlled classroom study in the Spring 2005. In this quasi-controlled study, a control section of the course was taught using the traditional lecture format, and an experimental section was taught using our web lecture / in-class activities format; many measures were taken to ensure a valid comparison of educational outcomes could made at the conclusion of the study. Students in the experimental section scored higher grades on every assignment and exam, and therefore earned statistically significantly higher grades than students in the control section. Moreover, students in the experimental section self-reported learning more from the course than the control students, as well as indicating increasingly strong positive attitudes about web lectures and the new course format. We are further encouraged by these positive results, and plan to continue our research by evaluating enhancements to web lecture delivery, conducting laboratory experiments, and introducing the web lecture intervention into the other courses.

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