INVESTIGATING LEARNING WITH WEB LECTURES

A Dissertation
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The Academic Faculty

by

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INVESTIGATING LEARNING WITH WEB LECTURES

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LIST OF SYMBOLS AND ABBREVIATIONS

LHW	Lecture Homework
PPT	PowerPoint
TOC	Table of Contents
HCCEDL	Human-Centered Computing Education Digital Library
DBR	Design-Based Research
CLT	Cognitive Load Theory
CTML	Cognitive Theory of Multimedia Learning
GTID	Georgia Tech Student ID
VADL	Visual Analytics Digital Library
VAP	Video+Audio+PPT
AP	Audio+PPT
PT	PPT+Transcript
PO	PPT-Only
MCP	Multiple Comparison Procedure

SUMMARY

Learning can be improved when instructors use classroom time to engage students with hands-on activities and other kinds of active learning. However, time and cost constraints, especially in the higher education domain, can make integrating active learning into course curricula a significant challenge. With this dissertation, we have designed, implemented, and rigorously evaluated an inexpensive, easy-to-implement educational intervention that facilitates increased student engagement and active learning. A key technological component of this intervention is web lectures: condensed, studio-recorded lectures made available via the web as multimedia presentations that combine video of the lecturer, audio, lecture slides, and a table of contents. When web lectures are used to replace the traditional in-class lecture, classroom time can be utilized in other more engaging, learning-beneficial ways. This work is not just about *using* web lectures, however; it is also about *making* them with the best combination of modalities (*e.g.*, video, audio, slides, narrative text) and about *technologies* and *pedagogies* that bridge the gap between studying web lectures individually and subsequently applying and extending that lecture material in the classroom.

We explored the effectiveness of this educational intervention using two complementary threads of investigation. First, we used a controlled, experimental study to evaluate individual's learning with web lectures as standalone learning objects. Here, we found that our web lectures are more effective and efficient than other similar educational multimedia presentations. Second, we used longitudinal, naturalistic studies to evaluate the deployed classroom intervention as a whole. With these studies, we found that a course taught using our web lecture intervention produces as good or better student grades and significantly improved perception of learning and satisfaction than a traditionally-taught course. Guidelines for making and using web lectures are provided.

CHAPTER 1

INTRODUCTION

It is becoming generally accepted that increased student engagement and active learning benefit educational outcomes. The National Research Council is frequently cited for recommending that educators provide “active learning environments for all students, even in large section, lecture-dominated courses” (*Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology*, 1999), and the recently-released National Survey of Student Engagement emphasizes that successful completion of college correlates highly with the amount of academic engagement students have—especially but not only for underrepresented students ("Engaged Learning: Fostering Success for All Students", 2006). This laudable goal of improving educational outcomes through increased student engagement and activity, however, is not easily achieved. Successfully implementing the findings educational research—and in particular technology-based research—in real-world practice can be a formidable challenge (*e.g.*, (Berliner, 2002; Burkhardt & Schoenfeld, 2003; Cuban, 2001; Kent & McNergney, 1999; McConnell, 1996)).

Educators have striven to make changes in their teaching practices in response to learning sciences research that indicates students learn much better “by doing” rather than “by listening.” Thus, passive learning—the traditional lecture—has begun to share time in classrooms with more active learning that emphasizes student problem solving, discussion, presentation, and other learning-by-doing activities. At the same time, students continue to need information—facts, concepts, and context—to engage meaningfully in these activities (Bligh, 1998; Bransford, Brown, & Cocking, 1999). In the past, students have acquired this information via the traditional in-class lecture and readings. Therein lies one of the major challenges to increasing educational *efficacy* by integrating more engaged, active learning: With a limited number of in-class contact hours, how can instructors provide students both the information and the activity? This question is even more difficult to address in higher education—where our research is focused—because instructors are often required to teach a large amount of material in a short amount of time.

Cost, in terms of monetary expense and implementation / training / maintenance time, is another factor that can impede educational institutions from integrating more active learning into the classroom. Considering the rapidly increasing cost of education, educational interventions that require significant monetary and/or time investments are less likely to be adopted into practice. Moreover, increasing education costs make any improvements in educational *efficiency* a highly desirable attribute of a potential intervention. For teachers, improved educational efficiency could result in less time spent preparing and giving lectures.

1.1 Purpose of Research and Thesis Statement

The purpose of our research was to design, implement, and rigorously evaluate an inexpensive, easy-to-implement educational intervention that provides opportunities for more active learning and student engagement in the classroom. Thus, we have been studying the effects of moving lectures from the classroom to the web, so that classroom time can be used engaging students with "learning by doing" activities. Our primary goal was to improve the *on-campus* educational experience for students via *better understanding of course material* and *increased positive attitudes* toward their classes. A secondary goal was to decrease the cost of quality on-campus educational experiences. Our focus was on primarily lecture-based undergraduate courses. In the context of this work, a *lecture* is a slide-based (*i.e.*, PowerPoint), predominantly one-way presentation given by an instructor to multiple students. The term lecture can include many other types of instruction; the rather narrow conception used in our work was chosen based on its prevalence in higher education (Bligh, 1998).

Formative work and positive results from a pilot study conducted early in the course of this research led us to an intervention based on what we are calling *web lectures*. There are many forms of lecture-type instructional materials available on the web; for the purposes of this thesis work, web lectures are defined as multimedia presentations that integrate talking head + torso video, audio, lecture slides, table of contents, and navigation controls, which are made available via the web (streaming or download). These are not classroom recordings, with all the distractions of course administration, late-arriving students, *etc.* Rather, they are recorded in a simple, inexpensive studio, with modest effort. Material that would typically be covered in a 50-minute class is covered in a little over half that time in the web lecture. The idea was that when used to replace the traditional classroom lecture, web lectures free up time for in-depth discussion and various hands-on learning activities, and thus potentially increase the effectiveness, enjoyment, and efficiency of already limited contact hours. After much work leading up to this state, the *web lecture intervention* entails students studying a web lecture(s) before and outside of class, completing an associated lecture homework(s) (LHW), and attending class to participate in discussion and application activities based on the material presented in the web lecture(s). The subject matter covered in the assigned web lecture(s) is *not* rehashed in the classroom; rather, it is built upon, contextualized, and applied meaningfully in the class time made available by their use.

Pre-recorded lectures, especially in the context on which we have focused, have been used but not carefully studied (see Section 2.4). Hence, this research was important to establish whether web lectures viewed before class can actually enhance educational outcomes. But, this work was not just about *using* web lectures; it was also about *making* them with the best combination of modalities (*e.g.*, video, audio, slides, narrative text) and about *technologies* and *pedagogies* that bridge the gap between studying the web lecture on one's own and then applying and extending the lecture material in the classroom. Thus, this thesis involved a systematic program of both naturalistic (*i.e.*, classroom) and experimental (*i.e.*, laboratory) research that facilitated extensive investigation of learning with web lectures and development of some initial guidelines for creating and using them.

Our thesis statement is:

Web lectures as standalone learning objects are at least as educationally effective and efficient as similar learning objects. Furthermore, a course taught using the web lecture intervention will produce 1) the same or better objective learning outcomes and 2) the same or better subjective enjoyment and perceived learning, than a course taught using the traditional lecture format.

To address this thesis statement, we collected and analyzed a significant amount of quantitative and qualitative data from multiple classroom-based studies of the web lecture intervention (at various stages throughout its implementation) and one controlled lab study of web lectures as standalone learning objects. The course used in all of our intervention-level deployment studies was an undergraduate introductory HCI course (see Section 3.1), and the web lecture used as part of the lab experiment was one used at the intervention level. The 'similar learning objects' used for comparison in the lab experiment were chosen based on what we considered the most likely changes to web lectures, including the same presentation with audio but no video, the same presentation with textual transcriptions of the narrative but no audio or video, and the presentation alone (*i.e.,* PPT slides only).

1.2 Research Contributions

Our research provides three contributions:

- The design, implementation, and rigorous evaluation of web lectures, both as standalone multimedia learning objects and as part of a classroom-based educational intervention

- Identification of preliminary conditions under which the web lecture intervention improves learning outcomes and student satisfaction
- Initial guidelines for successfully creating web lectures and implementing a web lecture intervention

We believe the work is important in larger senses as well. First, use of web lectures is an evolutionary way to reform how we teach, and may be more readily adopted by institutions and individual educators than more revolutionary approaches. Second, our research indicates that web lectures can be used to decrease the number of hours a teacher meets with a single class while still maintaining or improving educational outcomes and student enjoyment. Thus, web lectures (which are inexpensive and relatively easy to produce) may be able to help slow the rise in higher education costs. Third, we all know that there are good lecturers and poor lecturers. Web lectures provide a way to expose more students to good lecturers, because the lecturer making the web lecture need not be the same as the person who meets students in the classroom. Lastly, the increasing ubiquity of educational multimedia materials (*e.g.*, iTunes U) begs for a better understanding of learning with lengthy, lecture-based multimedia presentations. Findings from our experimental study of learning with web lectures could be beneficial to many other educators when creating multimedia instructional materials similar to web lectures.

1.3 Thesis Overview

In this thesis, we present the design, implementation, and evaluation of our web lecture intervention, an inexpensive, easy-to-implement educational intervention that provides opportunities for more active learning and student engagement in the classroom. As part of this thesis work, we investigated learning with web lectures at the intervention level and as standalone learning objects. This plan of study required extensive evaluation in both the classroom and the laboratory.

Chapter 2 provides background, an explanation of our two-threaded research approach, and discussion of related work. Chapter 3 describes the numerous naturalistic evaluations of learning with web lecture we conducted, including: early formative work to understand the design requirements of web lectures, a semester-long pilot study to understand how to best implement the web lecture intervention, and two semester-long quasi-experiments to rigorously evaluate the efficacy and efficiency of the web lecture intervention. Additionally, Chapter 3 outlines changes made to the web lecture technology in response to student feedback. In Chapter 4, we provide the motivation, design, and results of the laboratory experiment that allowed us to evaluate the efficacy and efficiency of web lectures as individual educational multimedia presentations, outside the context of the larger web lecture intervention. Finally, Chapter 5 summarizes the results of all naturalistic and experimental studies of learning with web lectures, outlines initial guidelines for making web lectures and implementing the web lecture intervention, and discusses additional research currently underway along with potential threads of future work.

CHAPTER 2

BACKGROUND, RESEARCH APPROACH, AND RELATED WORK

In this chapter, we discuss some background, our research approach, and work related to several key areas of learning. In particular, we describe the technology and production details of web lectures, how this research is characterized by the Design-Based Research methodology, and related research that inspired and supports the use of web lectures both as standalone learning objects and as a way to increase active learning in the classroom.

2.1 Web Lecture Technology

Our web lectures are authored using Microsoft Producer (Producer), a plug-in for Microsoft PowerPoint (PPT) 2003. Producer facilitates seamless integration of one video feed, two audio feeds, PPT slides, and static or live web pages. Any or all of these components are brought together with customizable presentation layouts, including an optional table of contents, navigable in real time.

We considered developing our own software and evaluated a number of other commercial authoring tools (*e.g.,* (Accordent), (Apreso), (Articulate), (Breeze), (ConferenceXP), (ScreenWatch), (SofTV), (Tegrity)), but finally decided on Producer for a number of reasons:

- The software was a *free* add-on to Microsoft PowerPoint 2003
- It had the feature set we initially needed right out of the box
- The recording process was straightforward and did not require expensive equipment
- The streaming host infrastructure required was easy to setup and relatively inexpensive

- Students could view lectures from the most ubiquitous browsers and operating system platforms, without requiring them to download additional software
- It was extensible and supported our foreseeable customization needs

For recording, a small studio (Figure 1) was set up with a laptop, digital video camera, microphone, foot mouse, small LCD monitor, and appropriate lighting and background, at a total cost of less than US$3000 (and because the laptop could well be used for other purposes, the incremental cost beyond the laptop is about US$1000). Some details of the recording hardware and set up:

- Microphone: A table-top omni-directional microphone (Crown Soundgrabber II PZM Condenser Microphone) that plugs directly into the camera was used. We experimented with the camera microphone and a lapel microphone, but issues with sound quality and interference prompted us to adopt the table-top solution.
- Slide-advancement mechanism: After trying the laptop mouse and a wireless USB clicker, we ended up using a foot mouse (nXpeds Foot Pedal) to advance the slides during recording. Using the laptop mouse was too much of a distraction, and the hand-held clicker slightly interfered with the presenter's natural hand gestures.
- 'Teleprompter': A 15-inch LCD monitor was placed directly under the camera lens to act as an inexpensive teleprompter for the presenter. The screen simply mirrored the laptop screen, which displayed each PPT slides as it was being discussed. Having the external display directly under the camera lens helped the presenter maintain eye contact with the camera, instead of looking away to see the slides. A real teleprompter would even further support continual eye contact.
- Lighting: Some light in addition to a typical overhead light was needed to create video of adequate brightness. For this purpose, we used two stand lights

(Smith-Victor 10-inch Photoflood Lights) with diffusion filters (one white, one blue). The diffusion filters were needed to make the light a little less harsh.

- Background: A relatively dark background was needed to provide adequate contrast with the speaker. We painted a portion of the wall blue and a few pictures were hung for decoration. However, a simple blue sheet was hung in the background for some recordings, which also worked fine.

Figure 1 Small studio for web lecture recording

Recorded web lectures are published to the web in both streaming and downloadable formats for easy viewing anytime, anywhere. The host infrastructure implemented to stream web lectures is shown in Figure 2. The server machine (stream.cc.gt.atl.ga.us) runs the Winders Server 2003 operating system, which includes Windows Media Services 9. Apache web server software was also installed with the default settings. Client machines connect to our server over the internet simply by clicking on a web lecture link. Once connected, the Apache web server software serves up the HTML pages that makeup most of a web lecture, and Windows Media Services streams the video image of the presenter.

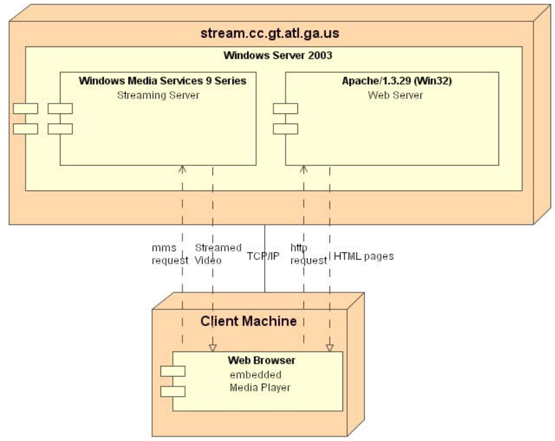

Figure 2 UML Deployment Diagram for the web lecture host infrastructure

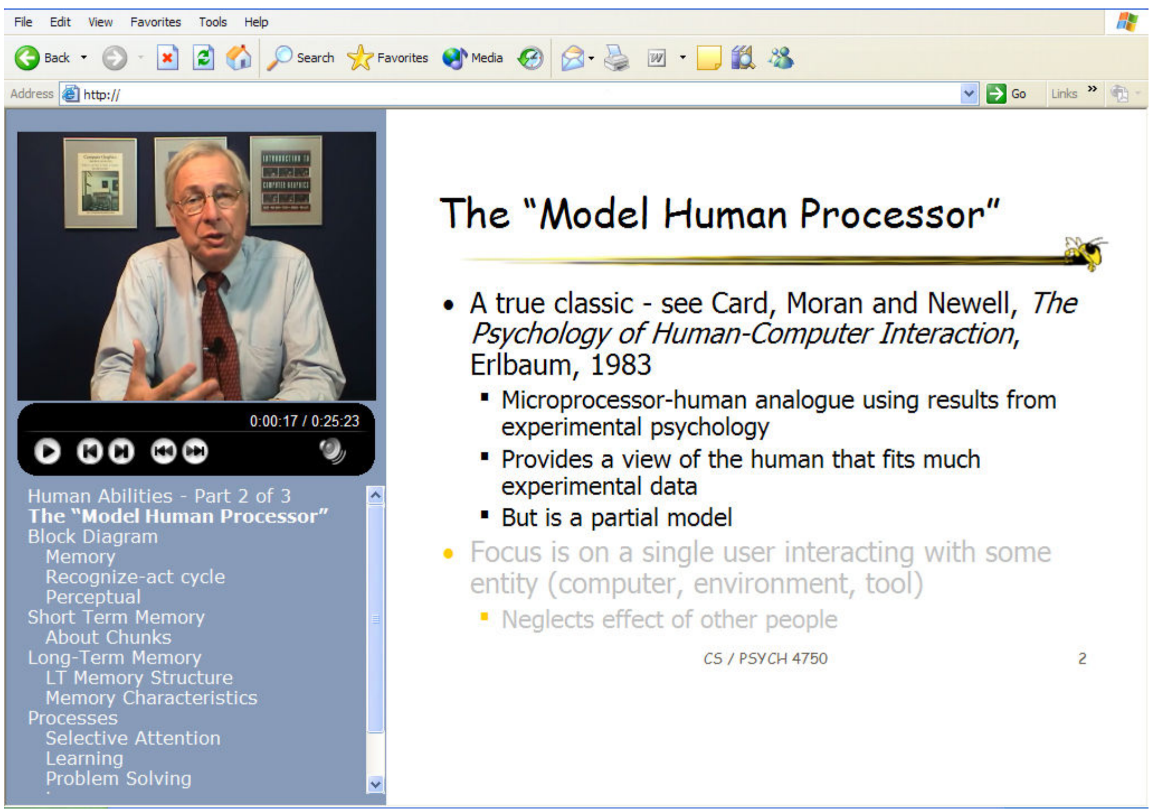

Figure 3 Web lecture playback in a web browser

Figure 3 above 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 Microsoft Windows Media Player. Controls immediately underneath the video are start/stop, forward/backward 10 seconds, forward/backward one slide, and audio volume. The lower left pane is the Table of Contents (TOC), corresponding to the titles on all (or a subset) of the PPT slides. The highlighted (in bold) title is the slide currently being shown at the right of the screen. Titles can be indented, as seen here, to help structure the presentation for the user. Users can skip around in the web lecture by clicking on the TOC entries, causing the appropriate slide, video, and audio to be presented. The right pane is the current PPT slide. To help focus viewers' attention, bullet points on each slide change from light gray to black as they are discussed by the lecturer. This is provided by using simple text color animations within PPT.

During recording, the lecturer uses the aforementioned foot mouse to advance through the slide-level animations and the slides themselves. When advancing a slide, the lecturer consciously pauses speech very briefly just before and after the advancement. This is to ensure navigating through the presentation using the TOC (slide-level indices) is not confusing to the viewer. For instance, if the lecturer speaks through slide advancement, a student jumping directly to a slide might hear the lecturer mid-sentence and need to back up to understand the current point. The slight pauses do not sound out of place in the final recording and do not add any significant amount of time to the presentation.

In fact, we found that recording web lectures in the studio significantly *decreases* lecture duration; a studio-recorded web lecture is usually about 40% shorter than the same lecture given live. We speculate there are a few reasons for this. First, all administrative announcements and other time- and class-specific details are omitted. Web lectures are intended to be reusable learning objects, so we were careful to leave out details that would not be relevant to subsequent uses in the same or other classes, by other instructors, *etc.* Second, no students are present to interrupt the lecture with questions[1], which also naturally cuts down on the time required to give a lecture. Lastly, the "studio" atmosphere naturally reduces the number of tangential topics discussed by the lecturer. In other words, when studio-recording a web lecture, the lecturer naturally sticks to the focal topic.

An attempt is made to keep each web lecture around 20 minutes in length. Even though the recording process naturally decreases the length of time required for lectures, some larger topics still need to be broken up into multi-part series of web lectures to accomplish this. For instance, lecturing on Design Principles in an introductory HCI course usually takes a couple in-class lectures; when recording web lectures for this topic, we divided the subject matter logically into a three-part series, with each part being as close to 20 minutes as possible (Part 1: ~10 min., Part 2: ~23 min., Part 3: ~18 min.). In addition to common sense and feedback from students, keeping web lectures around 20 minutes is good practice because a combination of psychological (*e.g.,* interference with short- and long-term memory processes) and physiological (*e.g.,* arousal and attention effects) factors suggest lecture time after 20-30 minutes is less effective and less efficient (Bligh, 1998).

Published web lectures are made available via the Human-Centered Computing Education Digital Library (HCCEDL) (Clarkson, Day, & Foley, 2006). On the general web lectures list page (Figure 4), web lectures in different formats and related files are linked from one central location for easy access. For each web lecture, the following formats/files are provided:

- Streaming web lecture (by clicking the web lecture title)

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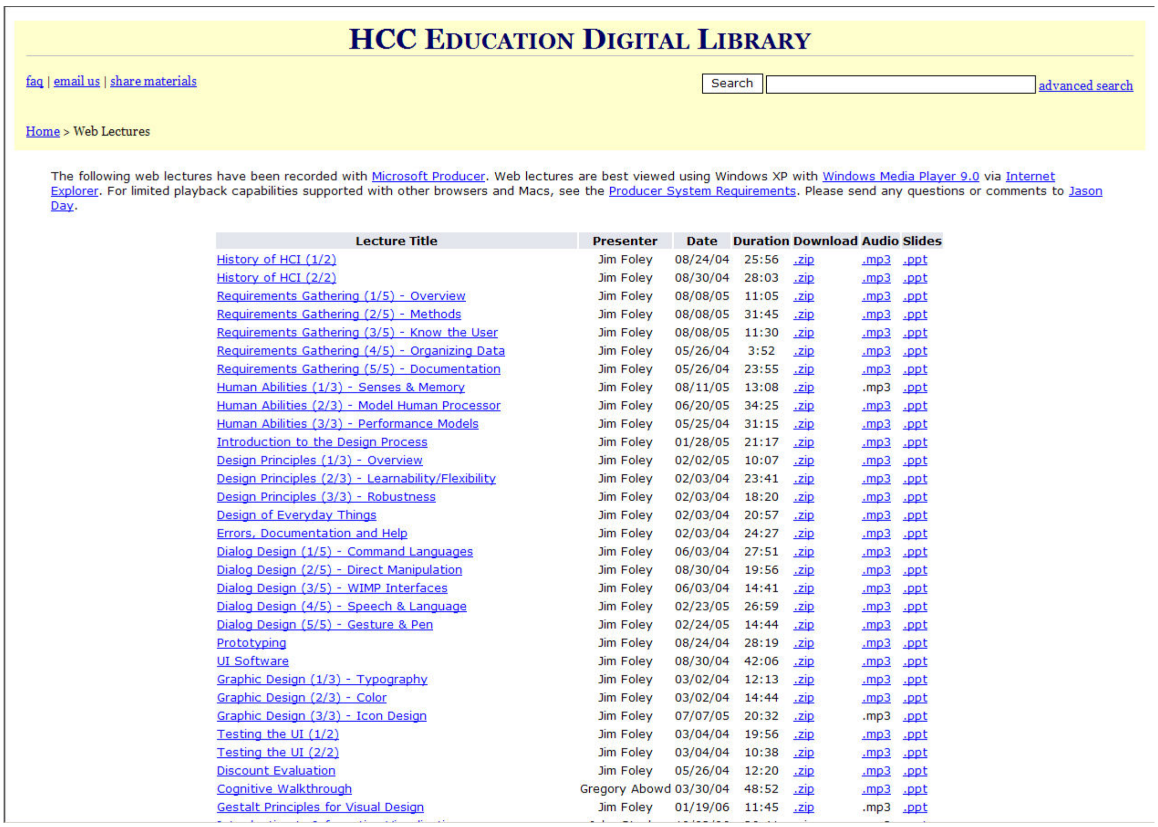
[1] This is a potential negative aspect of web lectures, as discussed in Section 3.5. Also note, however, that time is allotted for student Q & A over web lecture material at the beginning of each class meeting (see Section 3.4).

- A downloadable .zip archive of the web lecture to allow local playback
- An .mp3 file that contains only the audio from the web lecture (for audio playback via iPod or other MP3 player)
- A .ppt file that contains the slides used in the associated web lecture
- Although not live yet, we are working on making an .m4v file available for each web lecture as well, which would enable viewing full web lectures on video iPods.



HCC EDUCATION DIGITAL LIBRARY

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Home > Web Lectures

The following web lectures have been recorded with Microsoft Producer. Web lectures are best viewed using Windows XP with Windows Media Player 9.0 via Internet Explorer. For limited playback capabilities supported with other browsers and Macs, see the Producer System Requirements. Please send any questions or comments to Jason Day.

Lecture Title	Presenter	Date	Duration	Download	Audio	Slides
History of HCI (1/2)	Jim Foley	08/24/04	25:56	.zip	.mp3	.ppt
History of HCI (2/2)	Jim Foley	08/30/04	28:03	.zip	.mp3	.ppt
Requirements Gathering (1/5) - Overview	Jim Foley	08/08/05	11:05	.zip	.mp3	.ppt
Requirements Gathering (2/5) - Methods	Jim Foley	08/08/05	31:45	.zip	.mp3	.ppt
Requirements Gathering (3/5) - Know the User	Jim Foley	08/08/05	11:30	.zip	.mp3	.ppt
Requirements Gathering (4/5) - Organizing Data	Jim Foley	05/26/04	3:52	.zip	.mp3	.ppt
Requirements Gathering (5/5) - Documentation	Jim Foley	05/26/04	23:55	.zip	.mp3	.ppt
Human Abilities (1/3) - Senses & Memory	Jim Foley	08/11/05	13:08	.zip	.mp3	.ppt
Human Abilities (2/3) - Model Human Processor	Jim Foley	06/20/05	34:25	.zip	.mp3	.ppt
Human Abilities (3/3) - Performance Models	Jim Foley	05/25/04	31:15	.zip	.mp3	.ppt
Introduction to the Design Process	Jim Foley	01/28/05	21:17	.zip	.mp3	.ppt
Design Principles (1/3) - Overview	Jim Foley	02/02/05	10:07	.zip	.mp3	.ppt
Design Principles (2/3) - Learnability/Flexibility	Jim Foley	02/03/04	23:41	.zip	.mp3	.ppt
Design Principles (3/3) - Robustness	Jim Foley	02/03/04	18:20	.zip	.mp3	.ppt
Design of Everyday Things	Jim Foley	02/03/04	20:57	.zip	.mp3	.ppt
Errors, Documentation and Help	Jim Foley	02/03/04	24:27	.zip	.mp3	.ppt
Dialog Design (1/5) - Command Languages	Jim Foley	06/03/04	27:51	.zip	.mp3	.ppt
Dialog Design (2/5) - Direct Manipulation	Jim Foley	08/30/04	19:56	.zip	.mp3	.ppt
Dialog Design (3/5) - WIMP Interfaces	Jim Foley	06/03/04	14:41	.zip	.mp3	.ppt
Dialog Design (4/5) - Speech & Language	Jim Foley	02/23/05	26:59	.zip	.mp3	.ppt
Dialog Design (5/5) - Gesture & Pen	Jim Foley	02/24/05	14:44	.zip	.mp3	.ppt
Prototyping	Jim Foley	08/24/04	28:19	.zip	.mp3	.ppt
UI Software	Jim Foley	08/30/04	42:06	.zip	.mp3	.ppt
Graphic Design (1/3) - Typography	Jim Foley	03/02/04	12:13	.zip	.mp3	.ppt
Graphic Design (2/3) - Color	Jim Foley	03/02/04	14:44	.zip	.mp3	.ppt
Graphic Design (3/3) - Icon Design	Jim Foley	07/07/05	20:32	.zip	.mp3	.ppt
Testing the UI (1/2)	Jim Foley	03/04/04	19:56	.zip	.mp3	.ppt
Testing the UI (2/2)	Jim Foley	03/04/04	10:38	.zip	.mp3	.ppt
Discount Evaluation	Jim Foley	05/26/04	12:20	.zip	.mp3	.ppt
Cognitive Walkthrough	Gregory Abowd	03/30/04	48:52	.zip	.mp3	.ppt
Gestalt Principles for Visual Design	Jim Foley	01/19/06	11:45	.zip	.mp3	.ppt

Figure 4 View of the web lectures list page in the HCCEDL

When students click on a web lecture title, they are first presented with a splash screen that provides the title of the lecture, the name of the lecturer, a summary of the lecture, and the duration (Figure 5). Upon selecting the "Play" link, the primary web lecture UI (Fig. 3) appears and the web lecture begins.

Figure 5 Example web lecture splash screen

When used as part of a course, web lectures can be linked directly from the course syllabus hosted in the HCCEDL (Figure 6), on an instructor-generated course web page, or some similar means.

Details for "User Interface Design"

Title:	User Interface Design
Instructor(s):	Jim Foley
Affiliation:	Georgia Institute of Technology
Description:	N/A
Semester:	TuTh, Spring 2007
Course ID:	CS 3750B
Document ID:	435
Textbook(s):	[DOET]: Norman, D.. Design of Everyday Things. 2002. [ID2e]: Preece, J., Rogers, Y. and Sharp, H.. Interaction Design: Beyond Human-Computer Interaction. 0. [ID1e]: Preece, J., Rogers, Y. and Sharp, H.. Interaction Design: Beyond Human-Computer Interaction. 0.
Policies:	N/A

Class No.	Date	Readings	Topics	In-class materials	Assignments	Comments
1	Jan 9	ID1e 1; ID2e 1	Class introduction		Introduce yourself assigned	
2	Jan 11		Group project: Introduction	Project Brainstorming	Introduce yourself **DUE**	
3	Jan 16	ID1e 6; ID2e 9.4	Group project: Groups and Ideas	Groups present project ideas		
4	Jan 18	ID1e 7; ID2e 7	Requirements Gathering (1/5) - Overview Requirements Gathering (2/5) - Methods Requirements Gathering (3/5) - Know the User Requirements Gathering (4/5) - Organizing Data Requirements Gathering (5/5) - Documentation	No class	Requirements Gathering assigned Requirements Gathering assigned Project part 0 - Definition **DUE**	
5	Jan 23	ID1e 9; ID2e 10	Requirements gathering continued	Requirements gathering: Group activity	LHW #1 **DUE** LHW #2 **DUE**	All groups have one well-defined requirements gathering method posted on Swiki
6	Jan 25		HCC Electronic Digital Library activity	Class held in 104A computer lab. Selected teams present requirements gathering plans.	Slides posted to swiki **DUE**	
7	Jan 30	ID1e 3, 14.5; ID2e 3.1, 3.2, 3.3.1, 3.3.3, 15.4	Human Abilities (1/3) - Senses & Memory Human Abilities (2/3) - Model Human Processor	No class	HW B: Cellphone Keystroke Count assigned LHW 3 - Human Abilities 1 assigned	NOTE: As part of LHW 3, you will be posting and answering a question on the Web Lectures Forum
8	Feb 1		Human Abilities (3/3) - Performance Models	No class	LHW 4 - Human Abilities 2 assigned	
9	Feb 6	ID1e 1.6, DOET 1-3; ID2e 3.3.3	Introduction to the Design Process Design Principles (1/3) - Overview Design Principles (2/3) - Learnability/Flexibility	Discussion, Q&A	HW C: Hall of Fame/Shame Nominations assigned LHW 5 - Design Principles 1 assigned LHW #3 **DUE** LHW #4 **DUE**	
10	Feb 8	DOET 4-5	Design Principles (3/3) - Robustness Design of Everyday Things	Discuss LHW #5, live critique	LHW 6 - Design Principles 2 assigned HW B: Cellphone Keystroke Count **DUE** LHW #5 **DUE**	

Figure 6 Web lectures made available in a course syllabus in the HCCEDL

2.2 Design-Based Research

Our approach to understanding learning with web lectures included two complementary threads of investigation: 1) longitudinal, naturalistic studies of learning in the context of a classroom intervention, and 2) experimental studies of individual learning with web lectures as standalone learning objects. Our inquiries are primarily framed by constructivist learning theory (*e.g.*, (Bransford, Brown, & Cocking, 1999; Duffy & Cunningham, 1996)) and cognitive theories of multimedia learning (*e.g.*, (Richard E. Mayer, 2001; Sweller, van Merrienboer, & Paas, 1998)). This integrated research approach is best characterized by the Design-Based Research (DBR) (Collective, 2003) methodology.

DBR—originally conceived of as design experiments by Ann Brown (Brown, 1992) and design science by Allan Collins (Collins, 1992)—is a methodological approach that attempts to examine learning in messy, naturalistic contexts, while also producing evidence-based theoretical claims about learning in those environments. By systematically adjusting various aspects in "engineered" naturalistic settings, DBR attempts to create a type of experimentation that allows researchers to test and generate flexible theory—often in the form of design frameworks, guidelines, and methodologies (Edelson, 2002)—that generalizes to other contexts. DBR strives to both show that a design works and advance theoretical knowledge that is relevant beyond a design exemplar. Thus, embracing DBR requires providing local warrants for the effectiveness of the designed intervention while also attempting to contribute to a larger body of theory, making it a unique research paradigm that advances design, research, and practice (Barab & Squire, 2004). The value of the theoretical contribution is contingent upon the ability of the resulting design principles / guidelines to inform and improve practice: "the theory must do real work" (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003).

DBR's emphasis on deriving practical theory through naturalistic intervention does not obviate experimental lab studies of learning and cognition. Barab and Squire view the two approaches as complimentary, and Brown's original design experiment research program outlined an iterative cycle for naturalistic evaluation followed by traditional lab experiments. McCandliss *et al.* have actually criticized research programs that claim to be conducting DBR for not adequately integrating the lab-based portion of the research cycle that was integral to Brown's vision of design experimentation (McCandliss, Kalchman, & Bryant, 2003). Productively linking lab studies to local fieldwork can help identify relevant contextual factors and mechanisms of learning, and can contribute to better understanding of the intervention itself. For example, in the CoMPASS project naturalistic studies revealed learning benefits from students' use of conceptual representations, and lab studies helped identify some low-level features that affected students' use of the representations (Puntambekar & Stylianou, 2002).

Bell addresses the mixed-method nature of DBR by characterizing it as a high-level methodological orientation that can be used within/across various research traditions and theoretical perspectives, with the aim of maintaining a tight relation between design and research (*i.e.*, intertwining of everyday practice and theory production) (Bell, 2004). Bell acknowledges the influence of epistemological and theoretical orientations on design and research (*cf.* (Burrell & Morgan, 1979; Hirschheim & Klein, 1989)), but argues that to understand and/or design for complex human phenomena—which occur at the individual, social, cultural, *etc.* levels—theoretical and methodological pluralism is necessary. Such phenomena require investigations at many levels and are too complex to be understood by assuming only one theoretical perspective sufficiently characterizes them. Consequently, Bell argues, like Greeno *et al.* (Greeno, Collins, & Resnick, 1996), that a DBR approach supports the theoretical breadth to embrace aspects of behaviorist, cognitive, and socio-historic learning perspectives, and that educational phenomena often require multiple research and design methods to study and understand them.

More recently, Wang and Hannafin (Wang & Hannafin, 2005) have described DBR as a paradigm that encompasses research approaches alternately labeled as design experiments (Brown, 1992), design science (Collins, 1992), design research (Collins, Joseph, & Bielaczyc, 2004), development research (van den Akker, 1999), developmental research (Richey, Klein, & Nelson, 2003), and formative research (Reigeluth & Frick, 1999). As a summary of all these approaches, they define DBR as:

> a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories (Wang & Hannafin, 2005).

Wang and Hannafin also outline five basic characteristics of DBR: pragmatic; grounded; interactive, iterative, and flexible; integrative; and contextual. We briefly address how this work adheres to each of these characteristics. First, our work is *grounded* in relevant research and framed by constructivist and cognitive load-based theories of learning (see Section 2.3). Second, our research is *interactive, iterative, and flexible* in that we work very closely with practitioners and students, formative analyses are open-ended to allow for on-the-fly changes in response to instructor/student feedback, and multiple implementations were studied so that successive improvements to the intervention could be evaluated. Third, complementary naturalistic and experimental studies were conducted as part of our *integrative*, mixed-method approach. Fourth, the *contextual* nature of this work is evident in the well documented classroom studies we have conducted, and our aim to extract implementation guidelines to help practitioners apply our work in other educational settings. Lastly, the *pragmatic* characteristic of DBR requires design and theory to be synergistically developed throughout the research process; in addition to testing *whether* an intervention works, researchers must also assess *how well* an intervention works in terms of practical improvements (*e.g.*, efficacy, efficiency, appeal) (Reigeluth & Frick, 1999). Both of these aims are at the heart of our research and are evident in our thesis statement and contributions outlined in Chapter 1.

Our work designing, implementing, and evaluating learning with web lectures both independently and as part of a larger classroom intervention required us to conduct research in inherently complex educational settings. DBR offered a means to manage that complexity. Moreover, our goal to develop an inexpensive, easy-to-implement intervention is rooted in the desire to contribute a practical way for educators to increase the amount of time they have to engage students in active learning; this emphasis on informing and improving real-world practice is another reason DBR is a particularly appropriate methodology for our research.

2.3 Motivating Web Lecture Use

In light of contemporary learning theory, the traditional one-to-many lecture still prevalent in most classrooms is arguably not the most educationally effective. This statement can be attributed largely to the inherent lack of learner engagement in such passive lecture settings. Often, the problem is not that instructors do not want to foster learner engagement; rather, instructors simply do not have time to do so while also covering all required course material (Duffy & Kirkley, 2004).

This is not to say that lectures do not have a place in education. Bligh (Bligh, 1998) surveyed the literature for studies on lectures[2] and concluded that—along with being the *dominant* teaching method—lectures are an *effective* method in terms of *information transfer* (*e.g.,* providing a subject matter framework, conveying facts and concepts). However, lecturing alone is often not sufficient to stimulate deep thought and actively engage students. Thus, while acknowledging the time constraint challenges, Bligh argues that lectures should be used to facilitate acquisition of information by students, and other methods should be integrated into curricula to encourage meaningful engagement with that information.

Our goal, therefore, is to take advantage of the opportunities and technological affordances of web lectures in order to decrease the in-class time spent on information transfer and increase the in-class time available for more engaging learning activities that facilitate learners' active knowledge construction. In doing so, we considered the educational effectiveness of both components of this approach: Web lectures as a way to provide students with background knowledge of the material, and in-class activities for learner engagement with the material.

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[2] Bligh defines lectures as "more or less continuous periods of exposition by a speaker who wants the audience to learn something" (Bligh, 1998).

2.3.1 Web Lectures as Standalone Learning Resources

Edgar Dale's Cone of Learning (Dale, 1969) suggests the least retentive learning method involves learning through passive information presented through verbal symbols (*i.e.*, listening to spoken words: lectures), the most retentive learning method involves the student actively participating in hands-on learning activities, and retention from multimedia presentations falls in the middle. This suggests that students viewing web lectures should retain at least as much as students listening to traditional lectures. Obviously, retention is not the sole indicator of learning effectiveness, but it is one important aspect when considering a lecture delivery mechanism.

Much previous research suggests that using recorded lectures in distance learning contexts produces "no significant difference" (Russell, 1999) 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 support our use of web lectures as a learning resource. We believe that the most beneficial way to use web lectures is when they are carefully coordinated with regular classroom meetings, as a way to *augment* the classroom experience. *This is in marked contrast to the distance learning approach of using web lectures to completely replace the classroom experience*, and is more in the spirit of blended e-learning approaches emerging in the corporate training domain (Bersin, 2004; Bielawski & Metcalf, 2002; Thorne, 2003).

Although blended e-learning—alternatively called blended learning and hybrid learning—is more similar to our approach than distance learning, it still does not adequately characterize what we have implemented with the web lecture intervention. Blended learning attempts to create cost and time efficient training programs by integrating e-learning (*i.e.*, online learning resources, computer-based training) and face-to-face (F2F) learning (*i.e.*, on-the-job training, mentoring, coaching, classroom instruction). Most blended learning programs rely predominantly on the e-learning component, while the F2F component is often secondary and in the form of on-the-job training (Bersin, 2004; Bielawski & Metcalf, 2002; Thorne, 2003). Although there has been a recent trend to increase the amount of classroom instruction given as part of blended learning programs (Wilson & Smilanich, 2005), our web lecture intervention differs significantly from blended learning approaches in that it keeps the classroom as its primary focus (*i.e.*, a vast majority of instruction time is F2F). Another major difference lies in what we refer to as the *cycle time* between learners' exposure to e-learning and F2F components. Cycle time, in other words, refers to the frequency at which e-learning and F2F instruction are interleaved. Thus, most blended learning programs have long cycle times, because all or most of the e-learning component is administered and then followed by all or most of the F2F component, or vice versa. The cycle time of the web lecture intervention, on the other hand, is very short: the e-learning component (*i.e.*, web lectures) is interleaved with the F2F component (*i.e.*, regular class meetings) on an almost one-to-one basis. This tight integration of both online and in-class instruction allows us to take full advantage of the affordances of each learning environment. With the exception of some of the research projects discussed in Section 2.4, blended learning approaches implemented in academic settings (Dean, Stahl, Sylwester, & Peat, 2001; DeLacey, 2002; Houdeshell, Pomeranz, & Giguere, 2004; Oliver, 2005; Rivera & Rice, 2002) exhibit similar differences when compared to the web lecture intervention.

Obviously, teaching courses with a significant online component is not new, yet theoretical frameworks and empirical evidence addressing many research questions are limited (Tallent-Runnels et al., 2006). In light of this, Tallent-Runnels *et al.* suggest looking to research in related areas when designing studies to investigate such learning environments. In particular, they recommend looking to models and guidelines developed in multimedia learning research (Tallent-Runnels *et al.*, 2006). For inquiries into learning with web lectures, we have found two such theoretical frameworks particularly useful: Cognitive Load Theory and the Cognitive Theory of Multimedia Learning.

2.3.1.1 Theoretical Guides for Structuring Web Lectures: Cognitive Load Theory and the Cognitive Theory of Multimedia Learning

Cognitive Load Theory (CLT) considers how the interaction between cognitive architecture and information structures can inform instructional design. Four basic assumptions are made about cognitive architecture in CLT (Chandler & Sweller, 1991; Sweller, van Merrienboer, & Paas, 1998):

1. We have a very limited working memory.
2. We have an effectively unlimited long-term memory.
3. Our primary learning mechanism is schema acquisition; schemas are cognitive constructs that allow us to categorize multiple elements of information into a single element with a specific function.
4. We can effectively bypass working memory limitations through automation of schema use and other cognitive processes.

The information structures we interact with have different levels of elemental interactivity that affect how difficult it will be for us to learn any given material. Learning low-elemental interactivity material will not depend on other elements, while learning high-elemental interactivity material requires understanding of multiple inter-dependent elements. Paas *et al.* use learning a photo-editing program as an example (Paas, Renkl, & Sweller, 2003). Learning the effects of various function keys is an example of low elemental interactivity, because each element can be understood without reference to any other elements. Learning to edit a photo, on the other hand, is an example of high elemental interactivity; although the relevant elements can be learned independently (*e.g.*, color tone, darkness, contrast), these elements interact and must be processed simultaneously to be understood.

CLT posits three different types of cognitive load on working memory: intrinsic, extraneous, and germane. Intrinsic cognitive load is directly proportional to elemental interactivity and therefore cannot be altered by instructional design for a given learning task. Omitting interacting elements to form a simpler, *different* learning task (*e.g.* simple-to-complex approach) is perhaps one way to reduce this load. Extraneous cognitive load refers to unnecessary working memory demands imposed by the way material is presented or the learning activities required (*e.g.*, spatially or temporally separating text from illustrations forces learners to hold information in working memory to make sense of each). Finally, germane cognitive load is load incurred when learners are devoting working memory to the beneficial process of schema acquisition and automation (*e.g.*, instructional techniques such as example variation and prompting imagination can facilitate learners' schema acquisition and automation). Both extraneous and germane cognitive load can be influenced by instructional design, but extraneous load interferes with learning whereas germane load aids learning. These three cognitive loads are additive; total cognitive load must be below working memory capacity to facilitate learning. Thus, for a task with a given intrinsic load, the goal of the instructional designer is to reduce extraneous load to free up working memory available for germane load. For instance, studies by Mousavi *et al.* indicate that extraneous cognitive load can be reduced by designing instructional materials that make use of both auditory and visual presentation modes (Mousavi, Low, & Sweller, 1995).

The Cognitive Theory of Multimedia Learning (CTML) (Richard E. Mayer, 2001) developed by Richard Mayer recognizes the impact of cognitive load on working memory as posited by CLT, and goes on to propose how learners actively construct knowledge while studying multimedia materials. For CTML, multimedia materials consist of both words and pictures, and presentations can be either book-based (*e.g.*, text and diagrams) or computer-based (*e.g.*, audio narration and animation). CTML research is concerned with determining the conditions under which multimedia materials are most likely to promote meaningful learning. The theory relies on the following assumptions:

1. The dual channel assumption: the human information-processing system consists of an auditory/verbal channel and a visual/pictorial channel. This assumption is based on a combination of Baddeley's (Baddeley, 1998) working memory model for auditory and visual processing (*i.e.*, sensory modalities), and Pavio's (Paivio, 1986) dual code theory for verbal and pictorial knowledge processing (*i.e.*, presentation mode).
2. The limited capacity assumption: each channel (auditory/verbal and visual/pictorial) has a limited capacity for cognitive processing.
3. The active processing assumption: a substantial amount of cognitive processing in each channel is required for learning to occur, which includes attending to the material presented (select), organizing the material presented into a coherent structure (organize), and integrating the presented material with existing knowledge (integrate).

Mayer distinguishes among three types of cognitive load that are loosely equivalent to those put forth by CLT: representational holding (intrinsic load), incidental processing (extraneous load), and essential processing (germane load). Mayer and Moreno have outlined nine ways to reduce cognitive load in multimedia learning (Richard E. Mayer & Moreno, 2003). For example, Mayer and Moreno suggest 'off-loading' when one channel is overloaded with essential processing demands. If one channel is overloaded, some of the load in that channel can be off-loaded onto the other channel for more efficient processing. An example of this in practice—referred to as the 'modality effect'—suggests students learn better when words are presented as audio narration with an animation as opposed to on-screen text with an animation.

We conducted an analysis of our web lectures with respect to the CTML design guidelines (*i.e.*, effects) produced by Mayer and Moreno, and found they measure up well:

- Modality effect (Richard E. Mayer & Moreno, 2003): the presenter's words are presented as audio narration, as opposed to on-screen text transcription—moving some essential processing from the visual to the auditory channel
- Multimedia effect (Richard E. Mayer, 2001): learners receive words and pictures (supporting diagrams in the PPT), as opposed to words alone—facilitating construction and connections between verbal and pictorial mental models
- Segmentation effect (Richard E. Mayer & Moreno, 2003): content is presented in learner-controlled segments, paced by the learner instead of presented as a continuous unit—helping avoid working memory overload by breaking material up logically (PPT divisions) and allowing individual control (playback controls and navigable TOC)
- Signaling effect (Richard E. Mayer & Moreno, 2003): PPT bullet animations and presenter gestures provide cues for how to process the material—reducing extraneous load
- Temporal contiguity effect (Richard E. Mayer & Moreno, 2003): audio and visual elements are presented simultaneously rather than successively—minimizing need to hold representations in memory
- Personalization effect (Roxana Moreno & Mayer, 2000): the presenter speaks in 1st and 2nd person conversation style, rather than 3rd person—helping learners relate material to personal experiences, reduce processing effort needed to make sense of the material, and promote mental interactions in active understanding
- Voice effect (Richard E. Mayer, 2005): the presenter speaks in a standard-accented human voice—facilitating deeper learning as compared to presentations narrated by machine voice or foreign-accented voice

Some aspects of web lecture design do not adhere to multimedia instructional guidelines. For instance, although PPT text is not a direct transcription of the presenter's narration, it could be argued that it is redundant information (*i.e.,* the redundancy effect

(Richard E. Mayer, 2001)), which could overload the visual channel and reduce resources available to select/organize/integrate other relevant information. However, Mayer notes that the redundancy effect may not apply to lecture-style presentations where notes or outlines (like those provided with PPT text) could aid learner processing (Richard E. Mayer, 2001). Also, it could be argued that the video of the presenter—in addition to also possibly overloading the visual channel—does not add instructional value, and in fact adds an extraneous material that competes with the PPT text and diagrams for cognitive resources (split-attention (Kalyuga, Chandler, & Sweller, 1999) or coherence (Richard E. Mayer, 2001) effects). In studies of animated pedagogical agents (which are similar to our video) in multimedia materials, however, no evidence has been found for the split-attention effect caused by the agent (Craig, Gholson, & Driscoll, 2002; Roxana Moreno, 2005).

Because they take advantage of both auditory/verbal and visual/pictorial modalities/modes of information presentation (*e.g.*, video, audio, diagrams, and PPT text) and adhere to many of the other CLT/CTML guidelines, we hypothesize that our web lectures are as or more educationally effective and efficient than similar methods of information presentation (*e.g.*, PPT, text, *etc.*) that may be overloading one channel or the other. This claim is addressed in the multimedia learning experiment discussed in Chapter 4.

2.3.2 Engaging Students in the Classroom

When a large portion of the lecture material is covered before class, much more in-class time is available to engage learners with the hands-on experiences suggested by Dale and other subsequent educational researchers. Duffy and Cunningham (1996), for instance, argue that educational approaches based on constructivist learning theory are more effective than traditional transmission models of instruction. Constructivist theory (Bransford, Brown, & Cocking, 1999) suggests that learning is best achieved by facilitating students' active construction of knowledge in meaningful contexts. Social interaction in participatory knowledge construction activities also plays a critical role in cognition and the process of learning (Lave & Wenger, 1991; Vygotsky, 1978). Constructivist-inspired learning environments often involve learners participating in open-ended, learner-centered activities that involve practical, meaningful application of the concepts of interest; collaborative problem solving and opportunities for public/personal articulation and reflection are also important.

One common misconception about constructivist models of instruction is that there is no place in them for listening to lectures or reading texts (Bransford *et al.*, 1999). Active knowledge construction—the foundation of constructivist learning theory—can occur whether learners are physically participating in unconstrained discovery or sitting still listening to a lecture or reading a book; constructivist models support building new knowledge from many sources, including everything from lecture and reading to application activities. Although lectures and reading can be included in constructivist-inspired instruction, alone they typically do not provide adequate support for learners' knowledge construction.

Schwartz and Bransford presented an integration of activity and lecture/reading that directly addressed the constructivist concern for what kinds of activities are most effective for helping students construct new knowledge for themselves. They investigated the use of a "discovery" activity (analysis and generation of contrasting cases) as a precursor to "telling" (listening to lecture or reading text). The basic claim was that "deep understanding requires both a differentiated knowledge structure (as develops when discerning the contrasts among cases) and an explanatory structure (as often comes through telling)" (Schwartz & Bransford, 1998). Schwartz and Bransford compared transfer learning[3] with students who completed an analysis activity followed by lecture (discovery + telling), completed two analysis activities (double discovery), and completed a text summary followed by lecture (double telling). A telling + discovery condition was not tested. Results strongly indicated that students learn more transferable knowledge in the discovery + telling condition than the other two conditions. Schwartz and Bransford attributed this improved learning to an increase in differentiated knowledge acquired (via discovery activity) prior to hearing a lecture. Thus, the discovery activity created a more effective "time for telling" (Schwartz & Bransford, 1998).

The web lecture intervention is in the same spirit as the discovery + telling instructional model proposed by Schwartz and Bransford, except it is more adequately characterized as telling + discovery (*i.e.*, "a time for application"). Instead of preparing student for lecture with activity, our approach prepares students for activity with lecture. Web lectures and normal text readings provide conceptual background knowledge to students before class, which is then reinforced and further contextualized through in-class discussion and application activities. This model offers a new way of integrating lecture and reading with activity, which helps learners build knowledge for themselves more effectively than either approach alone.

Again, with more in-class time made available by having students study web lectures, many opportunities arise to integrate constructivist-inspired learning activities into a course. It is reasonable to assume that students can better engage with the material when they come to class with a basic knowledge of it. Moreover, students can collaborate more effectively when everyone comes to class equipped with the knowledge necessary

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[3] Schwartz and Bransford were not saying learners need to analyze contrasting cases to learn from lecture. Rather, they were saying the discovery activities help produce more expert-like differentiated knowledge, which is better assessed using transfer tests as opposed to retention (verification) tests.

to support higher-level application (Duffy & Kirkley, 2004). 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 meaningful learning activities.

2.4 Studies of Alternative Lecture Delivery

Research into the use of recorded video material in the classroom dates back to the 1970s. Gibbons at Stanford University conducted a seminal study on Tutored Video Instruction (Gibbons, Kincheloe, & Down, 1977). This research found that when remote students watched recordings of live lectures in small (3-10 person) groups with a facilitator (tutor) present to periodically pause and prompt discussion, remote students typically outperformed the students who attended the live lectures. Similar findings were reported by Sox and others when using the TVI approach (Sox, Marton, Higgins, & Hickam, 1984).

Since the 1970s, technological developments, especially the ability to stream video over the internet, have brought new ways to apply Gibbons' results. For example, other researchers have followed up on Gibbons *et al.*'s TVI experiments by examining the TVI approach when remote viewers were distributed in space (DTVI) (Cadiz et al., 2000; Sipusic et al., 1999). These studies found that grades for TVI and DTVI students were about the same, and in-class lecture students' grades were significantly lower than both TVI and DTVI students. The web lecture approach also leverages recorded lecture material and facilitated discussion, except students remotely view web lectures (without a tutor) before convening in the classroom, where more time is available for class and small group discussion and participation in the context of related application activities.

When integrated effectively with other pedagogical methods, the affordances of video for learning can be extremely beneficial. For instance, in a physiotherapy program at the University of Birmingham significant increases in enrollment made class video viewing and actual patient observation infeasible, so the program was redesigned with a blended learning approach (Davies, Ramsay, Lindfield, & Couperthwaite, 2005). In the redesigned courses, students viewed patient video clips made available via CD-ROM and then attended class regularly to discuss diagnoses. This design allowed instructors to teach students the observational (via video) and analytical (via classroom discussion) skills required in clinical practice. Davies *et al.* made an informal judgment that student learning outcomes improved and reported results of a survey (N=82) and four focus groups (N=17), the major qualitative findings of which were that students enjoyed the mixed use of video observation and classroom analysis and appreciated the flexibility offered by the video medium. In particular, students noted that the ability to repeat segments of patient movements—something that is difficult or impossible to with real patients or when viewing a video in a class of 90+ people—was especially beneficial to improving observational skills.

Several studies of recorded lectures similar to our web lectures have been conducted, but many are highly technology-centric, and there are few quantitative results. Also, in most cases, the way in which the lectures were recorded, accessed, or integrated into course curricula differs from our use. For instance, Moses *et al.* (Moses, Litzkow, Foertsch, & Strikwerda, 2002) studied the use of studio-recorded online lectures at the University of Wisconsin with large-enrollment computer science courses for engineering students. Two of the three weekly class meetings were dropped and replaced by online lectures, thereby serving as a means to economize large-enrollment education. Subjective measures of 531 students over two semesters indicated an appreciation for the convenience and control afforded by the online lectures, along with some concern that this approach required more self-discipline. However, Moses *et al.* did not report any effects on students' grades or other learning outcomes.

The eClass project (Abowd, 1999; Brotherton & Abowd, 2004) at Georgia Tech recorded audio and video from live in-class lectures, aggregated with presentation slides, the instructor's annotations, and visited websites. These materials were available on the web and were used primarily for review and secondarily by students who missed a class. In contrast, our primary use of web lectures is prior to class, but they can be used for review as well. Although students made significant use of eClass in over 90 courses and reported positive attitudes, performance as measured by grades was not significantly affected.

A similar lecture delivery system, the InterLabs Web-lecturing tool, was developed and evaluated in an introductory Computer Information Systems (CIS) course at Bradley University (Uskov, 2002, 2003). The InterLabs Web-lecturing tool supports synchronous/asynchronous delivery of lecture audio and video, along with various computer-mediated communication facilities (*e.g.*, video conferencing, instructor/class email, news groups). Over a period of three successive semesters the CIS course was taught using three different formats: a traditional course format (without the Web-lecturing tool); a fully online format using the Web-lecturing tool; and a blended course format in which all lectures were delivered via the Web-lecturing tool, but the TA/instructor held face-to-face office hours and exams were taken in a classroom. Uskov reported descriptive statistics indicating that students earned higher grades in the online format over the traditional format and in the blended format over both traditional and online formats (*i.e.*, blended > online > traditional). However, the methodology of the study and the statistical analysis were not reported, making the validity of the comparisons questionable. A study with another related system, the Video Jockey (Meyer, Niessen, & Reuther, 1997), found similar results, but suffered from the same lack of methodological rigor.

Finally, Oliver and others stress the need for internet-based learning environments to make better use of technological affordances in order to create more active learning opportunities (Oliver, 2001; Oliver & Omari, 1999), but have neither qualitative nor quantitative data to support their claims. We do note that their motivation is similar to ours—to facilitate more active learning environments—however, their focus is on pure internet-based learning environments, whereas our focus is to facilitate more active learning through the combined use of internet and in-class learning environments. On the other end of the spectrum, a significant amount of research is being conducted with tablet PCs and pen-based technologies in general to facilitate more active learning during in-class lectures. Examples of this work include systems such as DEBBIE / DyKnow (Berque, Bonebright, & Whitesell, 2004; Berque, Johnson, & Jovanovic, 2001), Classroom Presenter (Anderson et al., 2007; Anderson et al., 2004), and Ubiquitous Presenter (Griswold & Simon, 2006; Wilkerson, Griswold, & Simon, 2005), all of which—among many other functions—allow instructors to electronically distribute, collect, selectively (and anonymously) display, and discuss various types of student activities. Numerous evaluations (including more than 1,500 students) of these systems' use have indicated strongly positive attitudes from both students and instructors, but again the impact on learning outcomes as measured by grades is rarely reported; of the 21 papers that came out of the first Workshop on the Impact of Pen-based Technology on Education, only three of included grade analysis as part of their evaluation (Berque, Prey, & Reed, 2006).

Not surprisingly, the rigor of research designs in this space has been called into question. Tallent-Runnels *et al.* surveyed the literature for studies on learning in courses with a significant online component and concluded that most studies are descriptive and exploratory, lacking the inclusion of control groups and adequate measurements for variables of interest (Tallent-Runnels *et al.*, 2006). This thesis work was designed to avoid such methodological pitfalls; classroom and laboratory studies were as rigorous as possible for the observation environment (*i.e.*, for the classroom studies, we controlled for as many factors as possible without sacrificing the naturalism of the learning environment).

CHAPTER 3

NATURALISTIC INVESTIGATIONS OF LEARNING WITH WEB LECTURES

In this chapter, we present the primary context in which our web lectures were studied, a summary of formative work and the first quasi-experimental classroom study, a discussion of the changes to the web lecture interface that resulted from feedback during initial classroom deployments, details of the second classroom quasi-experiment, and a summary of the findings from all of our naturalistic investigations of the web lecture intervention.

3.1 CS3750 User Interface Design

CS3750 User Interface Design is an introductory HCI course for junior- and senior-level undergraduate students at Georgia Tech. Although the majority of students who take the course are computer science majors, the course is cross-listed with the psychology department, so students from a range of other disciplines (*e.g.*, psychology; computational media; science, technology and culture (STAC); industrial design, *etc.*) enroll as well. Enrollment is typically 25 to 35 per class. The standard curriculum schedules 30 bi-weekly class meetings of 80 minutes each. The class is heavily project-based, with student teams completing a semester-long design project that entails an extensive requirements gathering and task analysis, prototype design and implementation, and some light evaluation. Students also complete several short homework assignments and are assigned weekly readings. When taught traditionally, 25 of the 30 class meetings are lecture, and the other five are reserved for a mid-term exam and project presentations. Assessment is based on the homeworks, the design project, and mid-term and final exams. Midterm and final exams are a combination of short answer and essay questions that assess retention and transfer knowledge of material from lecture, readings, and project work.

This introductory HCI course was the primary context for our classroom studies. It was selected based on the research team's expertise in the HCI domain, access to multiple sections of the course, and the ability to have a member of the research team (Professor Jim Foley) teach the course on a regular basis. After a formative evaluation of web lectures (Section 3.2), the course curriculum was redesigned to take advantage of the classroom time being made available by web lectures (Section 3.3); being domain experts made it easier for us to create educational and exciting in-class activities that built on material covered in the web lectures. Because of the tight relationship between theory and application, HCI education proved to be an ideal domain in which to study our web lecture intervention. Consider, for example, ethnographic interviewing—with our approach, students learn the theory behind and basic strategy used to conduct such an interview in a web lecture before class, and then have an opportunity in class to put the knowledge to use by participating in mock interviews with classmates and the instructor.

3.2 Formative Evaluation of Web Lecture Use

To obtain some experience with producing and using web lectures, we conducted an informal formative evaluation during the Fall 2003 semester. Web lectures were shown in two class periods—one with the instructor present and one with the teaching assistant (TA) present—each followed by a survey.

The surveys indicated that there is a definite minimum threshold for the production quality of web lectures, but students did not feel professional production quality was necessary. In fact, students commented that professional production quality would make them feel like they were watching an educational television program, and that they actually preferred a slightly more informal production that felt more like a lecture from a familiar instructor. The only major concern, audio quality, was immediately addressed with a higher quality microphone and more effective microphone placement during recording (the table-top omni-directional microphone mentioned in Section 2.1).

Students' initial response to the web lectures was mixed. A majority of students reported that the in-class web lecture experience was worse than a live lecture, specifying that they did not come to class to watch a video. Additionally, students said that watching the web lecture in class with the instructor seemed like a waste of time that could be spent on other activities; many students suggested they would rather watch the web lecture at their own convenience.

A common response to the open-ended survey questions expressed appreciation for the concise nature of the web lectures. For example:

- "[The] Professor presented information without going on tangents, so all material was presented in a shorter period of time."
- "All the material was covered in 20 minutes, within my attention span."
- "If we watched these outside of class, I think it would be a good way to quickly get the material."

The formative evaluation provided us with excellent guidance on how to achieve optimal web lecture production quality. We identified and corrected production quality issues and streamlined the process of recording, authoring, and publishing web lectures. Although the sample set was too small to draw any firm conclusions, the surveys provided us with an initial image of students' attitudes toward web lectures and encouraged us to conduct a larger-scale pilot study of web lectures when used as pre-class study activities.

3.3 Pilot Study of Web Lecture Use

Confident that our technology was adequate and stable, the next step was to evaluate the web lecture intervention when partially integrated into a course. Thus, we conducted a pilot study in CS3750 during the Spring 2004 semester, with 31 students enrolled. The course was modified so that 17 class meetings were lectures (rather than 25); the eight class meeting that were no longer used for lecture were repurposed as follows: five were new active learning classes, and three did not meet to match the extra student time taken to watch the assigned web lectures. Students were asked to watch 13 web lectures, lasting a total of 4 hours 37 minutes. The remaining five class meetings (for a total of 30) were used the same way as in previous versions of the course. In the five class meetings freed up by web lecture viewing, we piloted a variety of in-class activities: user interface (UI) critiquing sessions, additional project-anchored student presentations, and a UI "Hall of Fame / Shame" activity. This study is only summarized here; more details about the in-class activities and results are available in the following papers (Day, Foley, Groeneweg, & Van der Mast, 2004; Day, Foley, Groeneweg, & Van der Mast, 2005).

3.3.1 Summary of Pilot Study Results

The results of this study are based on data collected from four surveys and four focus groups throughout the semester. Some of the findings include:

- Satisfactory web lectures can be created with modest faculty time and inexpensive equipment.
- Students prefer studio-recorded video of the presenter in web lectures over recordings from live classroom lectures. Students studied web lectures using both types of presenter video; overwhelming survey responses indicated a strong preference for studio-recorded video.
- Web lectures are best viewed individually, outside of and before class. The other viewing approaches we tried—in project groups in/out of class, in class

with the instructor present, and in class with the TA present—were not well received. In focus groups we discussed other ways of integrating web lectures into the course as well (*e.g.*, viewing individually after class, viewing at a specified time outside of class with the TA online for questions, *etc.*), but individual pre-class viewing was the strong preference in all cases.

- Students' attitudes about the usefulness of web lectures in advance of class and for education in general were positive throughout the semester, increasing slightly as the semester progressed.
- Students' attitudes about the usefulness of web lectures for exam review were positive throughout the semester, but decreased as the semester progressed.
- Students desire some form of explicit motivation to study web lectures before coming to class.
- All five of the new class activities made possible by web lectures were rated positively by students both in terms of educational value and enjoyment; many students commented that the UI "Hall of Fame / Shame" activity was their favorite class of the semester.
- When asked about potential web lecture improvements, the addition of question-asking facilities in the web lecture interface was the most common suggestion.
- Students reported a slight preference for the web lecture course format over the traditional lecture course format.

3.4 1st Classroom Quasi-experiment

Up to this point, our work with web lectures concentrated on achieving optimal levels of web lecture production quality, determining the best way to integrate web lectures with regular in-class meetings, understanding 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. Encouraging findings from the aforementioned studies motivated a more controlled investigation that allowed us to evaluate the web lecture intervention not only in terms of students' opinions, but also in terms of objective educational outcomes (as measured by course grades). Thus, we designed and conducted a full-semester comparative study with two sections of CS3750 being taught at the same time: one section using the web lecture intervention (experimental, n=28) and one using the traditional lecture format (control, n=18). Many control measures were in place, including each section being taught by the same instructor, identical assignments and exams, and blind grading; this study is referred to as a quasi-experiment because participants could not be randomly selected and assigned to conditions. Note that while significant measures were taken to ensure a valid comparison of learning outcomes between sections could be made, no changes were made to normal course functioning that would disrupt the naturalistic classroom setting. This section highlights study details and results that are relevant to our thesis statement; more details can be found in the IEEE Transactions on Education journal article (Day & Foley, 2006a) and CHI paper (Day & Foley, 2006b).

Before conducting this more rigorous study, significant effort went into redesigning the CS3750 course to fully integrate the web lecture intervention. For the experimental section, the same topics were covered in 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 just under 9 hours) was deducted from the scheduled amount of in-class meeting time to control for time on task with the control section, equating to seven fewer class meetings.

In the pilot study, students indicated that they need and want some form of explicit motivation to study web lectures before class. Similar to discovery activities (Schwartz & Bransford, 1998), advanced organizers (Marzano, Pickering, & Pollock, 2001), and HWebs (Collard, Girardot, & Deutsch, 2002), lecture homeworks (LHWs) were implemented in response to student feedback. LHWs are short, 2- to 4-question assignments that address the material covered in a lecture. The idea is to help students critically think about new knowledge before experiencing it in class. Consequently, LHWs are not simply verification or summary-type questions; rather, they are synthesis-type questions that require students to discern and elaborate on concepts covered in the lecture (web lectures for students in the experimental section and live in-class lectures for students in the control section). Moreover, one or more questions typically ask students to relate ideas to previous course topics and/or project work. Fifteen LHWs were assigned throughout the semester, each worth 1% of the final course grade. When a web lecture(s) was assigned or a live lecture was given in class, the associated LHW was due at the start of the next class meeting; students in both sections had the same amount of time to complete LHWs.

LHWs serve three key roles in the web lecture intervention:

- Explicit motivation for studying web lectures (in that they count towards the course grade)
- A companion synthesis exercise that helps learners focus on and learn the web lecture material
- A pedagogical linking mechanism that bridges individual web lecture studying and subsequent in-class participation

Example questions from an LHW associated with a Cognitive Walkthrough web lecture are shown below:

> When creating a believability story, one asks four questions. Discuss each of these questions in relation to Norman's Execute-Evaluation Cycle (and associated Gulfs). How do they fit into Norman's cycle? Is there anyplace they don't fit particularly well?
>
> Consider Nielsen's 10 heuristics. Try to match each heuristic to one or more usability subprinciples we have

> studied (e.g., predictability, dialog initiative, observability). Explain your pairings. If one or more cannot be matched easily, explain why.

After discussing the web lecture(s) and LHW(s) in the experimental section, each class meeting used the remaining time for various hands-on learning activities. These activities included project-related group presentations, small breakout group discussions and presentations, re-design sessions, design critiques, design reviews with HCI experts, role-playing activities, discussions with local HCI practitioners, and others.

For example, UI critiquing activities were used successfully multiple times throughout the semester. Beyond being a required skill for professionals working in the area of UI design, critiquing is also a good mechanism for students to develop good UI design skills. This learning activity was used in three variations:

- Instructor Guided: An in-class critiquing session guided by the instructor. The instructor selected a number of UIs representing a spectrum of design quality. For each UI, the instructor demonstrated various aspects of the design and led class critiquing discussion.
- Group Activity: An in-class critiquing session carried out by small student groups. Student groups could (quickly) find their own UI to critique or select from a set provided by the instructor. Group members worked together to critique the UI, scaffolded by the instructor and TA. Each group gave a short presentation to the class justifying their design critiques.
- Individual Activity: Students individually found a nomination for the UI "Hall of Fame / Shame" outside of class and then presented and justified their selection to the class. After all nominations were presented, the class critically discussed the nominees and voted for the top three UIs in each category.

To prepare for the critiquing class activities, students studied various web lectures on design guidelines (*e.g.*, dialog boxes, web, *etc.*). In these cases, studying web lectures was motivated not only by the associated LHWs, but also by the necessity to adequately justify design compliments/criticisms when presenting to the class.

The control section of the course was taught in the traditional manner, with 25 class meetings for lecture, and five for the mid-term exam and project presentations. The only change was that the same LHWs used in the experimental section were added to the control section curriculum for experimental control purposes.

For both sections, attendance was required, and assessment was based on LHWs (15%), homeworks (10%), the semester project (40%), and mid-term (15%) and final exams (20%). 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 for time on task. Attendance did not turn out to be an issue in either section; no grades were reduced due to absenteeism.

3.4.1 1st Classroom Quasi-experiment Results

This section discusses the results of our first quasi-experimental study in terms of educational outcomes and subjective attitudes. Unless otherwise noted, p-values were calculated using independent-samples, two-tailed t-tests, with alpha = .05.

3.4.1.1 Educational Outcomes

Students in the experimental section clearly outperformed the control section in terms of educational outcomes based on course grades. On *all* assignments and tests, the experimental section's average grades were higher than the control section, as shown in Table 1.

Table 1 Average grades (%) by section

	Control Section	Experimental Section
Homeworks	76.00	88.00
Lecture Homeworks	67.00	86.12
Project	80.55	87.25

Exams	82.80	86.75
Final Course Grade	79.95	88.23

Three graded homeworks were assigned throughout the semester. One homework asked students to do a keystroke analysis of their cell phones, and the other two involved writing in-depth critiques of two other groups' project progress reports. As Table 2 shows, the experimental section scored higher than the control section on all three homeworks, though none of the differences were statistically significant.

Table 2 Average homework grades (%)

	Control Section		**Experimental Section**	
	M	***SD***	***M***	***SD***
Keystroke	58.77	0.83	74.00	1.28
Critique 1	95.33	0.17	98.00	0.39
Critique 2	73.33	0.83	92.00	1.05

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 higher than the control section on every LHW. The difference between the averages across all LHWs was statistically significant ($p<.01$). Figure 7 illustrates each section's average LHW grades throughout the semester; data for two of the LHWs had to be excluded from analysis due to a grading miscommunication between the TAs.

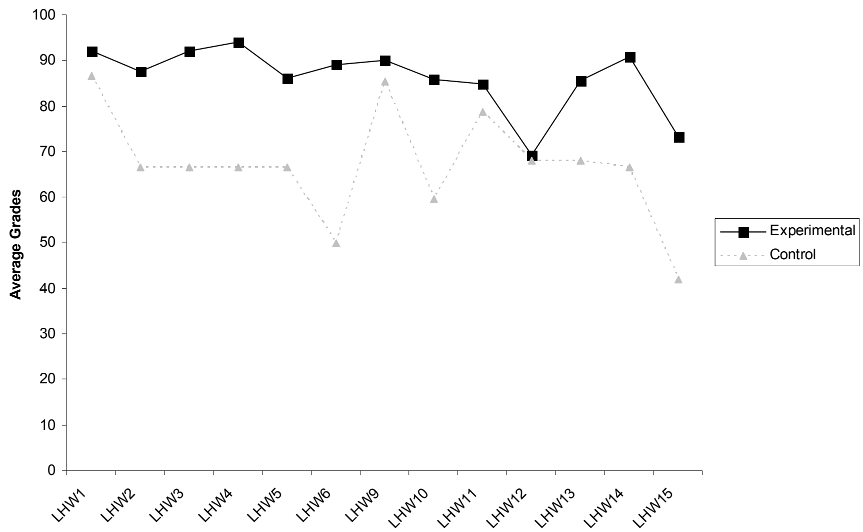

Figure 7 Average LHW grades (%)

The semester project was divided into four phases. 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 1 (p<.01). Average project phase grades for each section are shown in Figure 8.

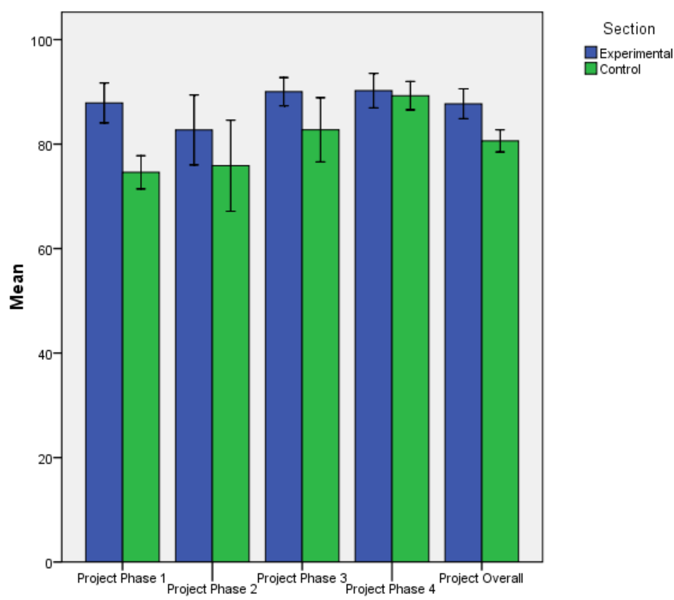

Figure 8 Average project grades (%)

On both the mid-term and the final exams, the experimental section's average grades were higher than the control section. The differences in average grades for the midterm and final exams were marginally statistically insignificant (p=0.10 and p=0.055, respectively). Table 3 shows each section's grades on the exams.

Table 3 Average exam grades (%)

	Control Section		Experimental Section	
	M	***SD***	***M***	***SD***
Mid-term	82.44	5.14	86.00	5.33
Final	83.60	6.50	87.53	5.21

Considering students in the experimental section had higher grades on all assignments and exams, it is no surprise that their final course grades were also higher than the control section. The experimental section's average final grade was 88.23 (*SD*=6.07), while the control section's was 79.95 (*SD*=4.69); the more than eight-point difference is statistically significant ($p<.01$). Because the semester project could not be graded blind like all other assignments, the final course grades of each section without including project grades were also compared. Again, the experimental section's average was statistically significantly ($p<.01$) higher than the control section. Thus, with or without projects included, the web lecture condition scored significantly better than the traditional lecture condition.

3.4.1.2 Subjective Student Attitudes

Data were collected via a late-semester focus group and surveys administered four times throughout the semester:

- 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 five-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 than control students, and with successive surveys, they reported increasingly positive attitudes about various dimensions of the web lecture / in-class activities course format.

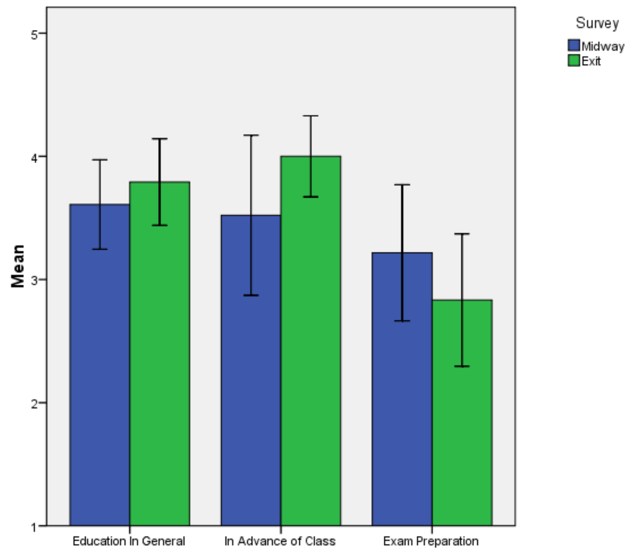

Figure 9 Students' perceived usefulness of web lectures (Scale: 1—Totally Useless to 5—Very Useful)

In the experimental section, students' perceived usefulness of web lectures was measured from three perspectives: a way to study for exams, a way to provide class time for other activities by viewing in advance of class, and a tool for education in general. Figure 9 shows students' perceived usefulness of web lectures for education in general and for freeing up class time for activities were—on average—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. This same decreasing trend was noted in our pilot study, in which responses to open-ended survey questions and focus groups indicated that the decline in perceived usefulness was due to students feeling the web lectures were better to introduce new material than for review. They reported that as the semester progressed and they became accustomed to the way in which web lectures were being used, they simply thought of them more as class preparation than as exam review.

The perceived usefulness of web lectures in comparison to the other major pedagogical elements of the course was also of interest. One survey question asked experimental 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 10 shows, students ranked web lectures the most useful; in-class activities were second; in-class lectures third; and readings ranked as the least useful.

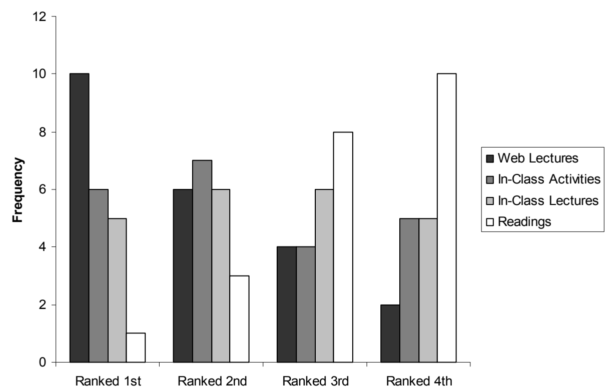

Figure 10 Ranked usefulness of four pedagogical elements

Two questions were used to understand experimental students' attitudes about the new course format with the web lecture intervention. The first question asked students to rate their attitude toward the new course format in comparison to other courses they had taken (Scale: 1-Very Negative to 5-Very Positive), 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 11 clearly represents students' increasingly positive attitudes towards the web lecture format; the increase from interim to exit surveys for both questions was statistically significant ($p<.05$).

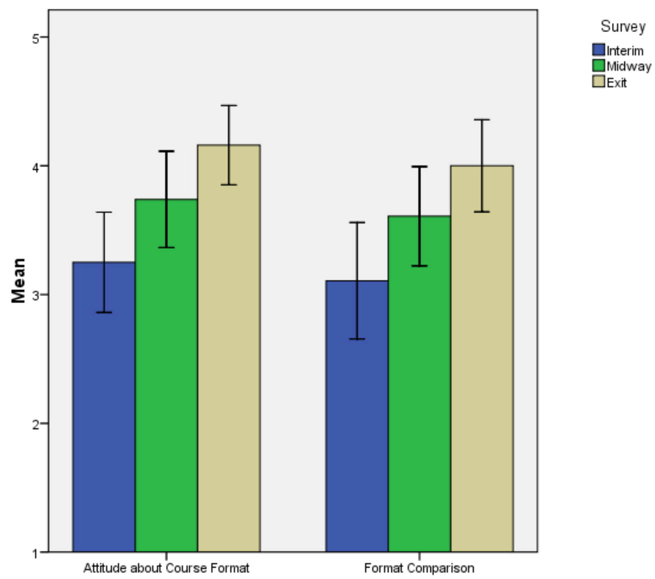

Figure 11 Students' attitudes about the new course format

Students in both sections were asked questions about the perceived helpfulness of the LHWs (Scale: 1-No Help at All to 5-Definitely Help). For example, students were asked if 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.

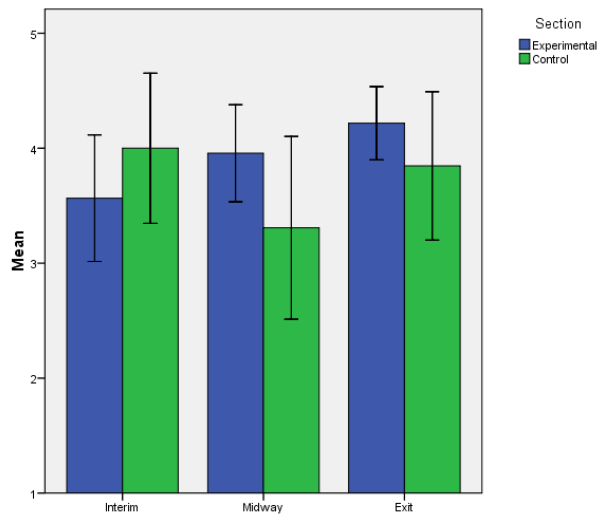

Figure 12 LHWs and focus

Interestingly, both sections reported positively that LHWs helped them focus (Figure 12) and learn (Figure 13) the lecture 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 ($p<.05$).

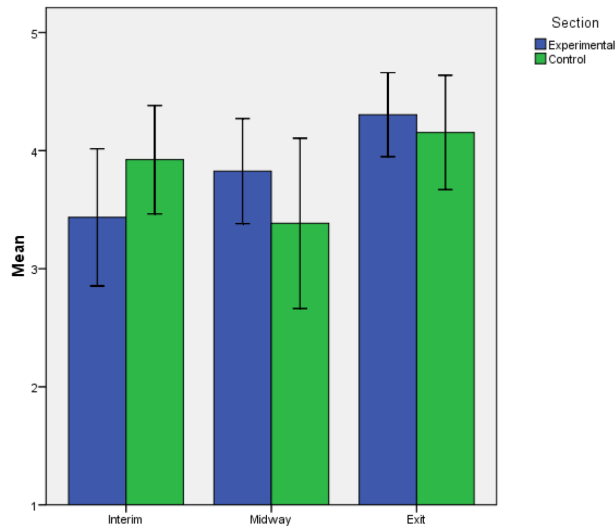

Figure 13 LHWs and learning

Finally, on the exit survey both sections were asked how much they *learned* in this course compared to other courses (Scale: 1-Much Less to 5-Much More). On average, both sections reported learning more from this course than other courses. Although not statistically significant, the experimental section reported more positively (*M*=3.80; *SD*=1.00) than the control section (*M*=3.43; *SD*=1.03). Students were also asked how much they enjoyed this course compared to other courses, using the same response scale. Although not statistically significant, the experimental section (*M*=3.92; *SD*=1.19) reported enjoying the course more than the control section (*M*=3.55; *SD*=1.24).

3.4.2 Discussion

The pedagogical methods used during this study successfully linked students viewing of web lectures with subsequent in-class discussion / application of the information covered in them. This conclusion is drawn from aggregate responses to Likert-scale survey questions, responses to open-ended surveys questions, and feedback obtained during the focus group. Clearly, web lecture students had positive attitudes about the LHWs helping them focus on and learn the material covered by the lectures (as did the traditional students). Moreover, many students expressed that discussing the LHW answers at the beginning of each class meeting was very helpful and that—because LHWs made them feel more prepared for class—discussion and other activities were more meaningful. All in-class activities made possible by web lectures were rated positively in terms of educational effectiveness and enjoyment, with the UI "Hall of Fame / Shame" once again the clear favorite. Also, multiple students noted that being held accountable for ideas covered in the web lectures during in-class presentations (*e.g.*, UI critiquing activities) made them take class preparation more seriously in this course than they did in other courses. Finally, when asked about ways to improve the link between pre- and in-class activities, all focus group participants agreed that providing a web forum for spontaneous questions and discussions outside of class (that could then be further addressed during class meetings) would be the most beneficial.

This longitudinal, quasi-experimental study provided further evidence supporting our thesis claim that students will enjoy a course taught using the web lecture intervention as much or more than a traditionally-taught course. More importantly, it provided evidence suggesting the web lecture intervention improves perceived learning and learning outcomes as measured by grades. Finally, in addition to significant improvements to educational efficacy, the web lecture intervention also increased the educational efficiency of the course: average course grades improved by over 10%, with 25% fewer class meetings. In summary, <u>web lecture students earned higher grades and reported enjoying and learning more from the course than tradition lecture students, while attending significantly fewer class meetings</u>.

3.5 Enhancements to the Web Lecture User Interface

In addition to providing evidence that the web lecture intervention is effective, efficient, and enjoyable, surveys and focus groups also provided guidance for ways to enhance the web lecture viewing experience and make the transition from individual viewing to in-class activities smoother and more effective. In this section, we discuss two web lecture UI enhancements that were implemented in response to feedback from students throughout the pilot and quasi-experimental studies.

Students' most common complaint about the individual web lecture viewing experience was the inability to ask questions about lecture content as soon as they came up. In a small to medium size class, students can relatively easily ask questions during a live lecture; they raise their hand and wait to be recognized. A potential disadvantage of web lectures is that the opportunity to spontaneously ask a question is lost, along with the chance to hear other students' questions. It is potentially valuable for students to be able to ask and be exposed to others' questions and comments, so the web lecture UI was augmented to offer access to two question-asking facilities: the Web Lectures Forum and a direct email form. Iconic links to each of these facilities were added directly underneath the video playback controls (Figure 14).

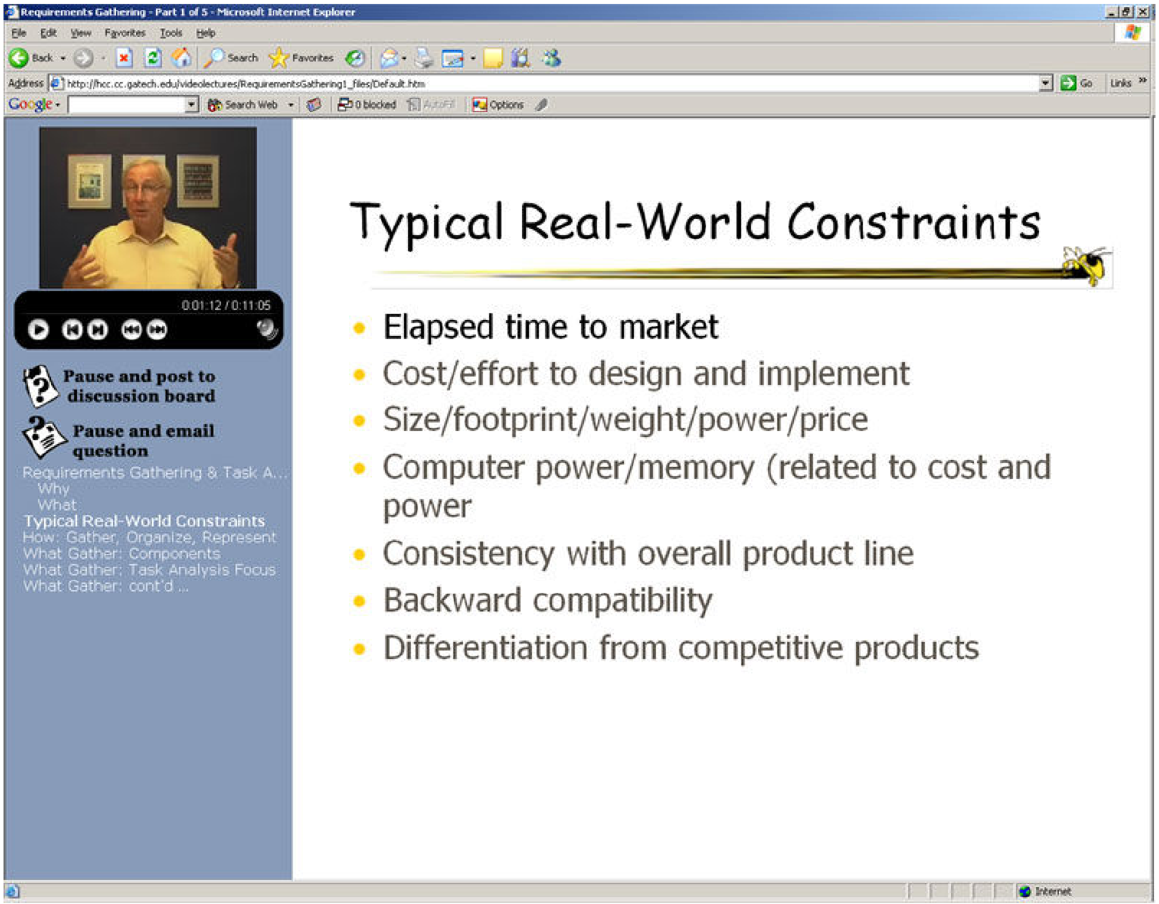

Figure 14 The enhanced web lecture UI—links to new question-asking facilities are located between the video and the TOC

Clicking the first icon, labeled "Pause and post to discussion board," automatically pauses web lecture playback and opens a new browser window with a web-based bulletin board called the Web Lecture Forum (Figure 15), which was developed by modifying open source code provided by phpBB (phpBB). The link to the forum takes the student to a pre-defined discussion area dedicated to the current lecture topic. The student can then post a question or comment to the forum, look at any other postings about the same topic (or other topics, by navigating around), make additional postings if desired, and then resume web lecture playback. The instructor, TA, and other students can respond to postings outside of class, and some of the resulting questions and comment threads can then be used as one way to drive subsequent in-class discussions. A formative evaluation of this approach with CS3750 during the Fall 2007 semester suggested students were comfortable asking questions in this fashion and felt discussions on the forum were beneficial.

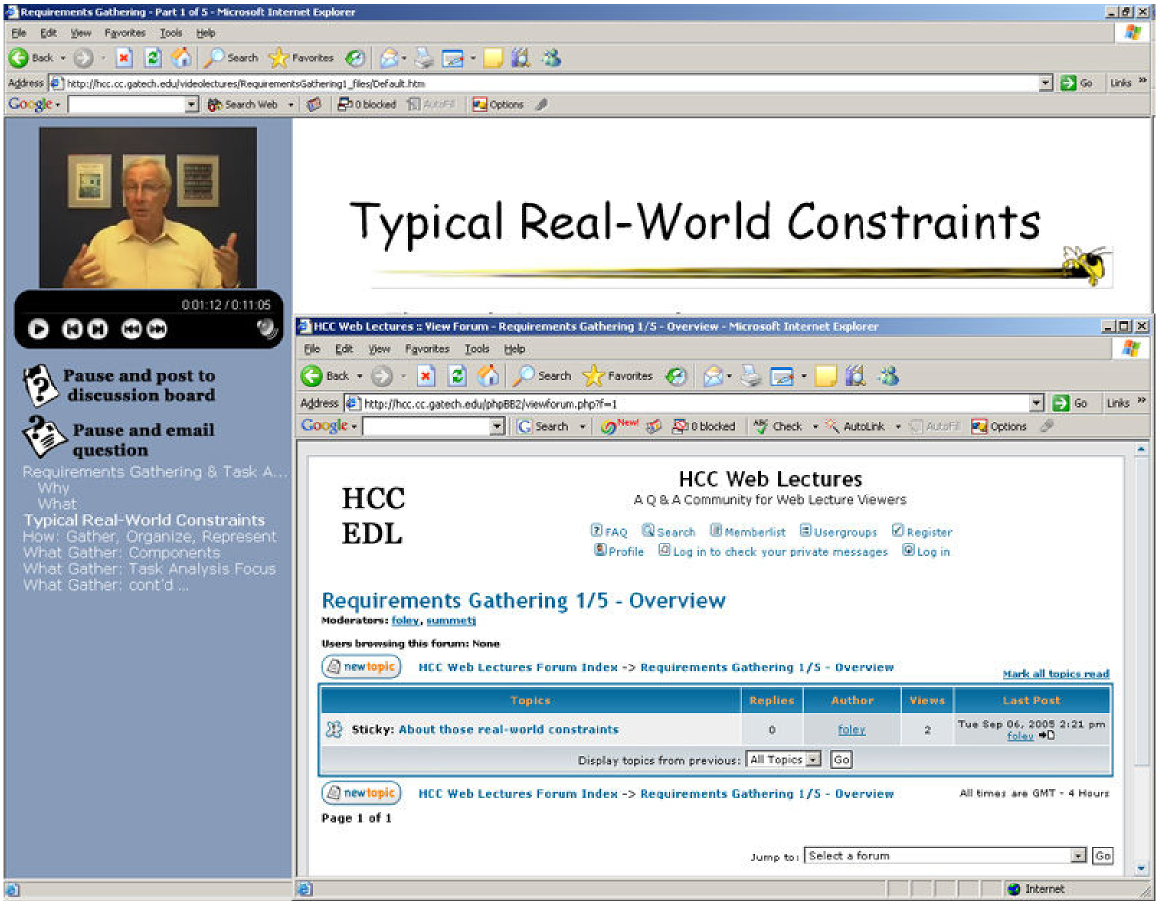

Figure 15 A view of the Web Lecture Forum accessed during a web lecture via the "Pause and post to discussion board" link

The second icon, labeled “Pause and email question,” is similar except upon clicking the user’s default email application opens (Figure 16). The email is pre-addressed to the instructor and TA, and the subject field is pre-populated with the name of the web lecture; students simply type their question into the body of the email message. The instructor or TA might answer questions via email, or the instructor might hold the questions for discussion during the next class meeting.

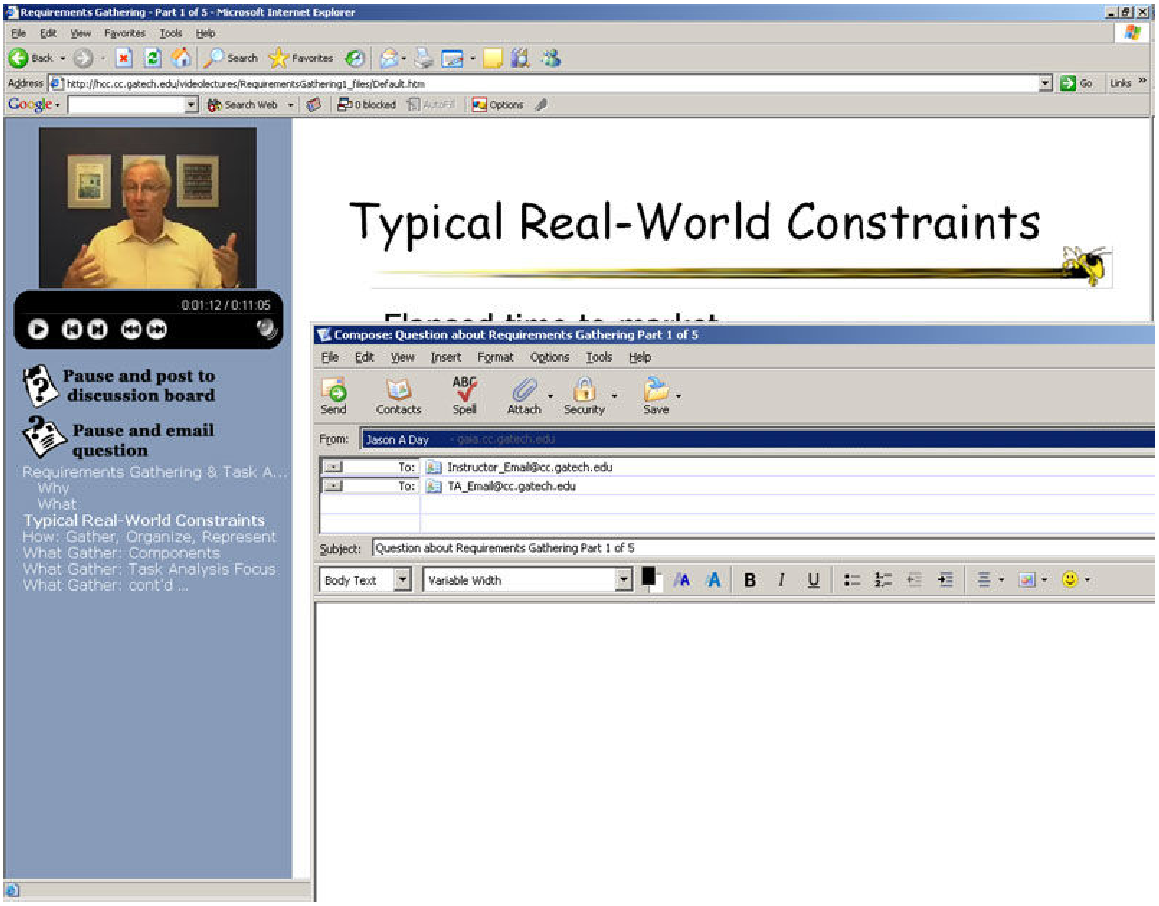

Figure 16 A view of the email form accessed during a web lecture via the "Pause and email question" link

The web lecture UI enhancements discussed here provide students with the opportunity to post questions and see others' questions/comments or to email them to the instructor/TA in a context-sensitive way that minimized student effort. The goal of these technological enhancements was twofold:

1) to make the individual web lecture viewing experience as effective and enjoyable as it can be by preserving, as well as possible, the positive aspects of the traditional lecture (*i.e.*, the ability to ask questions mid-lecture), and

2) to link asynchronous web lecture viewing with synchronous in-class discussions and activities related to the lecture material.

Informal feedback from students during a formative evaluation of these enhancements suggested they would be beneficial when fully integrated into the web lecture intervention; a more rigorous evaluation of their effectiveness was included as part of the second classroom quasi-experiment discussed in Section 3.6.

3.6 2nd Classroom Quasi-experiment

This section describes the second classroom quasi-experiment, which was the final naturalistic classroom evaluation conducted as part of this dissertation work. The first classroom quasi-experiment yielded strong initial evidence in support of our thesis claim that a course taught using our web lecture intervention will be as more educationally effective and enjoyable than a traditionally-taught course. However, a second classroom quasi-experiment was needed to enable us to answer some of our other research questions, as well as to validate the results of the first quasi-experiment. In particular, this second quasi-experimental study allowed us to:

- Add some additional control measures to the study design that were not present in the first quasi-experiment
- Deploy the web lecture intervention with a much larger group of students (approximately twice as many students as compared to the first quasi-experiment)
- More rigorously evaluate the impact of the web lecture UI changes (*i.e.,* forum and email question-asking facilities)
- Do some analysis of students' web lecture viewing behaviors

3.6.1 Study Design

Like the first classroom study, this study was conducted with two sections of the CS3750 course taught by Prof. Foley. With one exception, the curriculum and assessment was the same as discussed in Section 3.4. The only significant change to the course setup was the integration of the Web Lecture Forum with the LHWs. For approximately half of the LHW assignments—in addition to answering 1-3 normal LHW questions—students were asked to post one unique "exam-type" question on the Web Lecture Forum and to answer one question posted there by another student. The purpose of this task was to get students thinking critically about the lecture topic before attending class and encourage regular use of the Web Lecture Forum. Additionally, we hoped this approach would provide a large amount of student-generated content useful for guiding discussion during class meetings.

For this quasi-experiment, each section was matched on a variety of relevant factors in order to have the best possible basis for comparing educational outcomes and students' subjective attitudes of the traditionally-taught control section and the experimental section taught with the web lecture intervention. The two sections were matched or measured (and then controlled statistically by using the variables as covariates when appropriate) on the following factors[4]:

- Instructor – the same instructor (Prof. Foley) taught both sections
- Topics covered – exactly the same topics were covered, in the same order
- PPT lecture presentations – the exact same presentations were used for in-class class lectures and web lectures
- Assigned readings – the same
- LHWs, regular homeworks, and the group project – the same
- Mid-term and final exams – the same
- Individual differences:
    - How "strong" or "weak" a student is as assessed incoming GPA

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[4] An asterisk (*) next to the bullet indicates a control measure was put into place for the 2nd classroom quasi-experiment. All other control measures were in place for both classroom quasi-experiments.

    - *Prior knowledge of the course subject matter, as assessed by an HCI pretest
- Time on task:
    - Control section: time spent in class
    - Experimental section: time spent in class plus total running time of assigned web lectures

All grading for the two sections was counterbalanced and blind. To ensure that any difference in section grades were not due to differences in the two TAs' grading styles, each assignment and exam from both sections was be graded by one or the other TA, with all names removed. Because of the degree to which the design project is integrated into the course, blind grading for projects was not possible. However, for each phase of the project the TAs calibrated their grading by scoring two randomly selected reports from each section. After resolving any scoring differences, the TAs finalized a common set of grading criteria and scored the remainder of the project reports. Since this method of grading is not blind, final course grades for each section have been compared with and without inclusion of the project grades.

LHWs were matched not only by asking the same questions, but also by allotting the same amount of time between a live 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 also 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 or she might have inadvertently spent more time on those topics in the control section's live lectures than in the more bounded, pre-recorded web lectures.

We did not want any difference in performance between sections to be attributable to more *required* time on task. To compensate, the total running time of all assigned web lectures was subtracted from in-class time in the form of cancelled class meetings for the experimental section. Specifically, students were assigned just under 575 minutes of web lectures; thus, seven experimental-section class meetings (spread out throughout the semester) were cancelled to control for time on task. Because web lectures afford students the opportunity to pause, rewind, *etc.* and the obvious inability to monitor all students' out-of-class activities, note that total running time may or may not be equivalent to the actual time spent studying web lectures (*i.e.*, students could have spent more or less time than what was assigned). We make a modest assumption that this potential variance in time on task is offset by control students' ability to similarly review PPT slides, personal notes, *etc*. These types of messy methodological considerations are part and parcel for naturalistic classroom research, thus we do not consider this to be a major threat to the validity of our studies.

Some other factors are difficult to control in a naturalistic classroom setting. These include:

- Individual learning styles
- Individual personality type, which has been shown to have an effect on learning outcomes with multimedia instructional materials (Reuther & Meyer, 2002)
- Hawthorne effect (students knowing they are in the control or experimental section) (Mayo, 1933)
- Class meeting time, which of necessity differs between the two sections, and might affect student alertness or, due to conflicts with certain required courses, might affect the majors and hence background of students in the two sections
- Possible differences in enthusiasm or attitude exhibited by the instructor in each section

Nevertheless, given that assignment to conditions was essentially random (*i.e.*, students did not know about the experiment when signing up for one section or the other) and the fact that sample cell sizes were greater than 30, there is a very reasonable chance that these factors balanced out between sections. As noted above, individual difference data were also included as covariates where appropriate in the statistical analysis to increase the methodological rigor of this study.

Finally, a validated login dialog was implemented and active throughout the semester to ensure control students did not view web lectures. To access a web lecture, a GTID matching one in the experimental class enrollment had to be entered[5]. Along with this, some limited web lecture logging was in place during this study, which was not included as part of previous classroom studies. We used a combination of Google Analytics and custom logs to capture some high-level web lecture viewing patterns.

3.6.2 Study Details

This study was conducted during the Spring 2007 semester. The two sections met back-to-back in the same room on Tuesdays and Thursdays: the control section from 1:35 – 2:55pm, the experimental section from 3:05 – 4:25pm. In the first classroom quasi-experiment, the experimental section met before the control section. For this study, the meeting order was purposely reversed to address the potential threats to validity relating to students' selection of an earlier/later class times, instructor fatigue, lecture adjustments, *etc.*

A total of 72 students participated in this 15-week study: 33 students in the control section, 39 in the experimental section. All students gave informed consent prior to participating in the study. Students in the experimental section were given the opportunity to transfer into the control section, though none opted to do so.

One TA was assigned to each section. The TA for the control section was a graduate HCI student who had previous experience serving as a TA for CS3750, while

[5] There is still a small chance that control students had access to web lectures (*e.g.*, asked for the GTID of a friend in the experimental section).

the TA for the experimental section was a graduate HCI student with no prior TA experience. We do not feel the difference in TA experience represents a threat to validity, because—as noted above—all grading other than the projects was done section-blind and counterbalanced throughout the semester. If in fact TA experience made a difference through other interactions (*e.g.,* feedback given in person or over email), any advantage would arguably be in favor of the control section, since it had the more experienced TA.

3.6.3 2nd Classroom Quasi-experiment Results

This section presents the results of the 2nd classroom quasi-experiment, including participant demographics and analysis of course grades, log data, and subjective student feedback. Throughout, statistical significance was determined using alpha = .05. For more details on the analysis, see Appendix D.

3.6.3.1 Study Participants

Demographic data were collected with an in-class survey. Table 4 below summarizes the gender and age demographic data by section and as a whole sample. Clearly, age and gender were evenly distributed across the two conditions (though obviously in terms of gender, males greatly outnumber females in the whole sample).

Table 4 Sex distribution and mean age

	Sex		**Age**	
	Male	Female	***M***	***SD***
Experimental Section	30	9	21.44	1.94
Control Section	25	8	21.91	1.49
Both Sections	55	17	21.65	1.75

Academic year and major demographic data were also collected from all participants. Table 5 below provides the details of year and major distributions across conditions. Unsurprisingly, a large majority of students were upperclassman majoring in

Computer Science. Chi-Square tests confirm no significant differences between conditions for the distributions of sex ($X(1)$=.013, p=.908), age ($X(8)$=11.417, p=.179), year $X(4)$=4.246, p=.374), or major ($X(5)$=4.552, p=.473).

Table 5 Academic year and major distributions for both sections

	Control Section	Experimental Section
Year:		
Freshman	0	1
Sophomore	0	1
Junior	11	18
Senior	19	18
Other	3	1
Major:		
Computer Science	26	32
Computer Engineering	1	0
Electrical Engineering	0	1
Computational Media	6	4
Management	0	1
STAC	0	1

3.6.3.2 Attendance

As noted in the discussion of the first quasi-experiment, attendance in the experimental section was more important than usual considering the number of in-class meetings was reduced to help control for time on task. Also, because all the lectures were available at anytime via the web, we were naturally concerned about the effect the web lecture intervention might have on attendance (*i.e.,* would students come to class less because lectures were available elsewhere). This concern did not turn out to be a problem. In fact, attendance in the experimental section was slightly better than in the control section. Throughout the entire semester, students in the control group missed a total of 57 class periods (93.8% attendance rate), as compared to 45 (94.5% attendance rate) in the experimental group. When using an independent-samples, two-tailed t-test to compare the absence means for the control (*M*=1.67, *SD*=1.594) and experimental (*M*=1.15, *SD*=1.16) groups, however, we see that the difference was not statistically significant ($t(57.372)=-1.536$, $p=.130$). Some students in both sections received penalties against their final grades for missing more than the allowed 2 class periods, but these deductions were not included in the final course grades used in subsequent educational outcome analysis.

3.6.3.3 Web Lecture Log Data

Some limited web lecture logging was in place throughout this study. Google Analytics logs provided high-level access data, and custom logging tied to GTID logins provided some insight into how much time students spent studying web lectures.

The Google Analytics logs of overall web lecture accesses[6] throughout the Spring 2007 semester (Jan. 10 – April 30) are shown in Figure 17 below. The logs reveal access consistent with when web lectures were assigned. For instance, the two largest access peaks (Jan. 22 and Feb. 6) coincide with the assignment of the two longest multi-part web lecture series (Requirements Gathering and Design Principles). Moreover, the logs suggest that students were indeed studying web lectures most in the time leading up to associated class meetings. For instance, peak access occurred on Jan. 22, and class met to discuss Requirements Gathering on Jan. 23. Also, moderate clustered access occurred on the dates of and leading up to the two exams (Mar. 8 and April 30). Other trends were as expected as well: a visible drop-off in accesses is visible around spring break (the week

[6] An “access” is defined as the act of bringing up a web lecture and selecting the “Play” link on the splash screen (Fig. 5) to begin the presentation.

of Mar. 19) and accesses toward the end of the semester—when fewer web lectures were assigned and focus was on projects—drop-off somewhat.

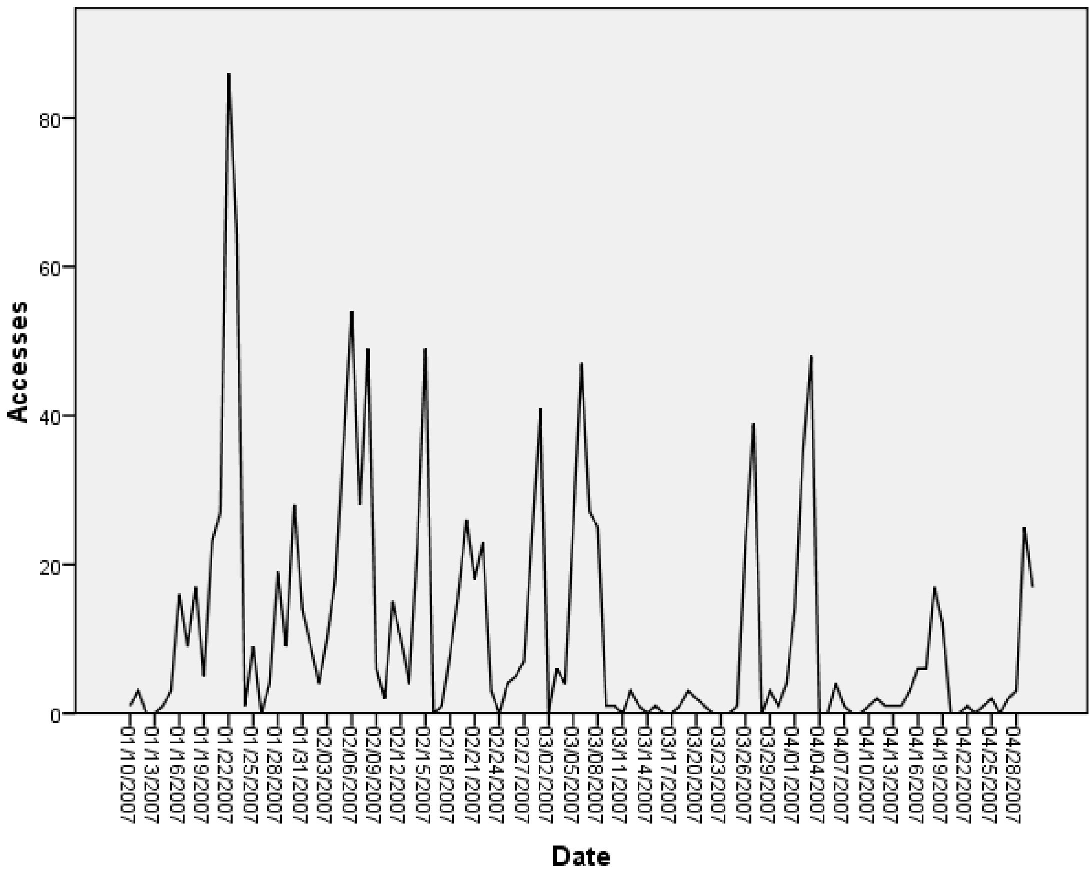

Figure 17 Web lecture access throughout the semester. The two longest multi-part web lecture series were discussed on Jan. 23 and Feb. 6/8, spring break recess was the week of March 19, the mid-term exam was on March 8, and the final exam was on April 30

Access logs for individual web lectures over the course of the semester indicate further that web lectures were primarily studied when assigned, along with minimal accesses leading up to both exams. As an example, the semester access log for the first Requirements Gathering web lecture (assigned on Jan. 18 and discussed in class on Jan. 23) is illustrated in Figure 18 below.

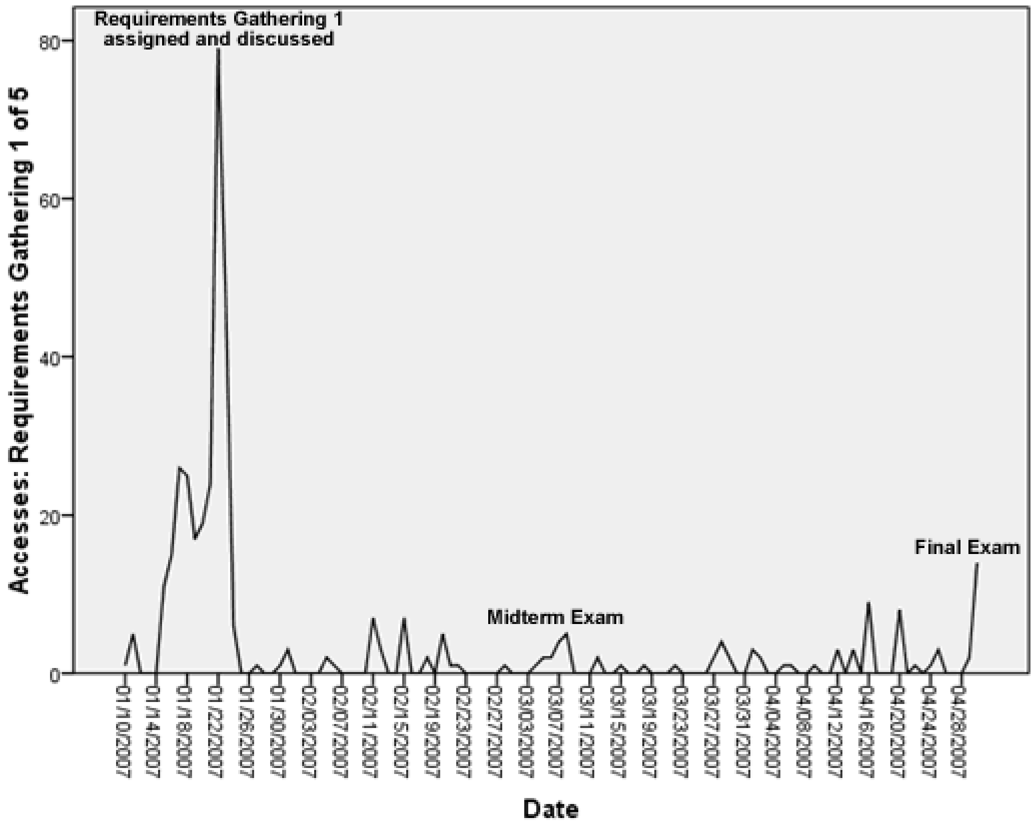

Figure 18 Access log for the first Requirements Gathering web lecture

Custom logging capability was also implemented as part of the validation required to access web lectures. Log entries were associated with GTID, and each entry stored a record of the viewing session duration. The intent was to use the logs to calculate each student's total time spent viewing web lectures. Unfortunately, we were unable to capture this metric in its entirety for two reasons. First, the custom logging had to be voluntarily approved by each student because it was tied to GTIDs; only 20 of 39 students opted in. Second, four days were not logged due to a hardware failure that occurred mid-semester. As a result, custom log data reported here is strictly for *descriptive purposes only*; it was not used in statistical analysis of educational outcomes.

Although not valid for rigorous analysis, the partial custom logs are interesting to explore in terms of descriptive statistics. For the 20 students whose viewing time was logged, the mean total viewing time was 554 minutes (*SD*=288.313). Recall that approximately 575 minutes of web lectures were assigned. Assuming the average would be slightly higher if the missing four days of logs were available, note that actual total time spent viewing web lectures was very close to the total assigned running time (which was also equal to class time cancelled to control for time on task). This approximate metric gives us additional reassurance that we successfully controlled for time on task across sections. Figure 19 below shows the total viewing time for each student who consented. Because students' total viewing times varied quite a bit (Minimum: 255.1 minutes; Maximum: 1427.6 minutes), we also checked for a correlation between final course grade and viewing time; no statistically significant correlation was found in these data (R=.194, p=.413).

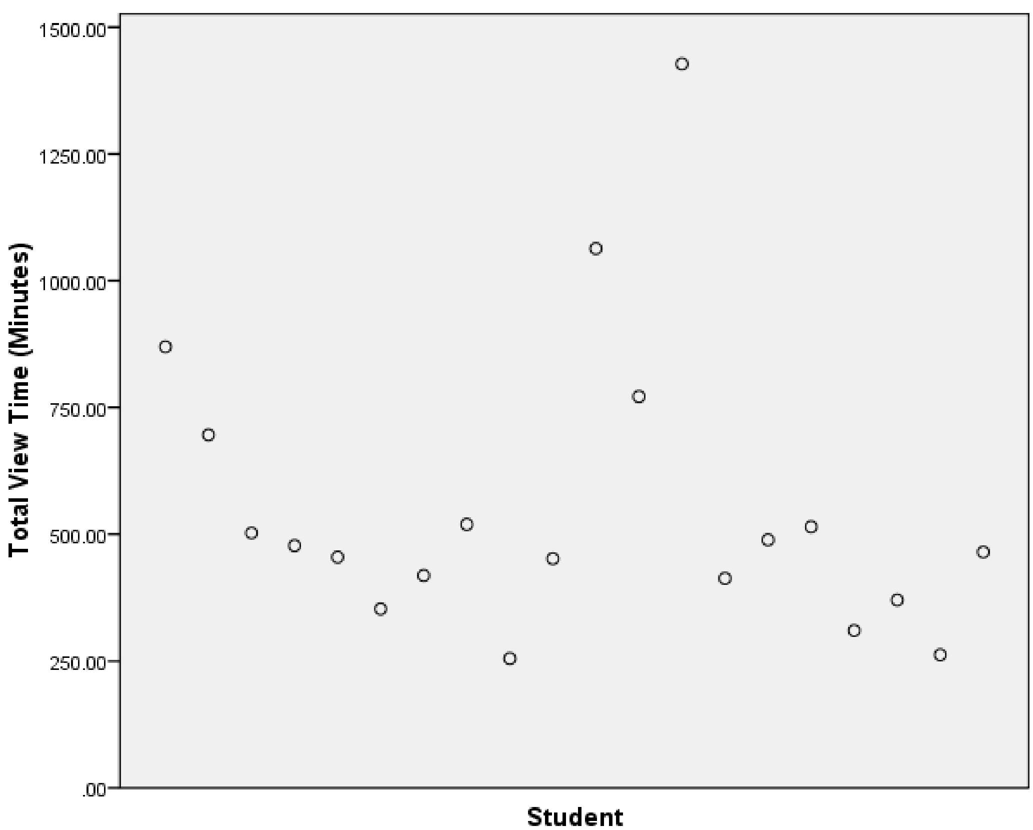

Figure 19 Total web lecture viewing time (without four days of data) for the 20 consenting students

3.6.3.4 Usage of Web Lecture UI Enhancements

All web lectures viewed by students during this study incorporated the question-asking facilities discussed in Section 3.5. Much subjective feedback from students during previous classroom studies—and positive feedback received during a formative evaluation—indicated that students would use and benefit from the ability to ask/answer questions while studying a web lecture. Surprisingly, actual usage did not reflect this whatsoever. In fact, not a single student used the 'Pause and email question' link to send a question to the instructor/TA throughout the entire semester, and no on-topic questions were posted/answered on the Web Lecture Forum that were not required as part of LHW assignments[7].

The Web Lecture Forum was used fairly regularly, but only as a means to complete LHWs. Although the forum was not used to post/answer non-LHW questions or for any other on-topic discussion, most students in both sections[8] did post relevant and thoughtful questions and answers as part of LHW completion. The forum-related LHW assignments had the following instructions:

> Imagine you are a professor writing an exam on the material covered in this lecture. Please come up with one original question and post it to the forum. In addition to posting a question, please answer one question that someone else has posted.

The following is a representative example question / answer:

> Question posted:
>
> We considered special skills to be an issue in choosing dialog styles. What other special skills may we have to consider besides typing and how can we design a system

[7] At the beginning of the semester, two short question / answer interchanges took place that were not part of LHW completion, they were strictly administrative in nature.

[8] Recall that identical LHWs were assigned to both sections. Thus, each section had a dedicated forum that was not visible to students in the other section.

both with direct manipulation and command line interaction that cater to the needs of these special skills?

Question answered:

Q: This is a very abstract question. Let's say you wanted to build the next version of Linux. You want to have a person with CL skills and little DM skills and a person with no CL skills and high DM skills feel right at home. What would be some good suggestions on how to map CLs with DMs? For example having a command line always open and showing the commands what happen when a user clicks on a GUI action. Your thoughts?

A: I actually logged into the solaris systems the other day in the CoC for the first time and quickly became accustomed to dealing with multiple operating systems at the same time. I think I would try to design a system with that type of interface - very customizable - but yet still have the command prompt available at a click of a mouse.

Another alternative to this is to design a system with a command button on your keyboard. The operating system would be that of a windows style direct manipulation interface while power users would have their quick short cuts plus the available command key that would provide an on-screen command prompt to allow quick interactions.

The point of having this command button is to take the strengths of direct manipulation - initial training, learning time, generality/flexibility - and combining those with the advantages of a command line - speed of use, screen space required. This system needs to cater two those two groups (novices and power users) and I believe the best way to do that is to have the option to quickly switch to a command line via a command line style action (aka, the key on your keyboard).

3.6.3.5 Incoming GPA and Domain Knowledge

In order to make a valid comparison of educational outcomes with this type of comparative study, it is important to consider the overall "strength" of the students in each group. Fortunately, we were able to obtain the cumulative incoming GPAs of all study participants, which we chose to use as our student "strength" metric. Other measures could potentially have been used (*e.g.*, SAT or other standardized test scores), but—even if we could have obtained these—arguably cumulative GPA was a better indicator considering all but two study participants were of junior academic standing or above, far removed from such entrance exams. Moreover, GPA is based on course performance, which is exactly what we wanted to compare between the two course sections.

Table 6 illustrates the mean incoming GPAs for each section. Students in the control section had slightly higher GPAs coming into this study, but a t-test indicated that the difference was not statistically significant ($t(70)=-.207$, $p=.837$). Consequently, we conclude that for the purposes of comparing educational outcomes as measure by course grades, the two groups evaluated in this study were of approximately equal academic "strength."

Table 6 Mean incoming GPAs (out of 4.0) and HCI pretest scores (%)

	Control Section		Experimental Section	
	M	***SD***	***M***	***SD***
Incoming GPA	2.992	0.570	2.966	0.482
HCI Pretest Score	56.90	11.426	55.82	10.102

Additionally, we assessed students' incoming domain knowledge with a short HCI pretest. The pretest consisted of eleven questions, which were a mix of true/false, multiple choice, short answer, and UI sketching; the questions were selected randomly from HCI exams from multiple instructors/institutions available via the HCC Education Digital Library. Pretests were scored condition-blind.

Table 6 above illustrates the mean pretest scores for each section. Again, students in the control section scored slightly higher on average than the experimental students, but a t-test indicated that the difference was not statistically significant ($t(68)=.416$, $p=.679$). As with incoming GPA, we considered this evidence supporting the assumption that the two study groups were approximately equal in terms of incoming domain knowledge.

3.6.3.6 Educational Outcomes

Although there are many possible measures of student learning, we used course grades as the objective metric with which to compare learning outcomes across sections. Table 7 below summarizes the average course grades for each section, as well the average aggregate grades for the major assessment components. Each type of assignment and final course grades are discusses separately in more detail below. Overall, the experimental section performed slightly better on average than the control section on homeworks, LHWs, the project, and final course grades; however, the control section scored slightly higher on exams (mid-term and final combined).

Table 7 Average grades (%) by section

	Control Section	**Experimental Section**
Homeworks	89.30	90.55
Lecture Homeworks (LHWs)	82.77	85.77
Project	76.17	76.56
Exams	83.89	83.71
Final Course Grade	80.66	82.28

Identical to the first classroom quasi-experiment, in this study three graded homeworks were assigned throughout the semester. The first homework asked students to do a keystroke analysis of their cell phones, and the other two involved writing in-depth critiques of two other groups' project progress reports. As Table 8 shows, the experimental section scored higher than the control section on the keystroke ($t(70)=.312$, $p=.756$) and second critique ($t(70)=1.117$, $p=.268$) homeworks, but the control section scored a little higher on the first critique homework ($t(70)=-.535$, $p=.595$). None of the mean differences were statistically significant.

Table 8 Average homework grades (%) by section

	Control Section		Experimental Section	
	M	***SD***	***M***	***SD***
Keystroke	83.46	3.015	85.68	3.021
Critique 1	92.73	17.945	90.13	22.522
Critique 2	92.88	17.679	96.79	11.892

As with the first classroom quasi-experiment, lecture homeworks represented 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 slightly higher than the control section on twelve of fifteen LHWs, the control section had higher scores on two LHWs, and the average scores were equal for one LWH. T-tests comparing individual LHW means did not reveal any significant differences (see Appendix D for details of these statistical tests). Further, the 3% spread between the sections across all LHWs did not represent a statistically significant mean difference ($t(70)=1.03$, $p=.305$). Figure 20 illustrates each section's average LHW grades throughout the semester.

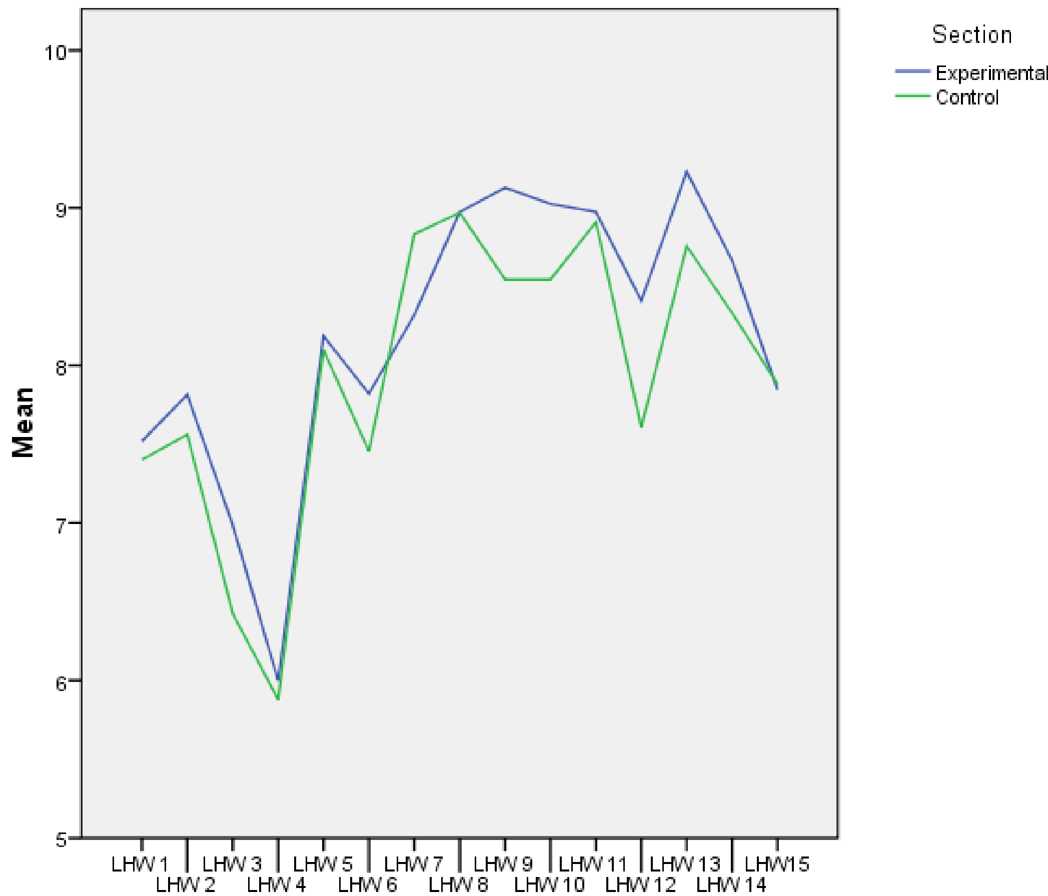

Figure 20 Average LHW grades (10 points possible) by section

On the four-phase semester-long design project, the experimental group earned higher scores on phase one ($t(70)=1.697$, $p<.05$) and phase two ($t(70)=.110$, $p=.913$), while the control group performed better on phase three ($t(70)=-.878$, $p=.383$) and phase four ($t(70)=-1.279$, $p=.205$); students in the experimental section had a slightly higher average on the project as a whole ($t(70)=.217$, $p=.829$). The experimental section's grades on phase one of the project were statistically significantly higher than those of the control group when comparing means using a one-tailed t-test, but all other mean differences were insignificant when evaluated at the 95% confidence level. Figure 21 shows each section's average overall project grades, as well as grades for each project phase.

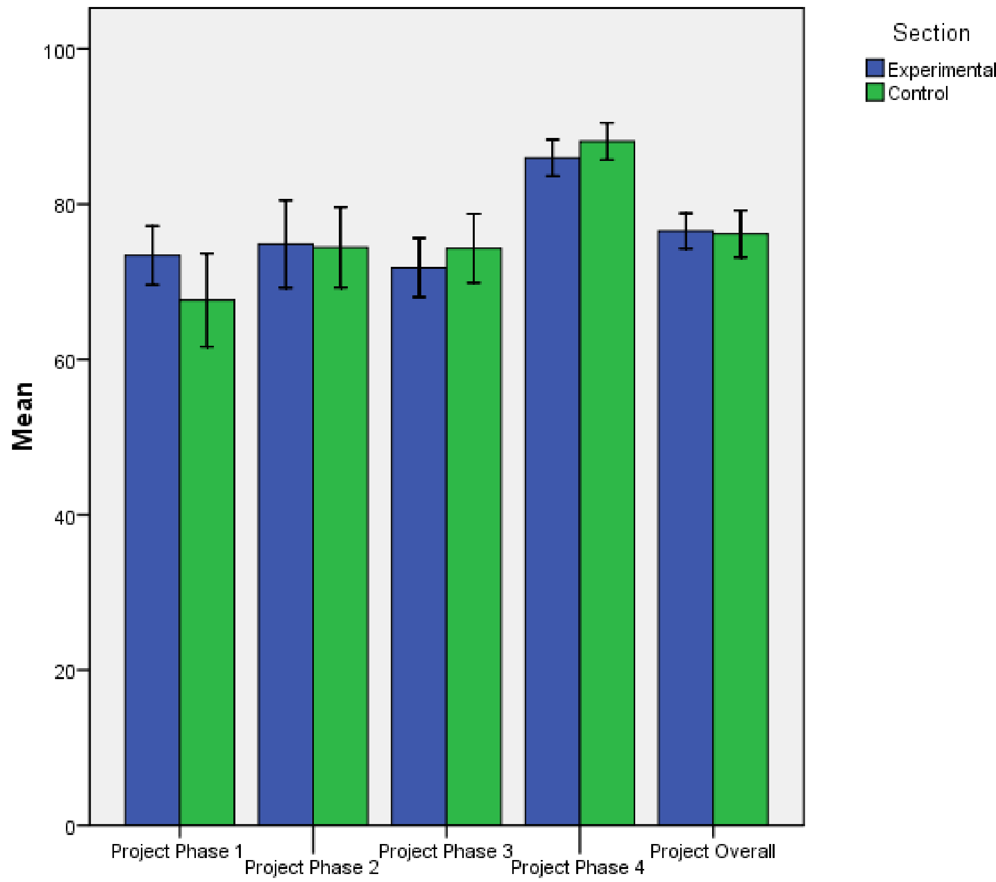

Figure 21 Average project grades (%) by section

A similar trend reveals itself in the data for exam grades. The control section (*M*=78.31, *SD*=7.267) performed slightly better than the experimental section (*M*=75.59, *SD*=7.725) on the mid-term exam, while the experimental section (*M*=90.09, *SD*=5.327) scored slightly higher on the final exam[9] than the control section (*M*=88.28, *SD*=4.155). Overall, the control students earned marginally higher grades on exams than experimental students. None of these mean differences, however, were statistically significant: mid-term ($t(70)=-1.526$, $p=.132$), final ($t(70)=1.593$, $p=.116$), and overall ($t(70)=-.149$, $p=.882$). Figure 22 below visually represents average exam grades.

[9] The experimental section final exam was administered Monday, April 30 from 11:30 – 2:20; the control section final exam was administered Tuesday, May 1 from 11:30 – 2:20.

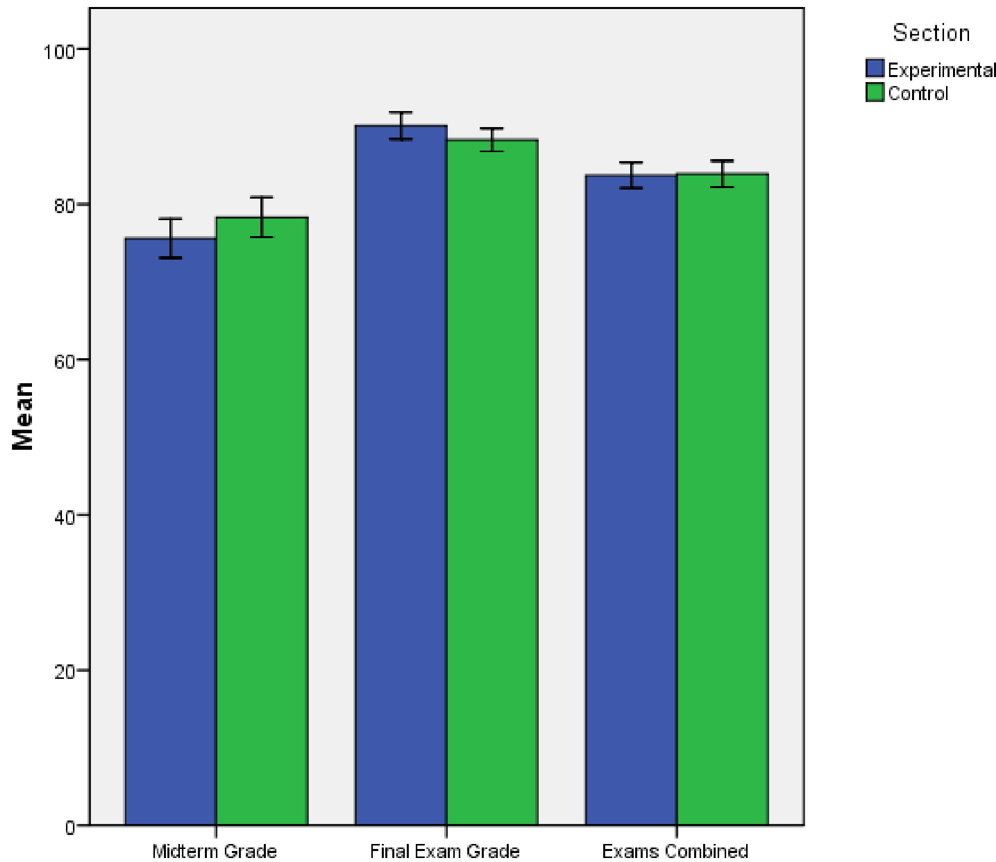

Figure 22 Average exam grades (%) by section

Students in the experimental section scored higher on average than those in the control section on over 70% of the assessment measures used in this course. Consequently, we found that their overall course grades were marginally higher as well: experimental section (*M*=82.28, *SD*=4.335), control section (*M*=80.66, *SD*=6.213). When comparing the final course grade means using a two-tailed t-test, we see that the difference is not statistically significant (*t*(55.811)=1.258, *p*=.214).

As reported above, there were no significant differences between conditions when considering the gender, age, year, and incoming GPA factors individually. However, to be sure the combination of these factors did not somehow significantly affect overall course performance, we also ran a univariate ANOVA analysis with final course grade as the dependant variable; section as the fixed factor; and gender, age, year, and incoming GPA were included in the model as covariates. The results from this analysis were essentially the same, however: there was no statistically significant main effect of section on final course grade ($F(1, 66)=1.234$, $p=.271$, $MSE=24.453$).

3.6.3.7 Subjective Student Attitude

For this study, subjective attitudinal data were collected using one focus group and three surveys. The focus group was conducted late in the semester with four volunteers from the experimental section. Surveys were administered multiple times throughout the semester:

- Early Survey – administered three weeks into the course
- Midway Survey – administered eight weeks into the course
- Final Survey – administered at the final exam, fifteen weeks into the course

Survey questions queried both sections about their attitudes toward HCI, LHWs, the Web Lecture Forum, and the course in general; students in the experimental section were additionally asked about web lectures, the new course format, and other aspects of the Web Lecture Forum. Surveys were primarily five-point Likert-scale questions, with a few open-ended questions. Surveys administered to the control section are included as Appendix A, and those administered to students in the experimental section are included as Appendix B.

Many of the questions asked throughout this study were the same as those asked during the first classroom quasi-experiment. Again, experimental students' perceived usefulness of web lectures was measured from three perspectives: as a tool for education in general, as a way to provide class time for other activities by viewing in advance of class, and as a way to study for exams. As Figure 23 shows, the average perceived usefulness of web lectures from all three perspectives was positive throughout the semester. Interestingly, we see again with this deployment of the web lecture intervention that as the semester progresses students become more positive when considering web lecture for education in general and studied before attending class, but the perceived usefulness of web lectures for exam review decreases. When asked about this trend in the focus group, students echoed responses heard during previous classroom studies: as they get used to the new web lecture / in-class activity format, they think of web lectures more as class preparation and less as a review mechanism. Interestingly, access logs still indicated moderate web lecture viewing during the time leading up to exams (when no new web lectures were being assigned). Average changes in students' perception of web lecture utility over the course of the semester were not statistically significant for education in general ($t(68)=-1.366$, $p=.176$) and exam preparation ($t(68)=.785$, $p=.435$), but the changes in mean response to the question about web lectures in advance of class do represent a statistically significant increase ($t(68)=-3.797$, $p<.001$).

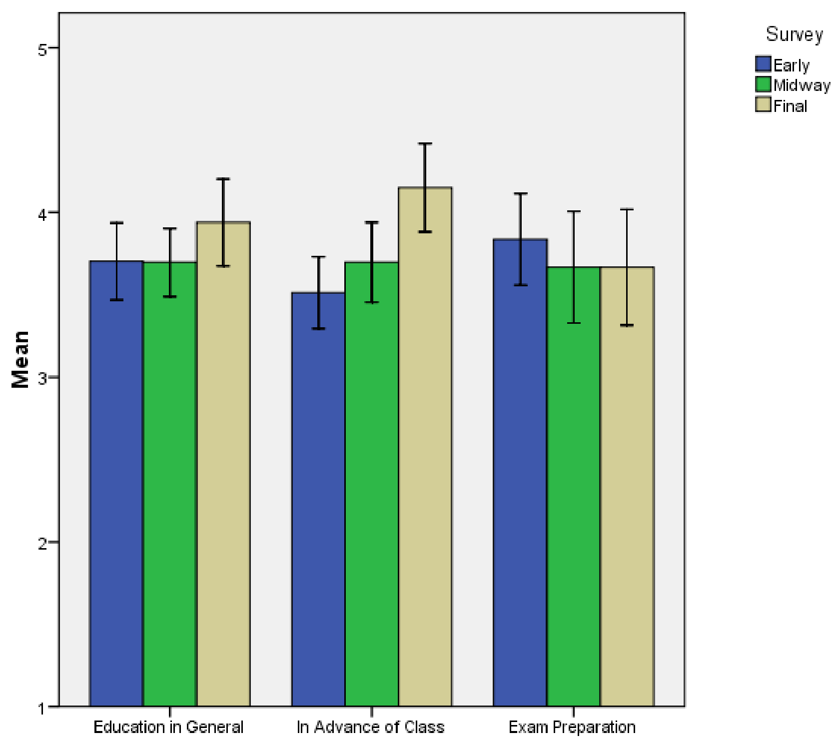

Figure 23 Students' perceived usefulness of web lectures (Scale: 1—Totally Useless to 5—Very Useful)

Students in the experimental section were also asked to rate their overall attitude about web lectures themselves and about the navigation controls provided by the web lecture UI (*i.e.*, playback controls and TOC). Again, students' attitudes on both measures remained positive throughout the semester, becoming slightly more positive by the end of the course (Figure 24). None of the mean response differences over time were statistically significant.

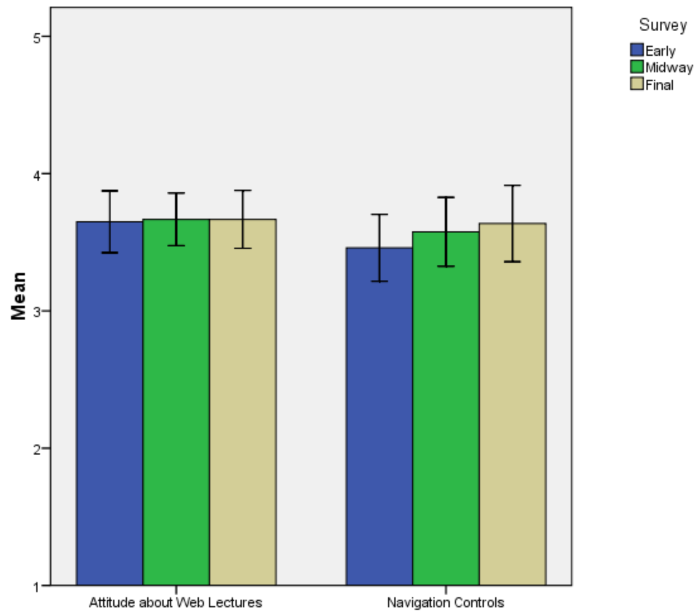

Figure 24 Attitudes about web lectures and navigation controls (Scale: 1—Very Negative to 5—Very Positive)

Two questions were used to understand experimental students' attitudes about the new course format with the web lecture intervention. The first question asked students to rate their attitude toward the new course format in comparison to other courses they had taken (Scale: 1-Very Negative to 5-Very Positive), 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 25 clearly illustrates students' positive attitudes towards the web lecture format; attitudes about the new course format started and remained positive, while students' increasingly strong preference for the web lecture format over a traditional lecture format represented a statistically significant change over the semester ($t(68)=-4.192$, $p<.001$).

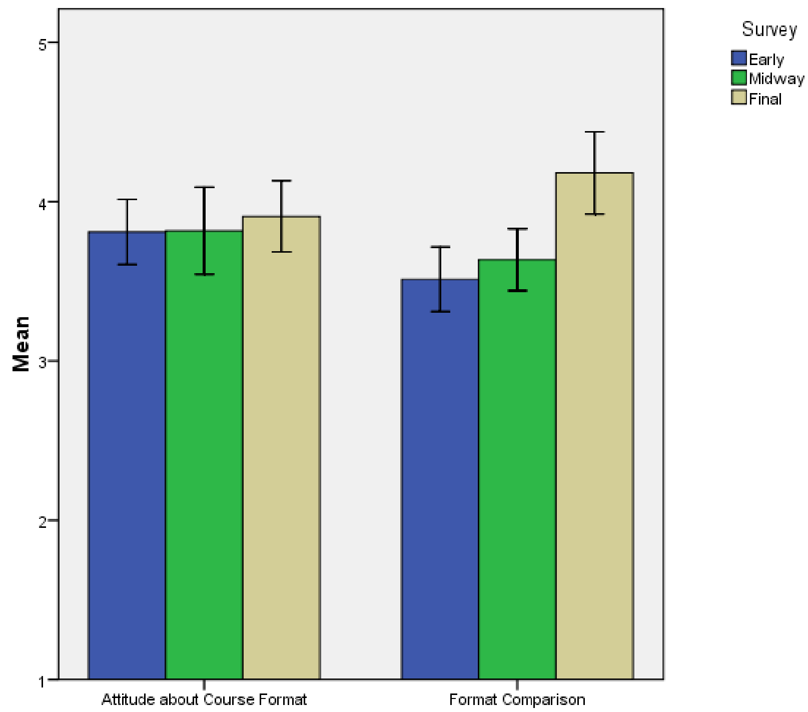

Figure 25 Attitudes and preference for the web lecture course format

We solicited attitudes about HCI from both groups on three dimensions (education, career, and life) using four survey questions:

- How relevant do you view HCI to your education? (Scale: 1—Very Irrelevant to 5—Very Relevant)
- How relevant do you view HCI to your career? (Scale: 1—Very Irrelevant to 5—Very Relevant)
- How likely is it that you will seek out a job that specifically uses HCI? (Scale: 1—Very Unlikely to 5—Very Likely)
- How relevant do you view HCI to your life? (Scale: 1—Very Irrelevant to 5—Very Relevant)

Our rationale for polling students on these measures was two-fold. First, we wanted to know if there were any significant differences between the groups' attitudes about HCI. If one group or the other had more positive attitudes about the subject matter, arguably it could have affected their course performance and consequently threatened the validity of the study. Second, we were interested in how students' attitudes about HCI changed throughout the semester, and—in particular—if one groups' attitudes changed significantly more than the other (*i.e.,* even if both groups started out with the same attitudes, any divergent trends in attitudinal change throughout the semester would be relevant). Figure 26 below illustrates the mean responses by section for all four questions.

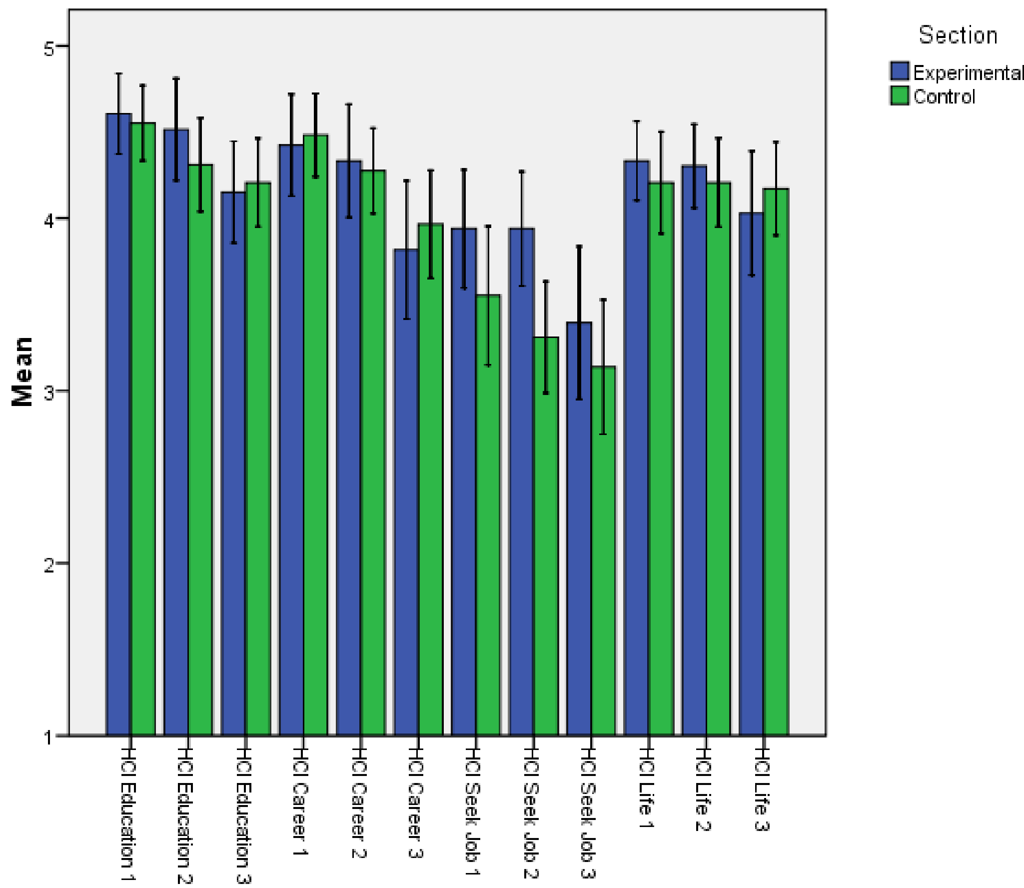

Figure 26 Attitudes about HCI by section over the course of the semester. On the x-axis, each question is listed with the associated, successive survey (1=Early, 2=Midway, 3=Final)

There were no statistically significant differences between groups' incoming (or final) attitudes about HCI (see Appendix D for details of the statistical analysis). Also, both groups' attitudes throughout the semester exhibit a decreasing trend on all measures; the decreases in the means were statistically significant (or marginally insignificant) for the same two questions in both groups: relevance of HCI to education (Experimental: $t(68)=2.190$, $p<.05$; Control: $t(61)=1.802$, $p=.076$), and relevance of HCI to career

(Experimental: $t(68)=2.272$, $p<.05$; Control: $t(61)=2.545$, $p<.05$). Though there was a trend for attitudes to wane as the semester progressed, overall average attitudes remained positive the whole semester for all students.

Students in both sections were also asked questions about the perceived helpfulness of the LHWs (Scale: 1—No Help at All to 5—Definitely Help). More specifically, students were asked if 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. Similar to findings from the first classroom quasi-experiment, both sections reported positively that LHWs helped them focus and learn the lecture material (Figure 27). The control section's attitudes fluctuated throughout the semester, but remained positive. Students in the experimental section reported consistently strong positive attitudes throughout the semester with regards to LHWs helping them focus on the web lecture material, and their perception of how helpful LHWs were in terms of aiding learning increased significantly from the early survey to the final survey ($t(66.596)=-1.765$, $p=.082$). Although both groups reported positively, the experimental group's mean responses were statistically significantly more positive than the control group for the LHW focus question early in the semester ($t(69)=2.187$, $p<.05$), and marginally insignificantly more positive for both questions at the end of the semester (LHW focus: $t(60)=1.646$, $p=.105$; LHW learn: $t(60)=1.669$, $p=.100$). Finally, feedback from the focus group echoed the positive attitude toward LHWs that was evident in survey responses. Some representative comments from students when asked about LHWs include:

- "Excellent! They really get me thinking deeply about the material and are great help when preparing for tests."
- "I really like them. They added a lot to my understanding of each topic, I feel."

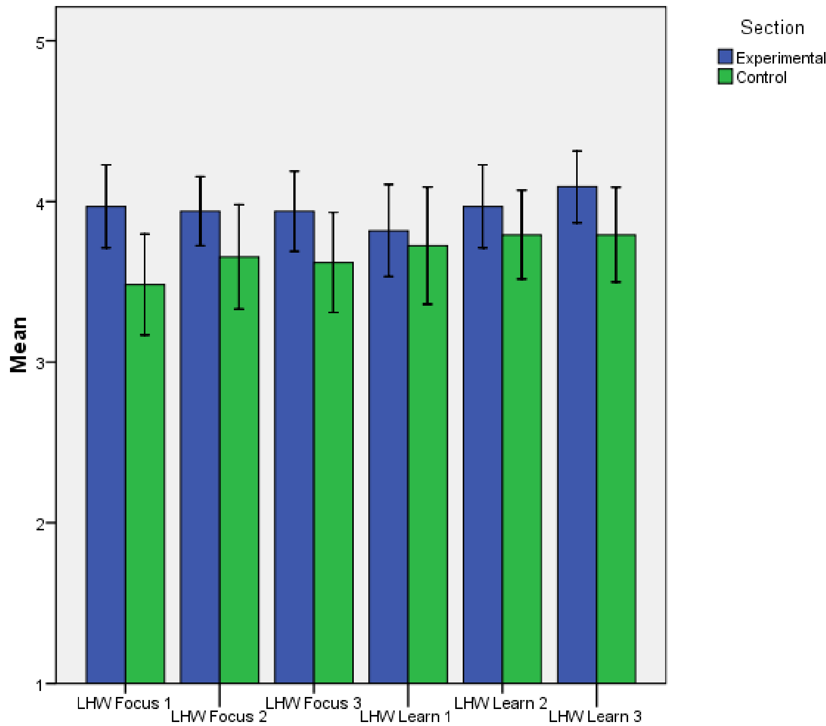

Figure 27 Students' perception of LHWs aiding focus and learning. On the x-axis, each question is listed with the associated, successive survey (1=Early, 2=Midway, 3=Final)

Since both sections were required to used the Web Lecture Forum to complete some LHW questions, all students' opinions were solicited using two survey questions. One questions asked students to rate their overall attitude towards the forum (Scale: 1—Very Negative to 5—Very Positive), and the other asked if the forum aided learning the material (Scale: 1—No Help at All to 5—Definitely Helps). As Figure 28 illustrates, student responses in both groups were negative early in the semester and continue to worsen over time. None of the between-groups mean differences were statistically significant, but within-group mean differences were for the attitude question (Experimental: $t(64)=2.359$, $p<.05$; Control: $t(59)=2.209$, $p<.05$). This result is not wholly surprising considering the very low usage of the forum (see Section 3.4.3.4).

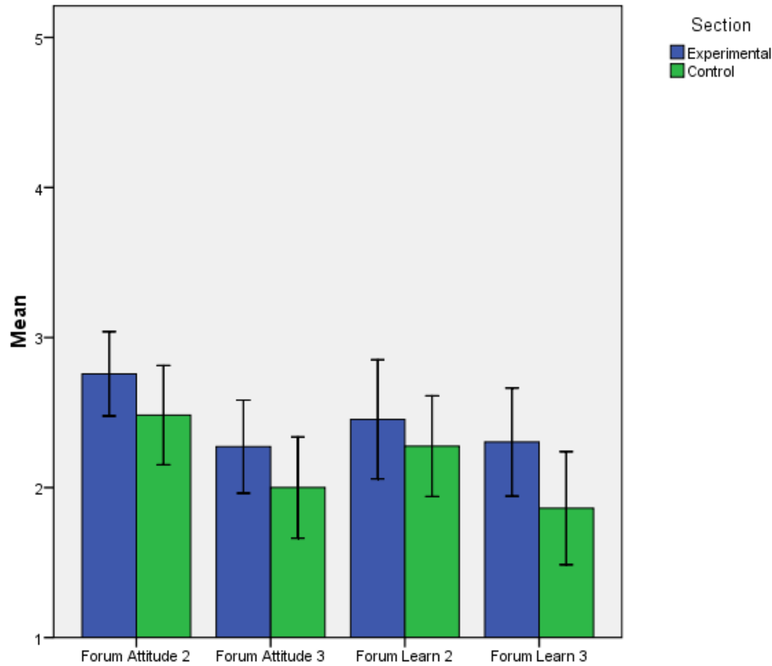

Figure 28 Students' responses to forum-related survey questions. On the x-axis, each question is listed with the associated, successive survey (2=Midway, 3=Final)

In the focus group, experimental students agreed that being "forced" to go somewhere else to post and answer LHW questions was cumbersome[10], and also commented that on-topic discussion independent of LHW posting was likely low because the Web Lecture Forum was introduced primarily in the context of the LHWs at the beginning of the semester. Focus group feedback was echoed in the open-ended survey responses.

Although a validated login was in place to allow only students in the experimental section access to web lectures, there was still a small chance control students viewed web lectures as well. Thus, control students were asked on the final survey if they were aware of the web lectures, and, if yes, how many they viewed over the course of the semester.

[10] Forum use was noted as cumbersome for two different reasons. For some students, it was because a separate username and password were required; for others, the mixture of normal paper-based LHW questions and online activity was undesirable.

Although 10 of 29 respondents (~34%) reported being aware of the web lectures, none reported viewing any. Responses to this question obviated our concern about control students viewing web lectures.

Finally for the Likert-scale questions, the end-of-semester survey asked both sections how much they *learned* in this course compared to other courses and how much they *enjoyed* this course compared to others (Figure 29). On average, experimental students reported positively for both comparative learning (M=4.09, SD=.678) and enjoyment (M=3.91, SD=.980), while control students responses were neutral (*i.e.,* "About the Same") for learning (M=3.00, SD=.598) and slightly negative for enjoyment (M=2.72, SD=.841). Experimental students self-reported learning ($t(60)=6.678$, $p<.001$) and enjoying ($t(60)=5.073$, $p<.001$) this course statistically significantly more than control students.

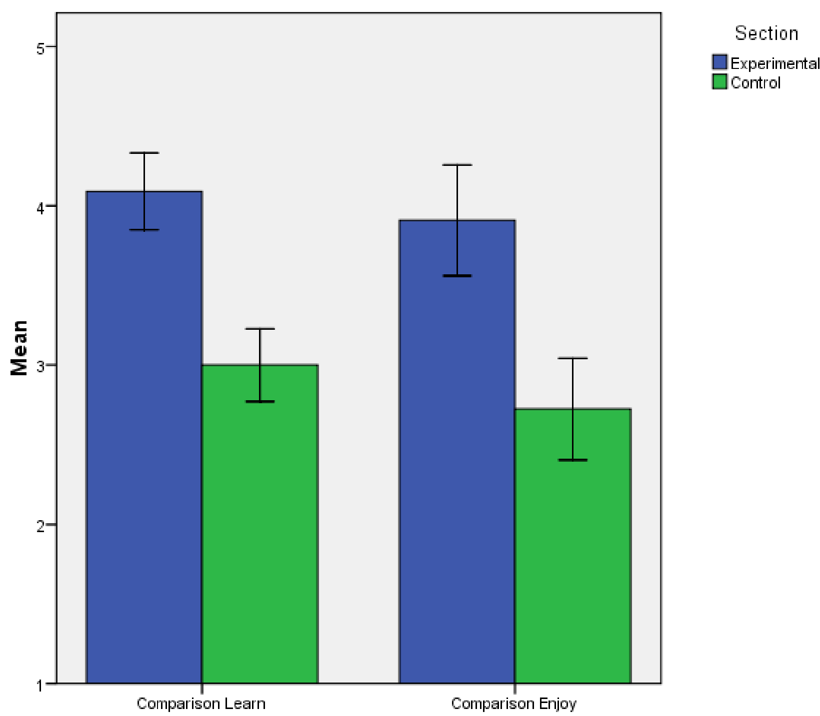

Figure 29 Students' reported learning / enjoyment in this course as compared to other courses (Scale: 1—Much Less to 5—Much More)

In addition to Likert-scale questions, we solicited experimental students' feedback using a few open-ended survey questions. Although a good amount of responses were administrative in nature (*e.g.,* concerns with grading, issues with communication regarding the project) and thus arguably irrelevant to the results of this study, analysis of relevant responses revealed some common themes. For each question, response themes are listed and representative quotes are provided. Full text of all students' responses to open-ended questions is included as Appendix C.

- *What do you like/dislike about using web lectures as part of this course?*

  A number of positive themes were identified in the open-ended response data:

  1. Appreciation for the flexibility afforded by web lectures and the new course format
     - "I like them in that you are free to watch them in a time that more appropriately fits your schedule as opposed to being forced to be somewhere at a designed time..."
     - "I feel like I learn more from this format because I get both lecture and discussion. More than in other classes I've taken, and I like the on-my-own-time nature of online lectures for that kind of necessary teaching."
     - "May watch at my leisure. Can watch multiple times. Can pause when taking notes or tired. More control over when I want to 'attend class.'"
  2. Appreciation for the ability to pause, rewind, or re-watch web lectures
     - "I can stop or review past video things I missed or forgot without hesitation or disrupting the class. If I am tried, I can study the web lectures at a better time for me as far as paying attention / learning. In class, I tend to read/copy lecture notes making me lose focus on the actual lecturer...this helps with the ability to rewind."
     - "Being able to go back for repeated explanations and elaboration on the PPT slides is helpful when I'm studying the web lectures. It allows me to go at my own pace if it's faster or slower than my current level of understanding..."

- "If you missed a piece of information, you can easily use the playback controls to review. I like being able to study more at home but still have time with the prof in class for things other than simply listening to lecture."

3. Appreciation for more time in class dedicated to discussion and other activities
   - "I really like that our time in class is less about me sitting and listening. More classes should be like this."
   - "I really think the outline at the bottom left helps organize the lecture for me. Also, it is really easy for me to take notes because I can pause the lecture, unlike in class where I often get behind. Finally, this approach makes the time in class better because the professor is dedicated fully to interacting with us instead of simply talking at us."
   - "I feel like I have better interaction with the professor even in a big class because of the web lectures taking care of much of the usual talking."
   - "…when we do other things in class besides lecture it's really helpful and fun. It happens more with this course schedule."
4. Appreciation for the video image of the instructor in web lectures
   - "I really like how the PPT slides appear along side the video. It makes the presentation much easier to understand."
   - "I like the freedom online lectures provide, and I like this idea to mix online and in class so I get the best of both. Because of the video in the lecture, I feel sort of like I'm in class anyway."

A couple negative themes were evident in the responses as well:

1. Dislike of reliance on Microsoft technology / OS and browser compatibility issues

- "I like this a lot, except that I have to use MS products."
- "Hate using IE, but otherwise all good."
- "The only thing I don't like is having to use a PC, because I'm a Mac person."

2. Some of the web lectures are too long

- "Sometimes too long. If lectures are more shorter, then will be good. Shorter but more."
- "…Some of the lectures are a bit too long, or maybe assign fewer at a time…"

- *What do you like/dislike about the web lectures forum integrated with the web lectures? How do you feel about making part of the lecture homeworks require posting to the web lectures forum?*

In addition to responses in line with the focus group feedback discussed above, two themes emerged. Theme 2 represents by far the most common response.

1. There was no real need to ask questions during a web lecture, because the beginning of each class meeting was devoted to web lecture Q & A
    - "The forum is pretty useless. I like to just wait to hear the teacher discuss our questions when I get to class. That is much more meaningful."
    - "… I never had any questions that couldn't wait until class met next. Most of the time, any questions I had could be answered simply by going back over a section of the web lecture after I watched through the first time."
2. Students would have been more motivated to participate in the forum beyond the LHWs if the TA and/or instructor had a significant presence

  - “The forum needs to be motivated in other ways beyond the LHW. Nobody uses it other than that…probably because the TA/Prof never had a presence on there.”
  - “One good thing about post/answer a test question HW is that it makes me want to post the BEST question. So, I reviewed the material more for those HWs where we did this exercise. Overall though, not enough buy-in across the teacher/TA/class for this to be fully realized.”

- *As the semester progressed, did your use or attitude about web lectures change? If yes, in what ways and why?*

One positive theme—liking the web lecture intervention more and more over time—was clearly dominant across responses to this question, as the following sample quotes illustrate:

- “I started to enjoy the flexibility of this format more. I learned a lot more in this class than I think I would have the same class taught with normal lectures.”
- “At first, it seemed like a burden. It frees up class time though for other activities and lets you decide when you want to study the lectures, instead of being an obligatory period of time in your day. I learn better some times than others, and this class let me take advantage of that more than others.”
- “I started wishing other profs would do this towards the end of the semester.”

3.6.4 Discussion

Many control measures were in place throughout the entire 15-week duration of this study, and analysis of demographic data, incoming GPA and domain knowledge, attitudes about HCI, and attendance confirmed no significant differences between groups; we are confident in the validity of comparisons between the experimental and control sections of the course examined. Thus, based on the combined comparisons of objective educational outcomes and subjective student attitudes, this quasi-experimental study provides further evidence that *our web lecture intervention is an educationally effective, efficient, and enjoyable alternative to the traditional lecture-based course format*.

In terms of educational effectiveness, students taking the web lecture version of the course performed as good as or better than those taking it taught traditionally with in-class lectures. Experimental students' scored better than control students on average on over 70% of assignments, and final grades were slightly higher. However, average final course grades were not statistically significantly different. In this study, the web lecture intervention clearly did not hinder performance in any way, yet we cannot make a valid claim that it significantly improved performance either.

Though still positive, these results are somewhat tempered when compared to the first classroom quasi-experiment in which web lecture students earned significantly higher grades. There were only two major differences between the first and second classroom studies. First, the web lecture UI was enhanced with question-asking facilities. These facilities were not used at all during web lecture viewing, however. The Web Lecture Forum was used, but only in association with LHWs, which were exactly the same for both groups. Hence, we do not suspect this change had any impact on grades. Second, class size was significantly larger in both sections during the second study. We suspect this difference did impact the effectiveness of the web lecture intervention.

Arguably, larger class sizes would affect a course taught using the web lecture intervention more so than one taught traditionally. The web lecture intervention makes it possible to devote most or all class time to active learning. However, as the number of students increases, the logistics of active learning become more challenging. For example, class discussions can be harder to moderate, adequately monitoring breakout groups can be difficult, and there is less time in which to fit individual / group presentations. In traditional lecture-based courses, where a majority of class time is spent on one-way presentation of subject matter, reduced student-instructor and student-student interactions make class size much less of a factor. Consequently, we conclude from this study that class size is a moderating factor for the effectiveness of the web lecture intervention.

In terms of educational efficiency, this study again found that students taking a web lecture course perform as well or better than traditional lecture students, while attending 25% fewer class meetings. Note that efficiency is used here more in terms of instructor (*e.g.,* fewer lectures to give) and physical resource (*e.g.,* classrooms) economies than student learning time. Based on syllabus changes, partial log data, and student feedback, experimental students spent about the same (or less) time as control students on course activities (in and out of class). However, some minor learning efficiency gains are also suggested by the results of the controlled study of learning with web lectures (see Section 4.4). Finally, this study suggests class size affects efficiency as well as efficacy of the web lecture intervention. More specifically, grading workload increases significantly as the number of students increases. Obviously, this relationship exists for almost any course, regardless of format; however, TAs commented that the workload was greater for the web lecture intervention in particular because of the number of LHWs.

Across almost every dimension measured, students provided strong positive feedback in favor of the web lecture intervention. First, students in the web lecture group self-reported learning *and* enjoying the course significantly more than control students. Almost 82% of experimental reported learning more or much more as compared to other courses (with the remaining 18% reporting learning the same), in contrast with only 13% of control students reporting learning more (with over 75% reporting learning the same). Similarly when rating enjoyment, 66% of experimental students reported enjoying the course more or much more as compared to only 17% in the control.

Second, the perceived usefulness of web lectures for education in general and especially as pre-class study materials was rated highly positively (increasingly so as the semester progressed). Similar positive feedback was reported in terms of overall attitudes toward web lectures and for the navigation controls provided by the web lecture UI. Interestingly, feedback from this study matched previous studies that found students' perceived usefulness of web lecture for review slightly decreased over time. Based on feedback via focus groups and open-ended survey questions, we attribute this trend to students becoming more familiar with web lectures being used as topic introduction rather than topic review. Despite slightly declining attitudes over time, log data indicated students do make moderate use of web lectures for exam review, though access patterns were significantly less pronounced around exams than with other lecture capture systems that were introduced into courses primarily as a means for review (*e.g.,* eClass (Brotherton & Abowd, 2004), Digital VideoJockey (Reuther & Meyer, 1997)).

Third, regardless of course format, students felt they benefited from the use of LHWs. Specifically, students in both sections rated LHWs positively in terms of helping focus on and learn the material being presented, with the experimental section reporting significantly stronger positive attitudes. These survey results, along with similarly strong positive feedback collected via the focus group and open-ended survey questions, validate our use of LHWs as focus / learning-beneficial synthesis exercises that serve as pedagogical linking mechanisms between pre-class and in-class activities in the web lecture intervention. Moreover, log analysis also suggests LHWs successfully served as explicit motivation for students to study web lectures before attending class. Beyond being a positive result for the web lecture intervention, these data are also encouraging in the larger sense that—even though LHWs essentially represent more work—students like them.

Feedback about the Web Lecture Forum, on the other hand, was not positive. In fact, students in both sections reported strong negative attitudes toward forum use. The forum was implemented originally to act as a technological link between students studying web lectures individually with subsequent in-class activities; it was one of two additions to the web lecture UI that enabled students to easily submit questions about web lectures during viewing. Although these capabilities were added in response to student feedback, students did not feel the need to use them once implemented (recall zero questions were submitted during web lecture viewing). As discussed above, experimental students felt that if they had questions they could simply wait to ask them during the next class meeting. Since the Web Lecture Forum was not used at all during web lecture viewing, we assume that students' negative attitudes toward the forum were based primarily on its forced integration as part of LHWs. We attribute these negative attitudes to two primary factors:

- Too little TA/instructor participation in the forums
- Cumbersome procedures required for forum postings to be graded

First, many students expressed the need for a TA and/or instructor presence on the forum; students are simply less motivated to participate in out-of-class discussion if they don't feel like their contribution will be recognized by the TA/instructor (*e.g.*, (Ruhleder, 2004)). We consider the need for increased TA/instructor participation in the forums a lesson learned for future deployments of the web lecture intervention. Second, in order to blind grade LHWs, students were required to not only post in their section's forum, but also to copy relevant postings to each LHW. Understandably, this procedure was considered cumbersome, and it also made students feel that posting to the forum was essentially worthless (especially considering the lack of TA/instructor presence). In typical, non-experimental deployments of the web lecture intervention, the blind grading control would not be required and increased TA/instructor participation would be fairly easily established, thus we believe forum integration will likely be received more positively by students.

Finally, when asked about their overall attitude about the web lecture intervention, experimental students responded very positively. Students provided a number of reasons for their positive attitudes in open-ended survey questions and the focus group. In particular, students felt that the course format associated with the web lecture intervention allowed them to take advantage of both in-class and out-of-class instruction; they expressed appreciation (in terms of learning and enjoyment) for the in-class activities made possible by web lectures[11], and also commented very frequently on the benefits in terms of flexibility of web lectures themselves and the intervention as a whole. Thus, it is not surprising that when asked to compare the web lecture format to the traditional lecture format, experimental students strongly favored the web lecture format. Responses became increasingly positive, with over 75% of experimental students indicating the web lecture format was better or much better than the traditional lecture format by the end of the semester—not a single student in the web lecture section indicated a preference for the traditional lecture format.

3.7 Conclusions

Over a four-year period, this dissertation work has included five naturalistic investigations of student learning with our web lecture intervention used in CS3750: two formative studies, a large-scale pilot study, and two quasi-experimental studies. The following list briefly summarizes our major findings and lessons learned from all of those studies:

- Satisfactory web lectures can be created with modest faculty time and inexpensive equipment; once created, web lectures can be used for multiple semesters with no additional faculty time or monetary investment.

[11] As in previous classroom studies, students commented that the UI "Hall of Fame / Shame" was their favorite in-class activity of the semester.

- Web lectures should be kept around 20 minutes in length each. This guideline is espoused in relevant psychology and physiology literature (Bligh, 1998), and student feedback in all our studies suggested this as well.
- Students prefer studio-recorded video of the presenter in web lectures over recordings from live classroom lectures.
- Web lectures are best viewed individually, outside of and before class. Access logs indicate students do generally study web lectures as assigned before attending class.
- Lecture homeworks (LHWs) are rated positively by students in terms of aiding focus and learning. As part of the web lecture intervention, LHWs can be used successfully as:
    - Explicit motivators for studying web lectures
    - Synthesis exercises that help students focus on and learn the material being presented
    - Pedagogical linking mechanisms for pre- and in-class activities
- Question-asking facilities built into the web lecture UI are not used by students while studying web lectures. Also, integration of the Web Lecture Forum as part of LHWs was not positively received, but increasing TA/instructor participation and eliminating the cumbersome turn-in process will likely improve this aspect of the intervention.
- Students have positive attitudes toward web lectures in advance of class and for education in general; attitudes become increasingly positive as the semester progresses.
- Students' attitudes towards web lectures for exam review remain positive throughout the semester, but decrease slightly as the semester progresses.

Access logs indicate moderate use of web lectures specifically for exam review.

- The web lecture intervention makes it possible to dedicate more class sessions to active learning. Class activities made possible by web lectures are rated positively by students both in terms of educational value and enjoyment; the UI "Hall of Fame / Shame" activity is consistently considered the favorite class of the semester.
- Students highly praise the flexibility afforded by web lectures and the web lecture intervention, and express a significant preference for the web lecture course format over the traditional lecture course format.
- Class size might be a mitigating factor: Though always evaluated as successful from the standpoint of both educational outcomes and student feedback, the positive effects of the web lecture intervention decreased slightly as class size increased in our studies.
- Web lecture students self-report learning more from and enjoying the course more than students taking the same course taught using traditional lectures.
- Students taking the course using the web lecture format earn the same or higher course grades than students taking the course using the traditional lecture format, while attending 25% fewer classes.
- Economies in terms of instructor time and classroom resources can be achieved by using the web lecture intervention, because equivalent or improved educational outcomes can be achieved with significantly fewer face-to-face class meetings.

3.8 Summary

We used a synthesis of quantitative data (*i.e.*, course grades, log files) and qualitative data (*i.e.*, surveys and focus groups) from multiple longitudinal naturalistic studies to understand learning with the web lecture intervention. With these studies, we were particularly interested in determining the effects of teaching a course using the web lecture intervention as compared to teaching a course using traditional in-class lectures. These effects were primarily evaluated using objective learning outcomes (as measured by course grades) and subjective perceptions of enjoyment and learning. Thus, the results of these classroom studies—especially the two quasi-experimental studies—provide evidence in support of the claim that a course taught using the web lecture intervention produces 1) the same or better objective learning outcomes and 2) the same or better subjective enjoyment and perceived learning, than a course taught using the traditional lecture format. These results were more pronounced in the study in which fewer students were enrolled, which suggests a potential (and common sense) limit to the scalability of the web lecture intervention. Regardless of class size, however, all of our classroom studies found the web lecture intervention was received positively by students on almost every dimension measured (usually increasingly so as the semester progressed), and course performance was unchanged or increased while attending 25% fewer class meetings.

CHAPTER 4

EXPERIMENTAL INVESTIGATIONS OF LEARNING WITH WEB LECTURES

To complement our primary focus on studying the web lecture intervention in naturalistic classroom contexts, we also investigated learning with web lectures as standalone learning objects in a more controlled laboratory setting. In this chapter, we provide some motivation for studying web lectures experimentally, details of the experimental design, the results of the study, and a discussion of the experimental outcomes.

4.1 Motivation and Hypothesis

As discussed in Section 2.2, our approach to this dissertation research was guided by the DBL-based claim that a combination of classroom and laboratory studies provides the best of both worlds in trying to pinpoint factors that are important for effective web lectures and to validate those factors in genuine educational settings (and vice versa). The positive results of early classroom studies begged the questions of what contribution, if any, the web lectures themselves were lending to the observed learning gains of the web lecture intervention as a whole, and how they might be improved. More specifically:

- Are web lectures any more or less effective or efficient than other similar multimedia instructional materials? Does the video add educational value? The audio? Or would simple PPT slides be as effective as web lectures?

CLT and CTML provide theoretical frameworks that can inform the experimental investigation of differences in learning efficacy with information-equivalent multimedia presentations using various combinations of modalities (*e.g.*, audio, video, text) (see Section 2.3.1.1). It is important to clarify that the questions we were interested in answering with this study relate to *multimedia* effects, as opposed to simple *media* effects. Research questions for multimedia effects—such as those espoused by CLT/CTML—investigate meaningful learning as part of learners' active knowledge construction. Media effects research (Clark, 1994; Kozma, 1994), on the other hand, concerns comparisons of medium (*e.g.,* computer vs. book) and is based on an information-delivery view of learning. The latter approach has lost hold in the educational psychology community based on empirical, methodological, conceptual, and theoretical problems (R. E. Mayer, 1997).

In this controlled study, the independent variable was the combination of modalities used by each presentation. The three information-equivalent conditions were: Video+Audio+PPT (VAP), Audio+PPT (AP), and PPT+Transcript (PT); and a fourth information-nonequivalent condition, PPT-Only (PO), was included as well. The VAP presentation was *exactly* the same as the web lectures used in classroom studies. The dependent variable was performance on a posttest that assessed participants' retention *and* transfer of the subject matter presented. Subjective attitudinal data were also collected with an exit survey.

Of the information-equivalent conditions, the VAP and AP conditions follow many, but not all, of the design guidelines suggested by CLT and CTML (see Section 2.3.1.1). The AP condition is arguably as or more effective than the VAP condition, because it adheres to all the positive effects of VAP, without the possibility of negative split-attention / coherence effects. The PT condition does not adhere to as many of the guidelines, and suffers from obvious negative modality effects (*i.e.*, overloading the visual channel with PPT and transcript text); it is therefore likely to cause high, learning-detrimental cognitive load. Thus, our hypothesis—*based on analysis using CLT/CTML principles alone*—was the following: posttest performance for the AP condition will be better than or equal to the VAP condition, the PT condition performance will be worse than VAP and AP, and the information-nonequivalent PO condition will produce the worst performance of all four conditions (*i.e.,* AP >= VAP > PT > PO).

In addition to allowing us to evaluate the effectiveness of web lectures as standalone learning objects in comparison to other similar multimedia learning objects, this study yielded data useful in determining whether CLT and CTML guidelines are applicable to multimedia instructional material somewhat different from those used in the development of the theories. The multimedia materials used in CLT and CTML studies were primarily textbook-like diagrams with audio or textual descriptions and short (less than 1 minute) presentations using animations with audio or textual descriptions; mathematics and cause-effect explanations (*e.g.*, how lightning forms, how brakes function) were common subject matter. In contrast, the multimedia presentations used in this study were much longer (almost 12 minutes). This difference in presentation length might be significant, considering the application of these theories has been called into question for lengthy multimedia presentations by Zolna and Catrambone (Zolna & Catrambone, 2005). Additionally, the VAP condition includes video of a human presenter, and although diagrams are used on the PPTs, no animations (other than the text highlighting) were present. Finally, the subject matter in this study was not mathematical or based on causal explanations, and a navigable TOC was provided.

4.2 Experimental Design

In this section, we outline the research design for the experiment. Full text of the materials used in the experimental protocol (*e.g.*, surveys, posttest) is included in Appendix E.

4.2.1 Experimental Conditions

The modality distribution of the four experimental conditions is shown in Table 9 below.

Table 9 Summary of modality distribution in experimental conditions

	Video	Audio	Text Transcript	PPT
Video+Audio+PPT (VAP)	X	X		X
Audio+PPT (AP)		X		X
PPT+Transcription (PT)			X	X
PPT-Only (PO)				X

The VAP condition was a combination of video, audio, and PPT, exactly like a web lecture; the AP condition was the exact same web lecture, except that audio narrative was present without video of the presenter; the PT condition was a standard PPT presentation with a transcription of the audio narration used in the VAP and AP conditions; and the PO condition was a standard PPT presentation (*i.e.,* the same set of slides used in all the other presentations). The VAP, AP, and PT conditions were all information-equivalent—only the combination of modalities in the presentation was manipulated—and the PO condition is a quasi-control condition used as a baseline for the kind of instructional material typically available to students before class. Note that the PO condition is not information-equivalent like the other three conditions; it is missing narration information that the other conditions present in one modality or another. Other combinations of modalities (*e.g.*, video and PPT without audio, audio and video without PPT) and/or other conditions (*e.g.*, a text excerpt) could be studied; the four selected for this experiment were chosen because we felt they were the most likely modifications to a web lecture and were the most frequently asked about by paper reviews, interested parties, *etc.* Figure 30 provides a screenshot of all four presentations used in the study.

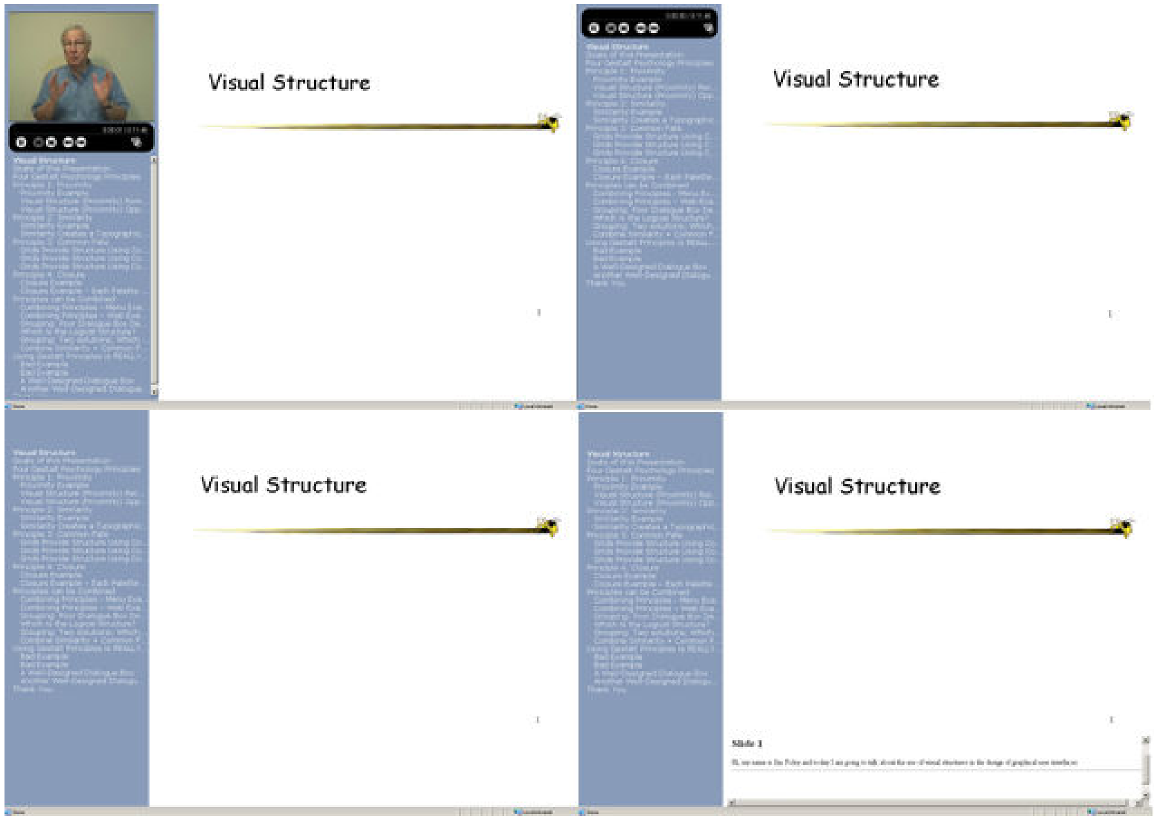

Figure 30 Multimedia presentation conditions used in the laboratory experiment. Clockwise from top-left: VAP (Video+Audio+PPT: web lecture), AP (Audio+PPT), PT (PPT+Transcript), and PO (PPT-Only)

4.2.2 Multimedia Instructional Materials

For the topic of the educational materials, we selected visual design—a presentation on the use of visual structure principles to inform UI design. This topic was selected because we felt it would be learnable by participants with no prior knowledge of UI design. Thirty PPT slides were used to describe four basic ideas of Gestalt perception (similarity, proximity, good continuation, and closure) and how those principles apply to UI design. Many of the PPTs included images illustrating a particular visual design principle or UI exemplar. The video used in the VAP condition was recorded in our web lectures mini-studio by Prof. Foley; slide transition timing from the video session was applied to all conditions. The audio for the AP condition was stripped from the VAP video, and that audio was transcribed for use with the PT condition. All conditions were presented within the Microsoft Producer interface, which included the navigable TOC. The full (uninterrupted) running time of all presentations was 11 minutes and 45 seconds.

4.2.3 Study Participants

All study participants were recruited from the Georgia Tech psychology subject pool via the Experimetrix website. Eligible participants had no prior coursework with the presenter and had not taken any HCI courses.

4.2.4 Experimental Protocol

The experiment was conducted in the Georgia Tech GVU Center usability lab. The participant area is equipped with two relatively new Windows PCs with 17-inch flat-panel LCD monitors. Upon arriving at the usability lab, each participant was randomly assigned to an experimental condition and taken through the following protocol:

1. Scripted introduction and tutorial on how to view the educational material
2. Entrance survey
3. Up to 20 minutes to study material for the randomly assigned condition
4. Up to 20 minutes to complete a 2-part posttest on the materials
5. Exit survey

The total session length was 60 minutes or less.

4.2.5 Scripts and Tutorials

To assure that each participant received that exact same information, a script was created for each condition. The scripts for each condition differed only when addressing the particulars of the educational materials determined by the condition. The scripts summarized the purpose and procedure of the study and provide a condition-specific tutorial for the controls and use of the multimedia presentation. To ensure participants were not exposed to presentation content before the session actually began, paper screenshots that display only the title slide were used during the tutorials.

4.2.6 Entrance Survey

The purpose of the entrance survey was to collect demographic data, serve as a redundant screen for incoming HCI coursework, and query participants' incoming experience with and attitudes about multimedia instruction.

4.2.7 Exposure to Instructional Materials

Participants' maximum time with the educational materials was limited to 20 minutes—about 12 minutes for a full viewing and about 8 minutes to review. At any time during the session, a participant could notify the experimenter that they were finished reviewing the materials and were ready to take the posttest. If a participant had not signaled within 20 minutes, the experimenter closed the participant's presentation and administered the posttest. The amount of time each participant spent studying the materials was recorded so that each condition could be evaluated in terms of learning *efficiency* in addition to learning *efficacy*. Thus, even if no difference in posttest scores were evident across the conditions, we had data useful for determining if one or more conditions required significantly more or less time to match the posttest performance of the others.

4.2.8 Testing Instrument

The objective dependent measure of educational effectiveness across conditions was based on posttest performance; all participants in all conditions completed a posttest with identical questions. Similar to those used by Mayer (Richard E. Mayer, 2001), the posttest used in this study consists of two separate learning assessment tests: a retention test with 18 questions and a transfer test with 5 questions. The retention test—comprised of questions in multiple choice, fill in the blank, and true/false formats—was administered using a web-based application. Questions were presented one at a time; participants were not permitted to go back to previous questions, and an answer was required for all questions. Participants were informed before taking the posttest that scoring was based on the number of correct answers. The paper-based transfer test was administered after participants finished the retention test. Because three of the questions on the transfer portion asked participants to critique UI screenshots, it was administered on paper so that participants could easily circle a section of interest quickly, draw suggestions directly on the screenshots, *etc.* The transfer portion consisted of questions that required participants to apply and extend the ideas presented in the lecture to novel problems, whereas the retention portion consisted of questions about information specifically covered in the PPT slides. Participants were allowed up to 20 minutes to complete *both* the retention *and* transfer portions of the posttest. The time each participant took to complete each portion of the posttest was also recorded for use in subsequent analysis.

All retention posttest questions were created based on information on the PPT slides *before* the audio/video was recorded. This was done to ensure that all questions could be answered from slide content alone. For instance, the slide shown in Figure 31 provides the answer to the following fill in the blank retention question:

> Which two principles can be combined to create a *stronger* typographical hierarchy? ___________and _____________

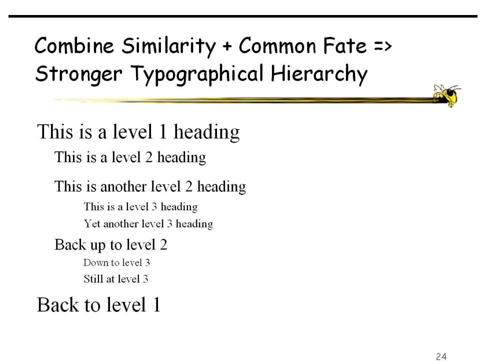

Figure 31 Example slide that provided information necessary to answer a question on the retention portion of the posttest

Because the questions on the transfer portion of the posttest were intended to assess participants' understanding and application of the principles covered in the presentation, the information needed to answer the transfer questions was not *explicitly* included in the slides as it was for the retention questions. However, relevant examples of applying the principles were included in the PPT slides that should have adequately prepared participants to answer the transfer questions. Consider, for example, the slide shown in Figure 32, and the following transfer question:

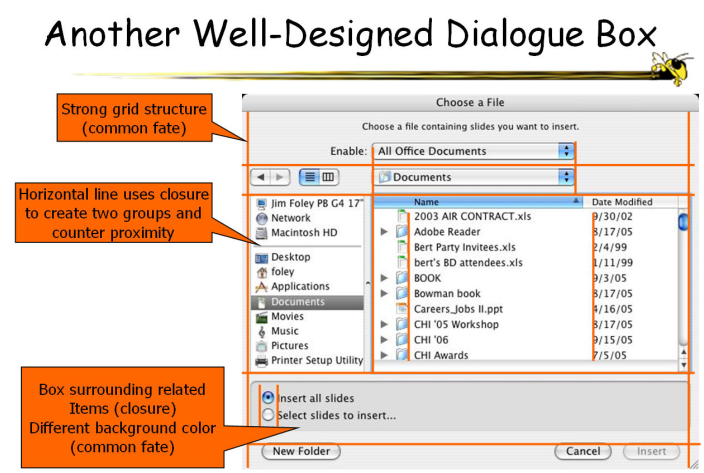

Figure 32 Example slide that provided a UI critique that could be similarly applied to answer a question on the transfer portion of the posttest

> In terms of visual structure, would you consider the UI screenshot below (Figure 33) good, bad, or a little of both? Use the four principles of visual structure discussed in the presentation to **justify your answer**.

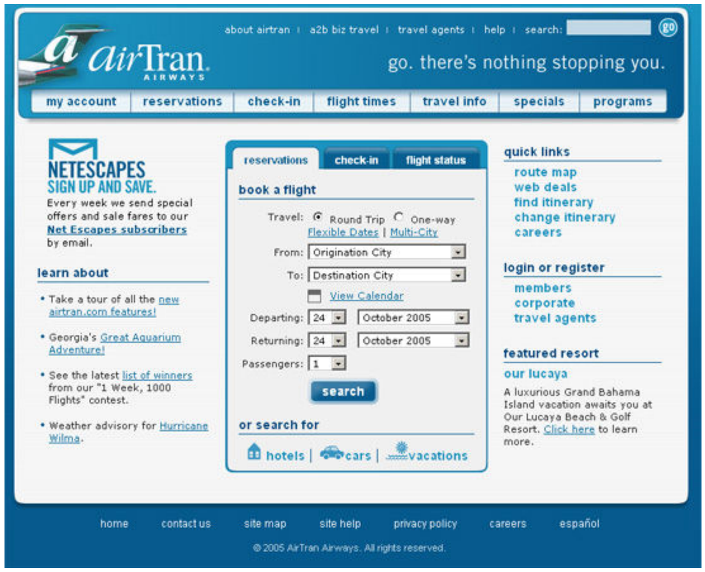

Figure 33 UI screenshot provided for critique on the transfer portion of the posttest

For purposes of scoring, each question on the transfer test was broken down into the smallest objective parts possible, to come up with a standard, objective scoring scheme. For example, consider the following transfer question:

> Sketch a simple representative example (not used in the PowerPoint presentation) of one of the four principles discussed in the presentation. Identify the principle and explain your example.

This question was worth 3 points, scored as follows: 1 point for a representative sketch not used in the PPT, 1 point for correctly labeling the principle, and 1 point for a correct and adequate explanation of the given example.

Two members of the research team independently developed a set of acceptable answers before the experiment was conducted. After all participants were run through the experimental protocol, each scorer revised the set of acceptable answers based on a review of the range of participant responses. These answer sets were then reconciled to come up with a final set of acceptable answers. Each scorer then scored a subset of the transfer tests independently, using the objective scoring scheme and set of acceptable answers. To assure inter-rater reliability, consistency across scorers was compared, and the process was repeated as needed until scoring differences were less 5%. Also, to control for bias during grading, all posttests were scored condition-blind.

4.2.9 Exit Survey

The exit survey was a mixture of Likert-scale and open-ended questions used to query participants' subjective attitudes about the multimedia instructional materials provided based on their randomly assigned condition.

4.3 Study Results

This section presents the results of the multimodal learning experiment, including participant demographics and analysis of posttest performance and survey responses. Throughout, statistical significance was determined using alpha = .05. For more details on the analysis, see Appendix G.

4.3.1 Study Participants

A total of 120 subjects participated in this study: 30 in each condition. Table 10 below summarizes sex and age demographic data. Clearly, cell sizes of 30 were adequate to produce an evenly distributed sample across gender and age.

Table 10 Sex distribution and mean age

	Sex		**Age**	
	Male	Female	***M***	***SD***
Video+Audio+PPT (VAP)	15	15	19.23	1.79
Audio+PPT (AP)	15	15	19.73	1.93
PPT+Transcription (PT)	15	15	19.97	1.61
PPT-Only (PO)	16	14	19.73	1.95
All Conditions	61	59	19.67	1.82

Academic year and major data were also collected with the entrance survey. As expected considering the mean age of 19.67, the largest percentage of participants (36.67%) reported freshman standing at the time of the experiment. However, as Figure 34 below illustrates, there were a significant number of sophomores, juniors, and seniors, as well as 2 graduate students. There was a wide distribution of majors among participants: 27 unique majors ranging from aerospace engineering to undecided. The most common majors were management (19.17%), industrial engineering (13.33%), and biology (10.83%). Figure 35 below illustrates the distribution of majors across the entire sample, with any major representing less than 3% of the total collapsed into the 'Other' category. Although the year and major pie graphs illustrate data for the whole sample, both year and major data were distributed relatively evenly across each of the experimental conditions. Chi-Square tests confirm no significant differences among conditions for the distributions of sex ($X(3)$=.100, p=.992), age ($X(24)$=26.027, p=.352) , year $X(12)$=10.132, p=.604), or major ($X(78)$=70.630, p=.711) .

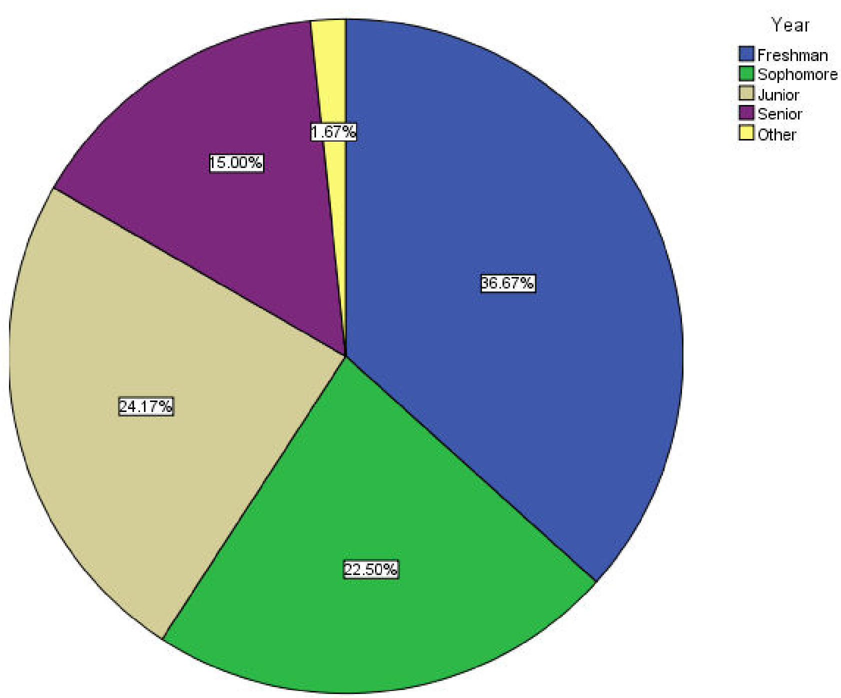

Figure 34 Distribution of academic year across the sample

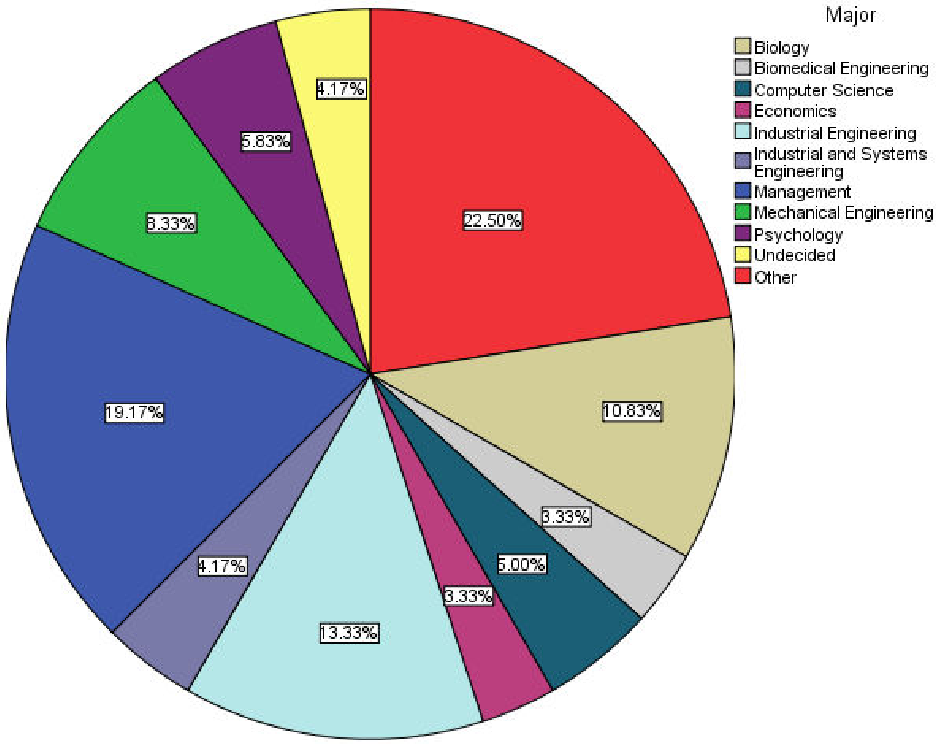

Figure 35 Distribution of major across the sample

Finally, the entrance survey solicited participant self-reports of past experience with educational technology / multimedia educational materials. Figure 36 below illustrates the distribution of responses across the sample, and Figure 37 the breakdown of average responses by condition. As the figures indicate, most participants reported having experience with educational technology (86.67% including responses Not Very Much/ Some / Quite a Bit), with only a small number of participants having a lot (4.17%) or no (9.17%) experience. A one-way ANOVA verified that there were no significant differences among the mean responses by condition ($F(3, 116)=.195$, $p=.899$, $MSE=1.08$).

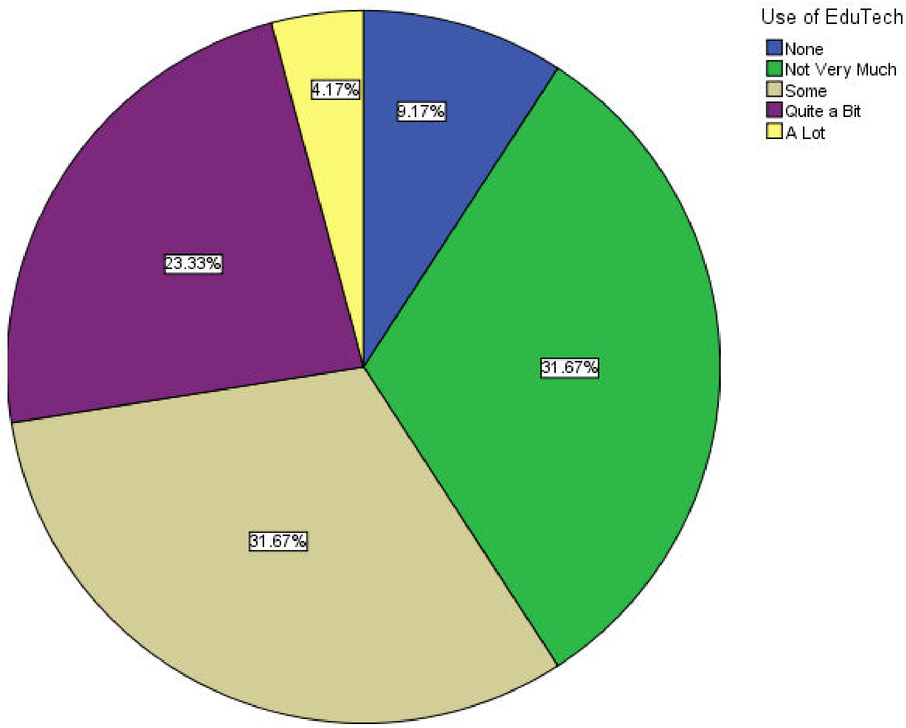

Figure 36 Distribution of responses to the 'experience with educational technology' entrance survey question for the sample

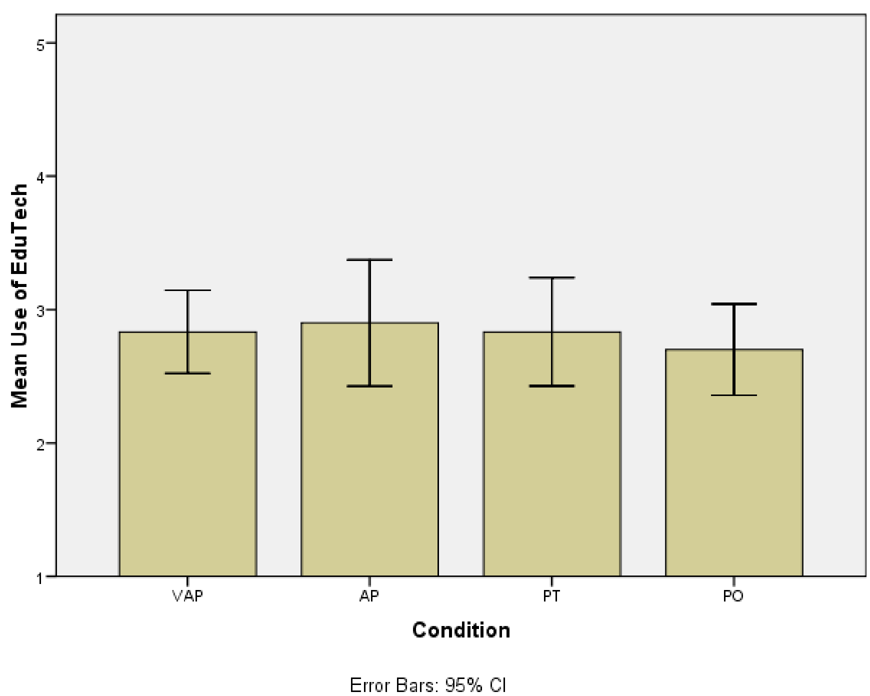

Figure 37 Average responses to the 'experience with educational technology' entrance survey question by condition (Scale: 1–None to 5—A Lot)

4.3.2 Presentation Review and Posttest Time

Participants were allowed *up to* 20 minutes to study the educational material (recall that the running time for all presentations was 11 minutes 45 seconds), and *up to* 20 minutes to complete the entire posttest (both retention and transfer portions). The average times taken for review and posttest completion are displayed in Table 11 below.

Table 11 Average times (in minutes) for review and posttest completion. Values in parenthesis after means indicate the number of participants who used the full 20 minutes allowed for study / posttest completion

	Study Time		**Retention Test Time**		**Transfer Test Time**		**Overall Posttest Time**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Video+Audio+PPT (VAP)	15.83 (7)	3.13	3.73	1.28	13.17	2.28	16.87 (2)	2.08
Audio+PPT (AP)	16.27 (5)	2.68	4.47	1.83	13.90	2.52	18.37 (14)	2.30
PPT+Transcription (PT)	16.17 (6)	3.06	4.40	1.75	13.03	2.65	17.43 (15)	3.02
PPT-Only (PO)	14.70 (3)	3.16	4.73	2.12	12.80	3.45	17.43 (12)	3.37
All Conditions	15.74	3.04	4.33	1.79	13.23	2.75	17.53	2.76

Of the information-equivalent conditions, VAP participants spent the least amount of time on average reviewing the presentation, completing the retention portion of the posttest, and completing the posttest as a whole; participants in the PT condition were the quickest to complete the transfer portion of the posttest; and AP participants spent the most time on all four metrics provided. When the PO condition is considered with the other information-equivalent conditions, we see that those participants spent the least time reviewing and taking the transfer test, but took the longest to complete the retention test. Although some differences in means are visible (and interesting) from the descriptive statistics, none of the time metric means were significantly different when compared using one-way ANOVAs:

- Review Time: $F(3, 116)=1.705$, $p=.170$, $MSE=9.091$

- Retention Time: *F*(3, 116)=1.726, *p*=.165, *MSE*=3.141
- Transfer Time: *F*(3, 116)=.889, *p*=.449, *MSE*=7.609
- Overall Posttest Time: *F*(3, 116)=1.539, *p*=.208, *MSE*=7.527

A visual representation of these time metrics is provided in Figure 38 below.

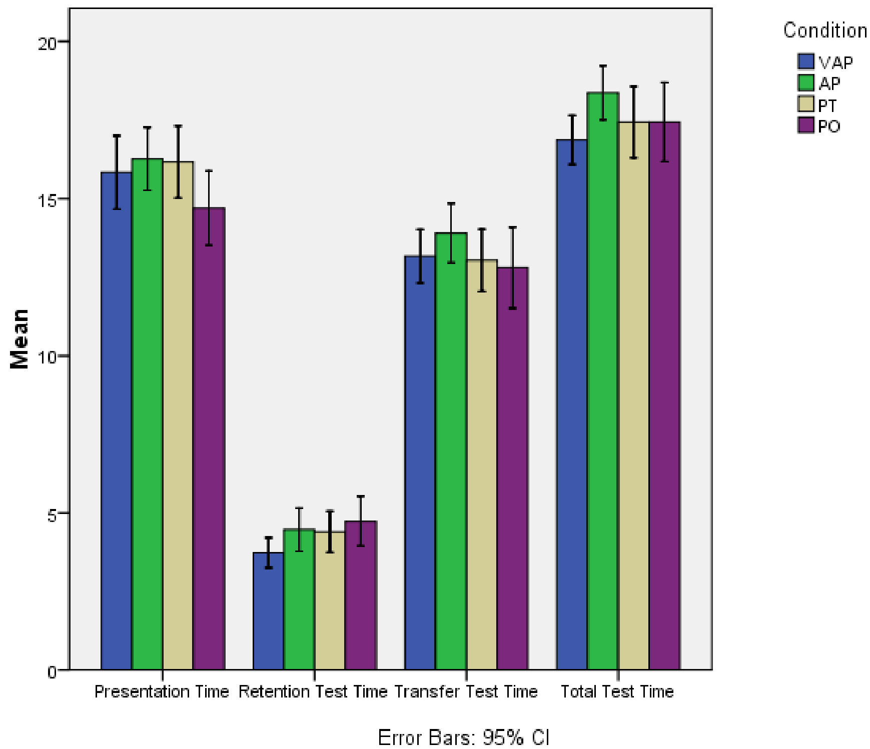

Figure 38 Average time metrics (in minutes) by condition

4.3.3 Posttest Performance

Scores by condition for the retention and transfer tests (and the combined overall posttest scores) are reported in Table 12 below. The retention and transfer tests were both scored out of 20 points; the overall test score is simply the sum of the retention and transfer tests (40 points).

Table 12 Average posttest performance

	Retention Test		Transfer Test		Overall Posttest	
	M	***SD***	***M***	***SD***	***M***	***SD***
Video+Audio+PPT (VAP)	18.30	1.15	17.10	2.11	35.40	2.57

Audio+PPT (AP)	16.63	2.09	14.07	3.45	30.70	4.52
PPT+Transcription (PT)	15.60	2.53	13.55	3.67	29.15	5.53
PPT-Only (PO)	14.87	2.79	13.32	3.63	27.18	5.50
All Conditions	16.35	2.55	14.26	3.69	30.61	5.54

Both retention and transfer test scores were the highest for participants in the Video+Audio+PPT condition, followed by those in the Audio+PPT condition, the PPT+Transcript condition, and participants in the PPT-Only condition scored the lowest. Overall posttest performance is visually represented in Figure 39 below.

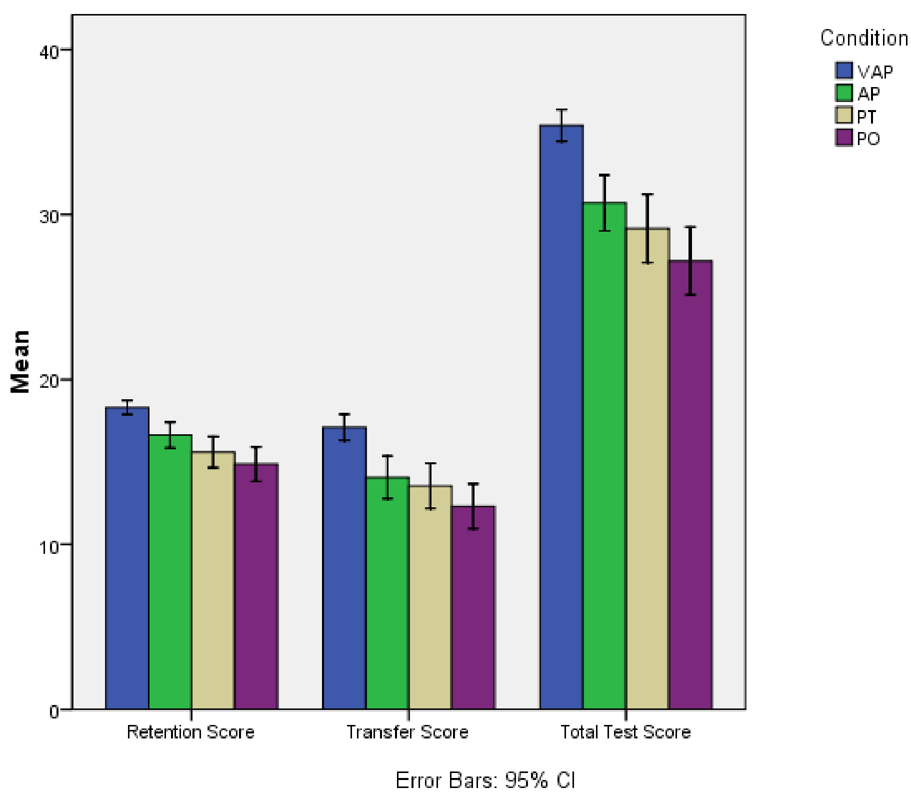

Figure 39 Posttest performance by condition. Retention and transfer scores are out of 20 possible points, and total test scores are out of 40

One-way fixed effects ANOVAs revealed significant differences in the means for the retention test ($F(3, 116)=13.385$, $p<.001$, $MSE=4.965$), the transfer test

($F(3,116)=11.529$, $p<.001$, $MSE=10.741$), and the overall posttest ($F(3,116)=16.77$, $p<.001$, $MSE=21.960$). Using the Tukey HSD post hoc multiple comparison procedure (MCP), we verified that participants in the VAP condition scored significantly higher on the retention, transfer, and—naturally—overall posttest than participants in the other three conditions. The only other statistically significant mean differences indicated that participants in the AP condition scored higher than those in the PO condition on the retention portion of the posttest and on the overall posttest, but not on the transfer test. The p-values for all pair-wise comparisons are presented in Table 13 below.

Table 13 Tukey HSD MCP for posttest scores by condition

Dependent Variable	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.
Retention Score	VAP	AP	1.667*	.575	.023
		PT	2.700*	.575	.000
		PO	3.433*	.575	.000
	AP	VAP	-1.667*	.575	.023
		PT	1.033	.575	.280
		PO	1.767*	.575	.014
	PT	VAP	-2.700*	.575	.000
		AP	-1.033	.575	.280
		PO	.733	.575	.581
	PO	VAP	-3.433*	.575	.000
		AP	-1.767*	.575	.014
		PT	-.733	.575	.581
Transfer Score	VAP	AP	3.0333*	.8462	.003
		PT	3.5500*	.8462	.000
		PO	4.7833*	.8462	.000
	AP	VAP	-3.0333*	.8462	.003
		PT	.5167	.8462	.929
		PO	1.7500	.8462	.170

Table 13 continued

	PT	VAP	-3.5500*	.8462	.000
		AP	-.5167	.8462	.929
		PO	1.2333	.8462	.467
	PO	VAP	-4.7833*	.8462	.000
		AP	-1.7500	.8462	.170
		PT	-1.2333	.8462	.467
Total Test Score	VAP	AP	4.7000*	1.2099	.001
		PT	6.2500*	1.2099	.000
		PO	8.2167*	1.2099	.000
	AP	VAP	-4.7000*	1.2099	.001
		PT	1.5500	1.2099	.577
		PO	3.5167*	1.2099	.022
	PT	VAP	-6.2500*	1.2099	.000
		AP	-1.5500	1.2099	.577
		PO	1.9667	1.2099	.368
	PO	VAP	-8.2167*	1.2099	.000
		AP	-3.5167*	1.2099	.022
		PT	-1.9667	1.2099	.368

*. The mean difference is significant at the 0.05 level.

As reported above, there were no significant differences among conditions when looking at the gender, age, year, presentation time, and total test time factors individually. However, to be sure the combination of these factors did not somehow significantly affect posttest performance, we also ran a univariate ANOVA analysis with overall posttest score as the dependant variable; condition as the fixed factor; and gender, age, year, presentation time, and total test time were included in the model as covariates. Essentially, the results from this analysis were the same: there was a main effect of condition on overall posttest performance ($F(3, 112)=16.275$, $p<.001$, $MSE=21.067$), and a MCP analysis verified VAP posttest means were significantly higher than all other conditions. Although, when including the covariates, no other pair-wise comparisons were statistically significant (*i.e.,* AP overall posttest means were no longer significantly higher than PO, *p*=.084).

4.3.4 Exit Survey – Likert-scale Questions

All 120 participants responded to all Likert-scale questions on the exit survey. Table 14 provides an overview of responses to selected questions, and Figures 40 and 41 provide visual representations of means and response frequencies for each question / condition. The text for each question was as follows:

- Q1) In terms of your general learning, how would you rate the effectiveness of the educational materials you were provided? (Scale: 1—Very Ineffective to 5—Very Effective)
- Q2) In terms of preparing you for the posttest, how would you rate the effectiveness of the educational materials you were provided? (Scale: 1—Very Ineffective to 5—Very Effective)
- Q3) Consider the presentation mode of the educational materials separately from the content. How does the mode of delivery affect your comprehension of the content? (Scale: 1—Greatly Decreases Comprehension to 5—Greatly Increases Comprehension)
- Q4) How likely is it that you would choose to use the kind of educational materials you were provided? (Scale: 1—Very Unlikely to 5—Very Likely)

Table 14 Average responses to exit survey questions by condition

	Q1: General Learning Effectiveness		**Q2: Posttest Preparation Effectiveness**		**Q3: Comprehension**		**Q4: Likelihood of Use**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Video+Audio+PPT (VAP)	4.33	0.48	4.40	0.56	4.53	0.51	4.47	0.57
Audio+PPT (AP)	3.80	0.71	3.97	0.56	3.80	0.85	3.73	0.74
PPT+Transcription (PT)	3.50	0.68	3.63	0.81	3.50	0.82	3.53	0.73

PPT-Only (PO)	3.50	0.68	3.43	0.82	3.67	0.61	3.60	0.97

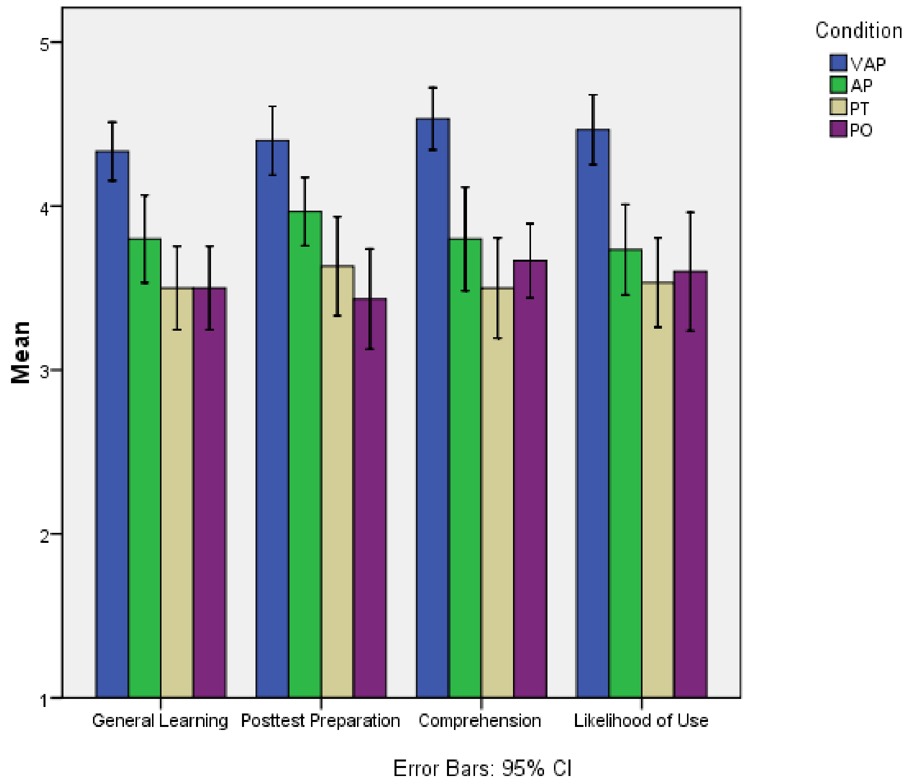

Figure 40 Average responses to exit survey questions

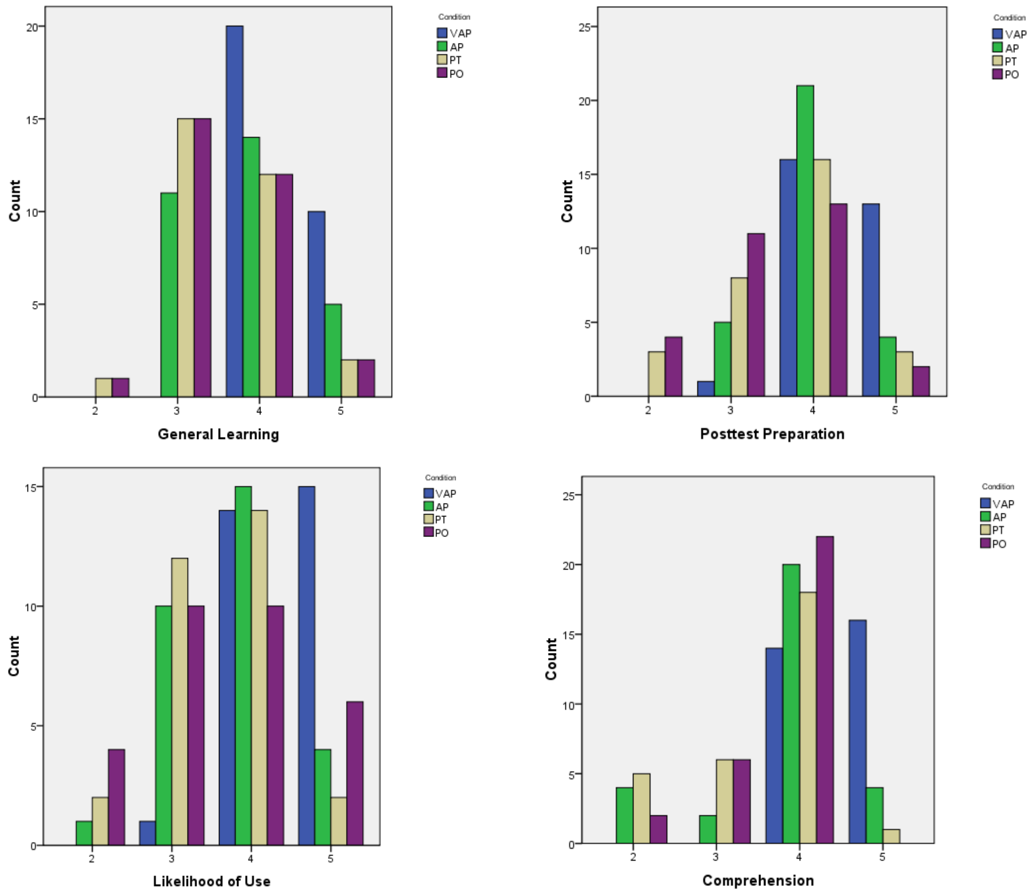

Figure 41 Bar charts showing survey response frequencies for each question

One-way ANOVAs revealed a significant main effect of condition for all four questions:

- General Learning Effectiveness: $F(3, 116)=11.089$, $p<.001$, $MSE=.418$
- Posttest Preparation Effectiveness: $F(3, 116)=11.013$, $p<.001$, $MSE=.487$
- Comprehension: $F(3, 116)=9.477$, $p<.001$, $MSE=.504$
- Likelihood of Use: $F(3, 116)=12.369$, $p<.001$, $MSE=.586$

Table 15 below provides the results of a Tukey HSD post hoc MCP.

Table 15 Tukey HSD MCP for survey responses by condition

Dependent Variable	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.
General Learning	VAP	AP	.533*	.167	.010

Table 15 continued

		PT	.833*	.167	.000
		PO	.833*	.167	.000
	AP	VAP	-.533*	.167	.010
		PT	.300	.167	.280
		PO	.300	.167	.280
	PT	VAP	-.833*	.167	.000
		AP	-.300	.167	.280
		PO	.000	.167	1.000
	PO	VAP	-.833*	.167	.000
		AP	-.300	.167	.280
		PT	.000	.167	1.000
Posttest Preparation	VAP	AP	.433	.180	.082
		PT	.767*	.180	.000
		PO	.967*	.180	.000
	AP	VAP	-.433	.180	.082
		PT	.333	.180	.256
		PO	.533*	.180	.019
	PT	VAP	-.767*	.180	.000
		AP	-.333	.180	.256
		PO	.200	.180	.684
	PO	VAP	-.967*	.180	.000
		AP	-.533*	.180	.019
		PT	-.200	.180	.684
Likelihood of Use	VAP	AP	.733*	.198	.002
		PT	.933*	.198	.000
		PO	.867*	.198	.000
	AP	VAP	-.733*	.198	.002
		PT	.200	.198	.743
		PO	.133	.198	.907
	PT	VAP	-.933*	.198	.000
		AP	-.200	.198	.743

Table 15 continued

		PO	-.067	.198	.987
	PO	VAP	-.867*	.198	.000
		AP	-.133	.198	.907
		PT	.067	.198	.987
Comprehension	VAP	AP	.733*	.183	.001
		PT	1.033*	.183	.000
		PO	.867*	.183	.000
	AP	VAP	-.733*	.183	.001
		PT	.300	.183	.362
		PO	.133	.183	.886
	PT	VAP	-1.033*	.183	.000
		AP	-.300	.183	.362
		PO	-.167	.183	.800
	PO	VAP	-.867*	.183	.000
		AP	-.133	.183	.886
		PT	.167	.183	.800

*. The mean difference is significant at the 0.05 level.

We were interested in participants' perception of the effectiveness of the educational material provided, both in terms of learning in general and in terms of preparing them for the posttest taken as part of the experiment. For general learning, statistical analysis indicated that participants in the VAP condition responded significantly more positively than the other three conditions; there were no other statistically significant differences in mean response across the remaining pair-wise comparisons. In terms of posttest preparation, participants in the VAP condition responded significantly more positively than PT and PO participants, but the mean difference between VAP and AP was marginally insignificant (p=.082). Additionally, AP participants responded significantly more positively than PO participants. No other pair-wise comparisons revealed significant differences.

We were also interested in study participants' perception of how the mode of delivery affected comprehension of the presentation content. As the pair-wise comparisons in Table 15 indicate, again VAP participants responded significantly more positively than all other conditions, and no other pair-wise comparisons revealed statistically significant differences.

Finally, the exit survey asked participants to consider the type of educational presentation they studied and rate how likely they would be to use such material if offered as part of a course. Similar to responses for the general learning and comprehension questions, participants in the VAP condition rated significantly higher likelihood of use than participants in the AP, PT, and PO conditions, but all other mean differences were statistically insignificant at the .05 level.

4.3.5 Exit Survey – Open-ended Questions

The exit survey had three open-ended questions; almost all participants responded to all three questions (of the 360 response areas, only 8 were left blank). All responses were aggregated by question and condition, and then coded. For each question, we summarize relevant trends the coding revealed and provide representative responses. Full text of all participants' responses is included as Appendix F.

- *What did you like best about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?*

Across all conditions, common responses included the presence of the TOC for context and review and the helpfulness of the animated slides (*i.e.,* gray-to-black text color animations; see Section 2.1). Students in classroom studies also expressed appreciation for the navigable TOC. This pattern of positive feedback is not surprising, considering other studies have found slide-level indices into such multimedia presentation are heavily used, even when other access methods (*e.g.,* timeline, ink) are available (Brotherton & Abowd, 2004). Participants in the VAP and AP conditions highly praised the ability to use the audio/video controls for review and keeping the presentation at a pace suitable for their learning styles. Some participants in the AP condition particularly liked the addition of audio to the PPT, and the presence of an actual *human* voice was noted as well. Finally, participants in the VAP condition expressed appreciation specifically for the video of the presenter, for the addition of audio/video in general, and for the similarities to being in a live lecture. Representative quotes from participants in the VAP condition are:

- "I like how the presenter could be viewed. It was very nice to not just listen to a presentation that you watched, but that you actually had a person to look at—like in an actual lecture."
- "The idea of a video and PPT [is] really good. It is like going to class, but at your own pace and better because you can go back to things you missed."
- "I liked being able to watch the speaker talk because if I was having trouble focusing on what he was saying, I could look at him to refocus."
- "I think that both, the presentation and the video, make a great combination rather than just reading a presentation. It is a good way to learn."

- *What did you like least about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?*

The most common response across all conditions related to the speed of the presentation. Participants noted that the standalone pace of the presentation advanced a little too quickly. We attribute this to our effort to make the presentation as short as possible. Other common responses across all conditions included stating that nothing was wrong with the presentation and the volume was too loud. For the PT condition, participants found reading all of the transcribed text and the PPT text to be difficult: "The transcribed text at the bottom, it was too hard to pay attention to that and the slide." This comment could be explained by the split-attention effect (Kalyuga, Chandler, & Sweller, 1999) or a combination of modality and spatial contiguity effects (Richard E. Mayer &

Moreno, 2003). One participant in the VAP condition stated that the video was not necessary because the audio alone would have been enough, while one AP participant commented that seeing the lecturer as well as hearing them would be preferred.

- *Please describe any ideas you have about what would make the educational material more effective.*

Many responses to this question were suggestions for kinds/number of examples and the order of material in the presentation. These responses point out a small flaw in the way we asked the question; we were more interested in ideas to improve the mode of delivery rather than the content, which was admittedly somewhat unclear in the question. Some of the suggestions were still relevant, however. For instance, VAP and AP participants suggested adding some interactive functionality such as integrated quizzes or student note taking areas. Interestingly, one VAP participant suggested making the video bigger: “It might be better if the speaker took up a little more of the window... perhaps if it were split screen, I know I sit in the front of my classes because sometimes it simply helps to see the words coming out of the lecturer's mouth. This keeps my mind from wandering and allows me to stay focused.” Also, across all conditions except the VAP condition, participants suggested specifically adding video or adding audio/video. Representative quotes are:

  - “If there was an audio/video component, I think I would have learned a bit more from it.”
  - “More visual stimuli (videos, animations) would bore the viewer less, but otherwise it was good.”
  - “Video or sound. More color. Seeing a real person giving the real world examples would be helpful.”

- *Please provide any other feedback you might have here.*

This question was not considered one of the three open-ended questions, but there were a few interesting comments from the VAP participants:

- "I would love to see this type of technology utilized in classrooms. I'd be able to take more hours, and have a more flexible schedule. A lot of class time is wasted in lectures, for the most part, professors are only lecturing on what is already in the book anyway. This would make class time for real-world application and really being able to work with the material."
- "Great concept. I would love to have this type of education provided before lecture, so that during lecture, more time can be provided for individual questions of the material."
- "I think it would make my study time less, because I would have auditory and visual reinforcement at the same time rather than at separate times."
- "I enjoyed learning this material. And I hope that you can convince some professors to use this presentation mode to teach us."
- "I would be pleased to see this used in the classroom."

4.4 Discussion

In terms of learning effectiveness, the VAP condition outperformed the other three conditions. Participants who studied educational materials using a combination of video, audio, and PPT scored statistically significantly higher than all other conditions on both the retention and transfer portions of the posttest. Analysis indicated that the samples were evenly distributed on relevant demographic data, and posttest performance was not significantly affected by self-reported multimedia exposure, sex, age, year, major, time spent reviewing material, or time spent completing the posttest. Thus, at least for HCI-related subject matter, this objective measure of learning ranks Video+Audio+PPT educational multimedia materials such as our web lectures the most effective, followed by materials with Audio+PPT, PPT+Transcript materials, and finally materials using PPT-Only.

In terms of learning efficiency, the data collected did not reveal any statistically significant differences among conditions. Although the mean study time differences were not found to be significant using inferential statistics, it is interesting and relevant to note the trends visible in the descriptive statistics. For instance, of the information-equivalent conditions, VAP participants spent the least amount of time studying the presentation and completing the overall posttest, yet still learned the most (as measured by posttest scores). Interestingly, while participants in the AP condition ranked 2nd in posttest performance, they took the longest amount of time for study and test taking. While we cannot make any valid claims beyond this 120 subject sample, these data do suggest small improvements in learning efficiency might be possible when combining video, audio, and PPT as compared to other combinations of modalities. When the PO condition is considered, note that those participants were the quickest to study the presentation; this is not surprising, considering they did not have to process the narration information that was presented using various modalities with the other three conditions. What is somewhat interesting with the PO participants, however, is that while their overall test taking time fell in the middle range, they took the longest to complete the retention portion and shortest to complete the transfer portion—all the while clearly performing the worst on the overall posttest.

These results are mostly consistent with our hypothesis based on Cognitive Load Theory and the Cognitive Theory of Multimedia Learning. In the sample, the VAP and AP conditions did yield better learning outcomes than the PT and PO conditions, and PT participants scored higher than those in the PO condition. However, based on our application of CLT and CTML guidelines to each of the information-equivalent conditions, we expected the performance of participants in the VAP and AP conditions to be approximately equal, with the presentation in the AP condition arguably being the best in terms of minimizing cognitive load. This was not the case. These data clearly indicate that Video+Audio+PPT materials produce significantly improved learning over the modality combinations used in other conditions, including Audio+PPT. To summarize, our hypothesis was AP >= VAP > PT > PO, the experimental sample yielded a ranking of VAP > AP > PT > PO, and statistical inferences to the population can be made for the following rankings: VAP > (AP, PT, PO); AP = PT; AP > PO; and PT = PO.

Based on this somewhat unexpected result, we believe effective distribution of cognitive load is only one important factor that facilitates improved learning with VAP presentations, and thus CLT and CTML have limited application to multimedia materials used for lengthy, lecture-style presentations such as those used in this study. The *only* difference between the presentations used in the VAP and AP conditions was the presence of a video image of the presenter (from the chest up), yet the overall posttest scores in the VAP condition were *more than 15% higher* than the AP condition. As suggested by Goldin-Meadow (Goldin-Meadow, 2004) and others (Church, Ayman-Nolley, & Mahootian, 2004; Perry, Berch, & Singleton, 1995; Valenzeno, Alibali, & Klatzky, 2003), we suspect that the gestures and other nonverbal cues visible in the video of the VAP presentation are another factor that contribute to learning gains. In terms of CLT/CTML, gestures and other nonverbal communication produce germane (essential) cognitive load that facilitates beneficial schema acquisition and active processing, rather than extraneous (incidental) cognitive load that interferes with learning.

The contribution of factors manifest in video of a *human* presenter might be an extension of the personalization effect (Roxana Moreno & Mayer, 2000) and image principle[12] (Richard E. Mayer, 2005). Open survey responses in this study and anecdotal evidence from classroom web lecture studies indicate learners' appreciation of the video for many reasons, the most common of which is the familiarity of an embodied (as opposed to disembodied when there is audio but no video) human instructor speaking

[12] The image principle suggests that learning is not affected by the visibility of a speaker's image, but all studies on which this is based involved animated agents rather than human presenters.

much like he/she would in a classroom. The video adds an element of personalization that could be helping learners identify with the presenter and actively relate personal experiences and knowledge to the material being presented. With students in web lecture classes—who have had prolonged exposure to web lectures along with consistent in-person contact with the presenter—this effect is even stronger; students report feeling "more committed" to watching the presentation because they personally know and consistently interact with the presenter. Related research with animated pedagogical agents has found evidence for positive personalization effects (similarly referred to as dialog (R. Moreno, Mayer, & Lester, 2000) or persona (Lester, Convers, Stone, Kahler, & Barlow, 1997) effects). For example, Atkinson (Atkinson, 2002) argues that lifelike animated agents in computer-based tutoring systems enhance learning because they share characteristics (*e.g.*, gesture, motivational and affective features) of successful human tutors. Arguably, humans are better at personalization and active dialog than animated agents; thus, learning improvements observed with agents are likely even stronger when the agent is replaced by video of a human.

Of the information-equivalent conditions (VAP, AP, and PT), PT was the poorest at distributing information across multiple processing channels using different modalities; all of the verbal information presented in the VAP and AP conditions was transcribed and forced into the visual channel in the form of additional on-screen text. Consequently, it is not surprising that the PT condition was the least learning effective of the information-equivalent conditions, as CLT and CTML would predict.

In contrast, the difference in test scores between the AP and PT conditions was surprising. Although participants in the AP condition did score higher than those in the PT condition on both retention and transfer tests, the improvement was only marginal in the sample (and far from statistical significance). Based on the modality distributions, we hypothesized the same rank order of learning effectiveness our results produced; however, we expected to see a larger performance difference between the AP and PT conditions. This unexpected deviation from CLT and CTML might be due to the presentation length (*cf.* (Zolna & Catrambone, 2005)), the lecture-based nature of the presentations, the broader subject matter, and/or the presence of a navigable TOC that effectively outlined the presentation content. Again, this result suggests the limited applicability of CLT and CTML guidelines for the types of multimedia presentations used in this study.

Also, it is interesting that the PPT-Only condition performed so poorly in comparison to the other conditions. Although this presentation condition lacked the additional narrative information available in the other three conditions, the test instrument was designed from information *only* on the PPT slides—exposure to the narration was not necessary to answer any of the questions. This condition is not discussed in terms of cognitive load because it was not information-equivalent, but the result is nonetheless important for instructional design, as PPT is a very common form of pre-, in-, and post-class educational material.

In addition to performing significantly better on the objective learning measure, VAP participants also self-reported subjective perceptions of learning and comprehension that were higher than the other three conditions. Moreover, when asked how likely they would be to use the educational material provided, VAP participants reported much higher likelihood of use than the other three conditions. Interestingly, for most of the Likert survey questions there was slight clustering between the VAP / AP conditions and the PT / PO conditions. Though posttest results did not show a significant improvement of AP over the PT and PO conditions as expected, survey results indicated a larger increase in perceived learning and comprehension. It was also interesting that—although not statistically significant—PO participants responded slightly more positively than the PT condition on the comprehension and likelihood of use questions; we suspect this can be attributed to students' simply being more familiar with PPT presentations, though that familiarity was clearly not enough to boost attitudes past what the VAP and AP presentations produced.

As mentioned above, open-ended survey responses suggest the value-added of video. Many participants in the VAP condition expressed strong positive opinions in favor of the video feed, citing its ability to aid focus, make the presentation feel more like a classroom lecture, and add to the feeling of engagement with the material. Schnotz suggested that affective and motivational factors such as these must also be considered when assessing learning gains from multimedia instructional materials (Schnotz, 2002). Also, many participants who were not in the VAP condition suggested adding video as a way to improve the presentation.

4.5 Conclusions

This study supports and extends much previous research in showing learning gains can be realized by presenting multimedia instructional materials using multiple modalities. We manipulated the modalities of three information-equivalent multimedia presentations, and found that combining video, audio, and PPT resulted in improved learning (on both objective *and* subjective measures) over the same presentations using combinations of audio and PPT, and PPT with transcription text. An information-nonequivalent condition with PPT slides alone was also included, which produced the poorest learning.

The motivation for conducting this study grew out of successful classroom deployments of the web lecture intervention conducted earlier in the course of this dissertation work. Because the VAP presentations were exactly the same as web lectures used in the intervention, the results of this study provide support for the contribution of web lectures to the learning gains observed at the intervention level. When evaluating the web lecture intervention in the classroom, the effect of web lectures cannot be teased out from other aspects of the intervention, such as increased participation in in-class application activities. Although we acknowledge the inherently decontextualized use of web lectures in the lab setting, we believe this study justifies the use of web lectures as opposed to the three other similar pre-class educational materials that were studied. Moreover, it provides evidence for the educational effectiveness of web lectures as standalone learning objects.

The significantly better learning of participants studying the VAP presentations cannot be wholly attributed to multimedia design consistent with CLT and CTML guidelines. Otherwise, AP participants should have performed the same (or better) than VAP participants. we identified some other factors present in the video that may have contributed to the observed learning gains, such as the visibility of gestures of and other nonverbal communication, and affective and motivational factors (e.g., personal identification with a human presenter), but more work is needed to determine the extent of these factors' effect on learning with video-based multimedia materials. As a start, this study provides experimental evidence and subjective support for the value-added of video in educational presentations, which suggest multimedia instructional designers should integrate video of a human presenter when possible. Note that the presenter video used in this study was studio-recorded from the torso up; arguably, this type of recording likely produces a more one-on-one, engaging experience than less personalized video, such as recorded classroom lectures.

Our investigation was framed by CLT and CTML, but the results were not completely in line with our interpretation of what those theories would predict. Learning measures for the AP and PT conditions were much closer than an analysis of cognitive load for each would suggest. Longer, lecture-style characteristics of the presentations, the presence of a navigable TOC, and different subject matter have been identified as possible causes of these unexpected results. Some of the effects of high or low cognitive load may not be as powerful when exposure to the material is longer than the conditions under which those effects were recognized in developing CLT and CTML. These results suggest that CLT and CTML have limited application to multimedia materials such the ones used in this experiment, and indicate the need for more studies to determine the conditions under which CLT and CTML guidelines can be effectively applied.

4.6 Summary

This experiment used a synthesis of quantitative posttest data and qualitative survey data to understand learning with web lectures as standalone multimedia educational materials. In particular, with this study we experimentally investigated the educational efficacy and efficiency of our web lectures in comparison to similar multimedia presentations. The positive results reported above provide evidence supporting the claim that—for these educational multimedia presentations—the combination of video, audio, and PPT multimedia components is more educationally effective (in terms of both objective measures *and* subjective self-reports) than information-equivalent presentations that combine other multimedia components (*e.g.*, audio, transcription text), as well as being more effective than the common PPT presentation. Additionally, though no general claims can be made, this study also provides some evidence suggesting our web lectures are slightly more educationally efficient than similar multimedia educational materials. Finally, these positive results also provide support for the use of web lectures as pre-class study materials over other materials at the intervention level, and suggest that web lectures themselves contribute to learning gains observed when the web lecture intervention is deployed in the classroom.

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

In this final chapter, we summarize the results of all studies included in this thesis work, highlight preliminary conditions under which the web lecture intervention is successful, discuss some resulting guidelines for implementing the web lecture intervention, and present some avenues for future work.

5.1 Summary of Results

The goal of this work was to improve the on-campus educational experience for students via better understanding of course material and increased positive attitudes toward their classes. A secondary goal was to decrease the cost of quality on-campus educational experiences. To this end, our major contribution as part of this thesis work is the design, implementation, and rigorous evaluation of an inexpensive, easy-to-implement educational intervention that provides opportunities for more active learning and student engagement in the classroom.

Typical of the HCI design process, the design and implementation of our web lecture intervention involved an iterative cycle of deployment and evaluation over the course of several formative and pilot studies. Once the logistics of web lecture production and integration into an on-campus course were worked out, multiple rigorous evaluations were conducted to validate our approach.

Two complementary threads of research allowed us to evaluate web lectures as standalone learning objects *and* as part of a larger educational intervention. First, a controlled experiment comparing several similar multimedia learning objects revealed that the combination of video, audio, and PPT used in our web lectures produces significantly more effective and slightly more efficient learning (on both objective *and* subjective measures). Second, two full-semester quasi-experimental classroom studies—comparing a course taught using the web lecture intervention with one taught traditionally—found that our web lecture intervention produces equivalent or better course performance as well as improved student perception of learning and course enjoyment, all while attending significantly fewer class meetings. Thus, we can confidently conclude that our proposed thesis statement was validated by this systematic program of research:

Web lectures as standalone learning objects are at least as educationally effective and efficient as similar learning objects. Furthermore, a course taught using the web lecture intervention produces 1) the same or better objective learning outcomes and 2) the same or better subjective enjoyment and perceived learning, than a course taught using the traditional lecture format.

In other words, students using web lectures not only learned as much or more in terms of objective measures (*i.e.,* course grades, experimental posttest), but also felt they learned and enjoyed more in terms of subjective measures (*i.e.,* class surveys, experiment exit survey), than students not using web lectures (*i.e.,* students in traditional lecture sections, experiment participants assigned to other conditions). Plainly put, students learn from and really like web lectures.

This work also allows us to identify the preliminary conditions under which the web lecture intervention is successful. More specifically, our studies verified the effectiveness of our web lecture intervention for an undergraduate, introductory HCI course. Deployments were successful for classes of varying demographic makeup and size, though larger class size did lessen the observed improvements the web lecture intervention had on overall course grades. However, all of the reported thesis work was conducted in the same course (CS3750), with the same instructor (J. Foley), at the same institution (Georgia Tech). Arguably, our web lecture format could be an effective and efficient alternative to the traditional in-class lecture format for other courses / instructors

/ institutions; evaluation of the web lecture interface in other educational contexts was out of scope for this thesis, but it is a major avenue of future research discussed in Section 5.3.2.

5.2 Guidelines for Implementing a Web Lecture Intervention

This thesis work was not just about *using* web lectures; it was also about *making* them with the best combination of modalities and about *technologies* and *pedagogies* that bridge the gap between studying the web lecture on one's own and then applying and extending the lecture material in the classroom. Naturally throughout the completion of this work, we identified several key characteristics of our web lecture intervention and learned several lessons about its implementation. In this section, we summarize this information in the form of general guidelines for implementing a web lecture intervention. These guidelines are based on *our* experience working with *our* web lecture intervention; although we believe they will be beneficial to others interested in implementing a web lecture intervention, we are *not* claiming they are hard and fast rules applicable to *any* web lecture intervention.

The multimodal learning experiment and formative classroom evaluations helped us identify the following guidelines for making web lectures:

- Web lectures should be made using a combination of video, audio, and slides. With out web lectures, we found strong evidence that presentations with video, audio, and PPT are significantly more educationally effective than other similar multimedia presentations and PPT alone.
- Production software should be inexpensive and capable of publishing streaming A/V presentations. Microsoft Producer was free and served our needs very well; however, the *only* major complaint heard from students throughout our classroom deployments related to issues of Microsoft

dependency. Some platform/browser-independent solutions are now available, such as TechSmith Camtasia Studio (CamtasiaStudio).

- Expensive A/V equipment is *not* required to create satisfactory web lectures.
  - Equipment needs include: A laptop, a digital video camera, a firewire cable, two stand lights with diffusion filters, a quality tabletop microphone, a cordless slide-advancement mechanism (*e.g.,* foot mouse), and a dark sheet or paint for the background.
  - High-quality audio is more important than high-quality video. Although our research found the combination of audio and video to be significantly more beneficial to learning than audio alone, students also clearly expressed that low-quality audio is unacceptable.
  - Either the laptop display or another external monitor should be placed directly under the camera during recording. This acts as an informal teleprompter and helps the presenter maintain approximate eye contact with the camera.
- Video of the presenter should be shot from the lower torso up (not just a talking head), so that gestures and other nonverbal communication are captured.
- If more than one topic (*i.e.*, bullet) is being presented on a slide, use simple text color animations to help learners focus on the current topic being discussed.
- Slide-level indices (*i.e.,* navigable TOC) should be included to help students navigate the presentation, serve as an outline of the lecture, and provide some context about current position within the lecture.
- To make navigation using the TOC as effective as possible, the presenter should not speak through slide advancement during recording.

- Additional technologies to bridge that gap between pre- and in-class activities are not necessary in a blended learning format with a short cycle time (see Section 2.3.1). For example, students did not make use of question-asking facilities added to the web lecture UI, because they felt any questions they had could wait until the next class meeting.
- Web lectures should be about 20 minutes in length. Large lecture topics can usually be broken up at appropriate places to make each web lecture in a series of web lectures all close to this ideal duration.
- On average, a studio-recorded web lecture will be about 40% shorter than the same lecture given live. In our experience, this is because:
  - All administrative announcements are omitted
  - Q & A is not recorded
  - The "studio" atmosphere tends to reduce the number of tangential topics discussed by the lecturer

The key characteristic of using web lectures in the intervention is the combination of both lecture *and* activity. All of the classroom-based studies helped us identify the following guidelines for using web lectures:

- Web lectures are most effective when *individually* studied *before* and *outside* of normal, face-to-face class meetings. Other viewing arrangements were piloted, but overwhelming student feedback identified this arrangement as the most preferred.
- Short, synthesis-type assignments (*i.e.,* LHWs) serve well as pedagogical linking mechanisms between students studying web lectures individually and subsequent in-class participation. In our experience, students find educational value in completing LHWs, and discussing them in class provides an excellent segue into deeper discussion and other activities.

- Class time made available by the use of web lectures should be used to extend and apply the material studied before attending class; class time should *not* be used to simply rehash material presented in the web lecture(s).
    - Time in the beginning of each class should be allocated to web lecture Q & A and discussion of pre-class assignments.
    - The remaining class time should be used to engage students with various relevant application activities (*e.g.,* project-related group presentations, small breakout group discussions and presentations, re-design sessions, design critiques, design reviews with HCI experts, role-playing activities, discussions with local practitioners).
    - We acknowledge that, in some circumstances, creating questions for pre-class assignments and preparing in-class activities can be challenging. For some instructors, this may be viewed as a drawback to the web lecture intervention.
- Although no formal comparison has been made, anecdotal evidence suggests the web lecture intervention is slightly better suited to a class schedule in which students meet more often for less time (*e.g.,* Monday/Wednesday/Friday for 55 minutes vs. Tuesday/Thursday for 80 minutes). It can be easier to keep students actively engaged during shorter class periods, and if class meetings are cancelled, there is less time between face-to-face meetings.
- Although we have limited empirical evidence, our quasi-experimental studies suggest that the web lecture intervention is slightly better suited for small- to medium-sized classes (*i.e.,* up to about 30 students). When we deployed in a larger class (~40 students), overall course grades increased, but not significantly (though subjective students measures still increased

significantly). Also, as class size increases, the logistics of in-class activities can become challenging, and the amount of grading work for TAs increases.

5.3 Future Work

In this section, we discuss multiple potential avenues for future work in both naturalistic and experimental conditions. First, we outline a number of extensions to the multimodal learning experiment, one of which is currently under way. Second, we describe multiple other educational contexts in which we would like to evaluate the web lecture intervention. Data collection for some of the contexts presented has already been completed or is currently under way.

5.3.1 Continued Experimental Evaluation of Web Lectures

There are many ways for us to expand and improve upon the multimodal learning experiment conducted as part of this thesis work. For instance, some limitations of our study that could be addressed in future studies include more rigorous pretests of incoming knowledge, spatial ability, and working memory capacity. Mayer's individual differences principle suggests that design effects are stronger for low-knowledge, low-spatial learners, and CLT in particular recognizes the importance of working memory capacity; these factors can be measured upfront and treated as covariates to control for individual differences.

In terms of extending the experiment, there are other relevant conditions to test. For example, we are currently preparing to test an information-equivalent passage of reading. The Reading-Only condition will *not* be a transcription of the audio narration (as was used in the PPT+Transcript condition); rather, it will be a true simulation of what a common textbook reading assignment over the presentation topic would entail. Like the PPT-Only condition, this is another type of material that is commonly provided for students, and thus will be another educationally relevant condition to examine. Currently, we are in the process of obtaining IRB approval to add a condition and increase the total number of study participants to 150, and creating the written educational material to be used in the Reading-Only condition.

The results of our first experiment identified a number of other conditions and parameters to consider manipulating in subsequent experiments. In particular, including animated agent and live lecture conditions could help us determine the conditions under which personalization effects are most beneficial to learning. Also, subjective data suggests that participants' familiarity with the presenter could be an important factor in determining learning effectiveness; this is a parameter we could experimentally manipulate to get a better understanding of its possible effects on the learning efficacy of multimedia educational materials. Another potentially interesting parameter to investigate is the amount of gesture and other nonverbal communication visible in the video image. This would include varying the amount of gesture use, the visibility of the presenter (e.g., full body, torso up, head-only), the speech style (e.g., monotone, highly accentuated), *etc*. A better understanding of the role of gesture and nonverbal communication in multimedia learning could have a significant impact on the use of video in multimedia instructional materials. Additionally, to increase the external validity of our results, we are considering creating and testing materials with multiple presenters.

Also, a number of factors were identified that differentiate the presentations used in our study from those used in most CLT and CTML studies. To determine their possible effects on the applicability of CLT and CTML guidelines for multimedia educational materials, subsequent experiments could manipulate presentation length, subject matter, and presence of a navigable TOC. To better understand the impact of cognitive load on learning with the types of presentations we are using, we are also considering the use of direct objective measures such as dual-task performance (Brunken, Plass, & Leutner, 2003) in addition to our indirect objective learning outcome measures.

Finally, we have discussed other variations of the multimodal learning experiment, including:

- o Running participants without imposing a time limit for reviewing the materials or completing the posttest
- o Allowing participants to work on the test mechanism while studying the presentation (*i.e.,* making the test mechanism more like an LHW and less like an exam)
- o Administering retention and transfer tests at a later date to explore long-term effects
- o Implementing a within-subjects design where participants would be exposed to different presentations using different presentation modes

5.3.2 Continued Naturalistic Evaluation of Web Lectures

Inevitably, there will be some limitations to the applicability of this intervention. It was not within the scope of this thesis to fully explicate the educational contexts in which the web lecture intervention will be successful, but we recognize the importance of making some strides in that direction. Thus, our future naturalistic work will concentrate on evaluating the web lecture intervention in a number of relevant variations.

The logistics involved in conducting classroom-deployment studies (*e.g.,* teaching / course schedules, inter-school communication, IRB approval) can be significantly more challenging than those involved in controlled lab studies. Fortunately, we have secured opportunities to conduct multiple small-scale studies that exhibit interesting differences as compared to the context in which we have studied the web lecture intervention thus far. Some of these studies have already been conducted, but the data have not been analyzed.

- An evaluation of web lecture use in CS3750 when the in-class instructor is not the same as the web lecture presenter

- An evaluation of web lecture use in a graduate HCI course at an institution other than Georgia Tech (Atlanta-campus)
- An evaluation of web lecture use in a graduate HCI course at an institution other than Georgia Tech, when the in-class instructor is not the same as the web lecture presenter
- An evaluation of web lecture use in an advanced HCI course taught by an instructor who is not part of the research team, using his/her own web lectures

The first study aimed to evaluate the effectiveness of web lectures—from both instructor and student perspectives—when an instructor uses another person's web lectures as part of their course. To this end, Professor Melody Moore-Jackson partially implemented the web lecture intervention by using eleven of Prof. Foley's web lectures while teaching CS3750. Data were collected via two surveys and an informal interview with Prof. Moore-Jackson.

The second study sought to obtain feedback from non (Atlanta-based) Georgia Tech students using web lectures. This study was conducted with 15 students in a graduate HCI course (CS6750) taught by Prof. Foley at the Georgia Tech Lorraine campus in Metz, France. This class provided a particularly interesting study sample in that English— the language used in all web lectures and in the class— was not the native language for any of the students. Data were collected via surveys administered three times throughout the semester.

The third formative study involved having an instructor who was not part of the research team teach a class at another university while using Prof. Foley's web lectures; essentially, this is a combination of the previous two studies. Professor Charles van der Mast used our complete web lecture series when teaching his Highly Interactive Systems course (IN4034) for first-year students in the Master's of Media and Knowledge Engineering program at TUDelft in Delft, Netherlands. Data were collected via an exit survey administered to 26 students and an email interview with Prof. van der Mast. A similar formative study was run the previous year with the same course, at that time co-taught by Prof. van der Mast and Prof. Foley. Data for that study were collected via two surveys and two focus groups. Although the data from these studies have not yet been analyzed, Prof. van der Mast's continued use of Prof. Foley's web lectures speaks to the success he is finding with their use. In fact, Prof. van der Mast is now using our web lectures regularly in four courses:

- IN1821 HCI—an introductory HCI course for first-year undergraduate Computer Science students
- IN4034 Highly Interactive Systems—a graduate HCI course for first-year Master's of Media and Knowledge Engineering students
- IN4083 Usability Engineering—a graduate HCI course for first-year Master's of Computer Science students
- IN4179 Intelligent User Experience Engineering (co-taught with Professor Mark Neerincx)—a graduate HCI course for Master's of Computer Science students

Additional data regarding Prof. van der Mast's extensive use of web lecture in multiple courses over multiple years will be collected via phone interview.

The last formative study allowed us to gather feedback about the process of recording web lectures (from someone not on the research team) and to evaluate the effectiveness of their use in an advanced HCI course. Professor John Stasko studio-recorded all the lectures that makeup the graduate Information Visualization course (CS7450) at Georgia Tech. Prof. Stasko used the standard presentation layout (*i.e.*, no forum or email links) for his web lectures (Figure 42).

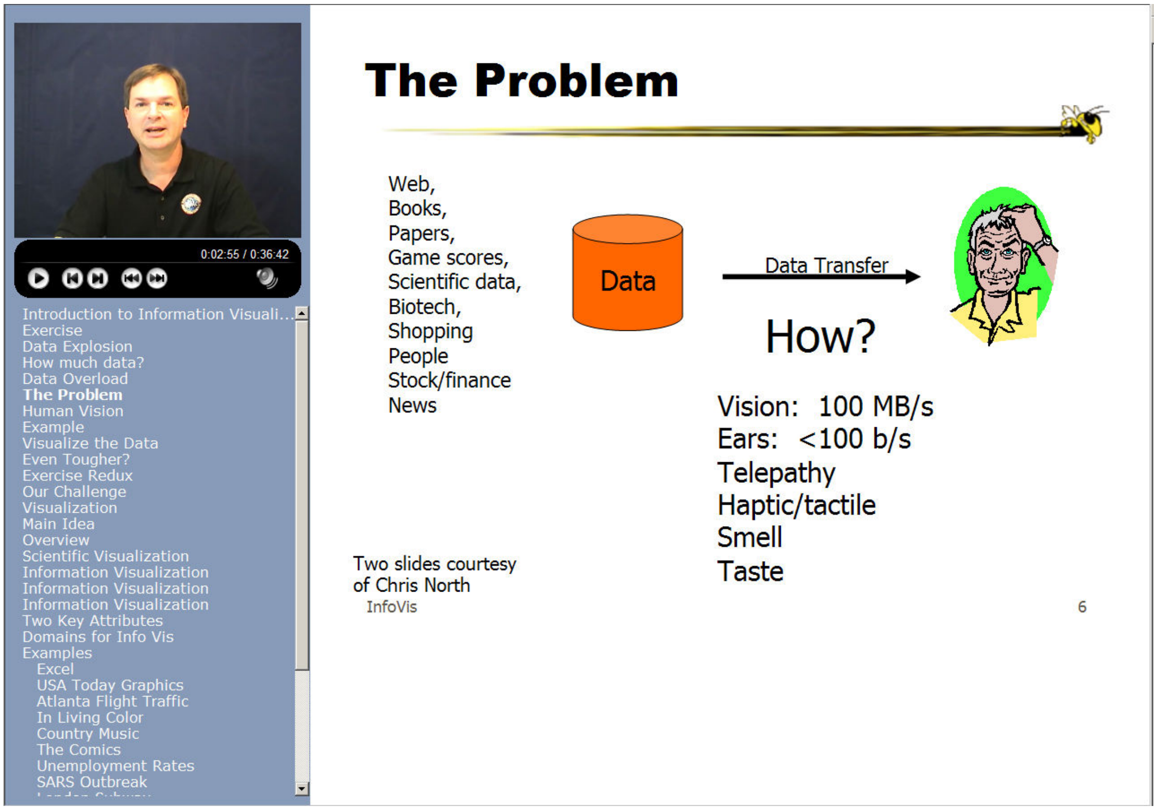

Figure 42 Screenshot of Prof. Stasko's "Introduction to Information Visualization" web lecture

When teaching the Information Visualization course traditionally with live lectures, Prof. Stasko usually gives a large number of demonstrations of various infoviz applications. In order to preserve that interesting and educational aspect of the lectures, we used Camtasia Studio (CamtasiaStudio) to record audio-narrated screen capture demos, which were then dropped into the web lectures at appropriate places. During these demos, the presentation layout used in the web lecture was changed so that most of the screen is dedicated to the screen capture video (Figure 43). Published Information Visualization web lectures are being made available to students in the HCCEDL and the Visual Analytics Digital Library (VADL).

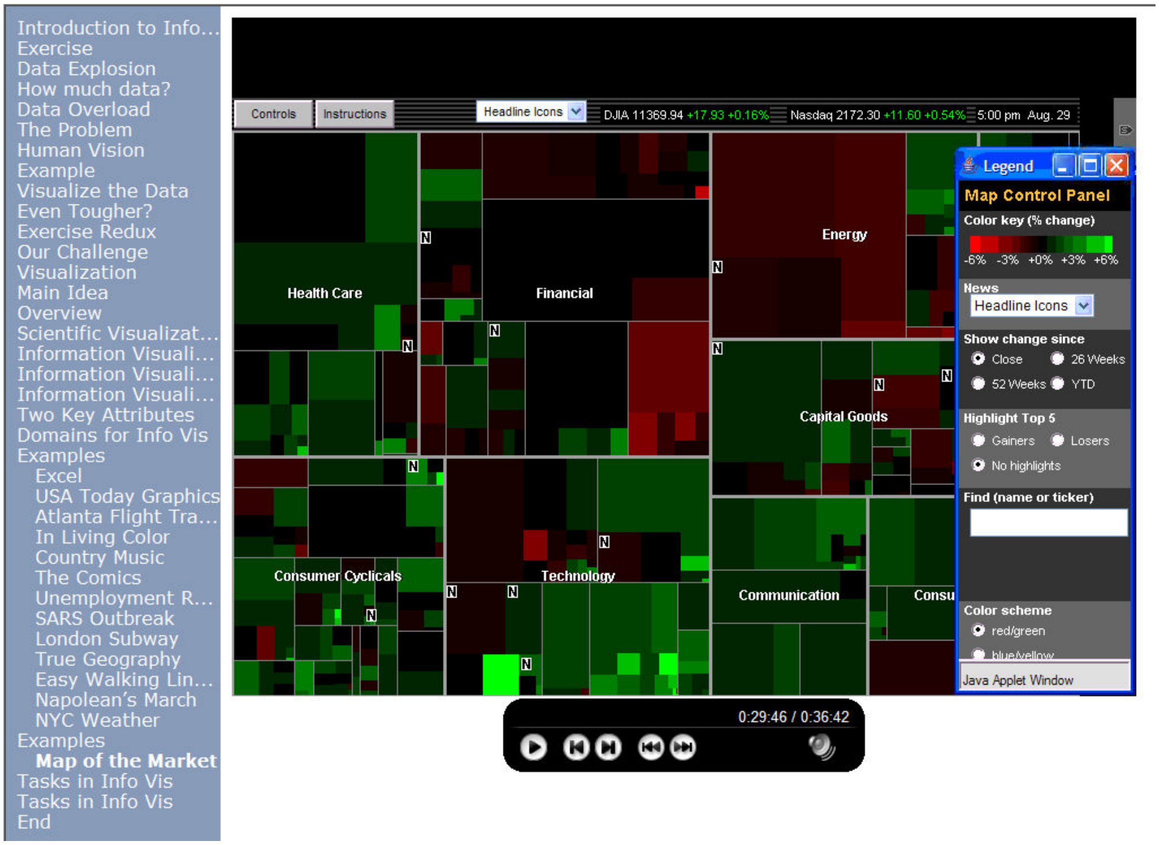

Figure 43 Example of a "Map of the Market" demo in the middle of a web lecture

Prof. Stasko used his web lectures in a modified version of the Information Visualization course. In place of the traditional format of two 80-minute class meetings a week mostly dedicated to lecture, Prof. Stasko had his 9 students study the web lectures outside and before class, and then the class met face-to-face once a week for 60 minutes. Data were collected via two surveys and a student interview.

Additional data collection is ongoing. For instance, Prof. Foley is currently teaching the graduate Information Visualization course and is planning to use some of Prof. Stasko's web lectures. Also, Prof. Abowd will likely use some of Prof. Foley's web lectures in his teaching of CS3750 this semester. Both of these uses provide new and interesting opportunities for gathering feedback about the web lecture intervention in other educational contexts.

At this point, we have not been able to conduct any evaluations of the web lecture intervention when deployed in courses outside the HCI domain. Naturally, this is another important avenue of future work.

5.4 Summary

In closing, we have presented our extensive work with the web lecture intervention, an inexpensive, easy-to-implement educational intervention that facilitates increased student engagement and active learning in the classroom. Substantial evidence from our classroom and laboratory studies indicates *learning with web lectures is both effective and enjoyable.* Thus, we are very pleased to present this promising approach so that other educators and students can realize its benefits.

APPENDIX A

Control Section Early, Midway, and Final Surveys Administered During the 2nd Classroom Quasi-experiment with CS3750

Survey 1: CS3750 Spring 2007

Please take a few minutes to complete this survey. Thank you for you valuable feedback!

Demographic Data

1. What is your gender? Male Female

2. What is your age? _______

3. What is your academic standing?

Freshman Sophomore Junior Senior Other:_______

4. What is your major?

CS Computer Engineering Industrial Design Psychology Other:_________

Attitudes about HCI

5. How relevant do you view HCI to your education?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

6. How relevant do you view HCI to your career?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

7. How likely is it that you will seek out a job that specifically uses HCI?

1	2	3	4	5
Very	Unlikely	Neutral	Likely	Very Likely

8. How relevant do you view HCI to your life?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

Attitudes about the Course Format

9. Do you think the lecture homeworks help you focus on the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

10. Do you think the lecture homeworks help you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

Survey 2: CS3750 Spring 2007

Please take a few minutes to complete this survey. Thank you for you valuable feedback!

Attitudes about HCI

1. How relevant do you view HCI to your education?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

2. How relevant do you view HCI to your career?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

3. How likely is it that you will seek out a job that specifically uses HCI?

1	2	3	4	5
Very Unlikely	Unlikely	Neutral	Likely	Very Likely

4. How relevant do you view HCI to your life?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

Attitudes about the Course Format

5. Do you think the lecture homeworks help you focus on the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

6. Do you think the lecture homeworks help you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

Attitudes about the Lecture Forum (Bulletin Board)

7. Based on your experience with lecture forum, how would you rate your attitude toward the forum so far?

1	2	3	4	5
Very Negative	Somewhat Negative	Neutral	Somewhat Positive	Very Positive

8. Do you think the lecture forum helps you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Helps	Definitely Helps

Survey 3: CS3750 Spring 2007

Please take a few minutes to complete this survey. Thank you for you valuable feedback!

Attitudes about HCI

1. How relevant do you view HCI to your education?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

2. How relevant do you view HCI to your career?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

3.

1	2	3	4	5
Very Unlikely	Unlikely	Neutral	Likely	Very Likely

4. How relevant do you view HCI to your life?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

Attitudes about the Course Format

5. Were you aware of the web lectures used by the other section of this course?

Yes No

If you answered Yes, how many of the web lectures did you view throughout the semester? ______

6. Do you think the lecture homeworks help you focus on the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

7. Do you think the lecture homeworks help you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

8. All other things being equal, in comparison to other courses you have taken, how much do you think you *learned* from this course?

1	2	3	4	5
A Lot Less	Less	About the Same	More	A Lot More

9. All other things being equal, in comparison to other courses you have taken, how much would you say you *enjoyed* this course?

1	2	3	4	5
A Lot Less	Less	About the Same	More	A Lot More

Attitudes about the Lecture Forum (Bulletin Board)

10. Based on your experience with lecture forum, how would you rate your attitude toward the forum so far?

1	2	3	4	5
Very Negative	Somewhat Negative	Neutral	Somewhat Positive	Very Positive

11. Do you think the lecture forum helps you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Helps	Definitely Helps

APPENDIX B

Experimental Section Early, Midway, and Final Surveys Administered During the 2nd Classroom Quasi-experiment with CS3750

Survey 1: CS3750 Spring 2007

Please take a few minutes to complete this survey. Thank you for you valuable feedback!

Demographic Data

1. What is your gender? Male Female

2. What is your age? _______

3. What is your academic standing?

Freshman Sophomore Junior Senior Other:_________

4. What is your major?

CS Computer Engineering Industrial Design Psychology Other:_________

Attitudes about HCI

5. How relevant do you view HCI to your education?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

6. How relevant do you view HCI to your career?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

7. How likely is it that you will seek out a job that specifically uses HCI?

1	2	3	4	5
Very Unlikely	Unlikely	Neutral	Likely	Very Likely

8. How relevant do you view HCI to your life?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

Attitudes about Web Lectures

9. How would you rate the production quality (i.e., image/sound quality) of the web lectures?

1	2	3	4	5
Very Bad	Bad	Neutral	Good	Very Good

10. How do you feel about web lectures for use in education in general?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

11. How do you feel about studying web lectures *in advance of class*, for spending class time on other activities?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

12. Do you think that reviewing web lectures to study for exams will be useful?

1	2	3	4	5
Totally	Quite Useless	Neutral	Quite Useful	Very Useful

13. How would you rate your overall attitude about the navigation controls (i.e., pause/rewind/fast forward playback controls and table of contents) provided by the web lecture interface?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly Positive

14. How would you rate your overall attitude about the web lectures?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly Positive

Attitudes about the Course Format

15. Based on what you know about the course format for this course (e.g. web lectures and in-class activities), how would you rate your initial attitude toward the course format?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly Positive

16. Do you think the lecture homeworks help you focus on the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

17. Do you think the lecture homeworks help you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

18. If you compare the new course format of web lectures and in-class activities with the traditional in-class lecturing format, how would you rate the new course setup in comparison?

1	2	3	4	5
Much Worse	Worse	About the Same	Better	Much Better

Open-Ended Questions

19. What do you like/dislike about using web lectures as part of this course?

20. Do you have any suggestions for improving the web lectures, course format, or any other aspect of this course?

Survey 2: CS3750 Spring 2007

Please take a few minutes to complete this survey. Thank you for you valuable feedback!

Demographic Data

1. Is English your native language? Yes No

   1a. If No, how many years have you been speaking English? _______

Attitudes about HCI

2. How relevant do you view HCI to your education?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

3. How relevant do you view HCI to your career?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

4. How likely is it that you will seek out a job that specifically uses HCI?

1	2	3	4	5
Very Unlikely	Unlikely	Neutral	Likely	Very Likely

5. How relevant do you view HCI to your life?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

Attitudes about Web Lectures

6. How would you rate your overall attitude about the web lectures?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly

7. How do you feel about web lectures for use in education in general?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

8. How do you feel about studying web lectures *in advance of class*, for spending class time on other activities?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

9. Do you think that reviewing web lectures to study for exams is/will be useful?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

10. How would you rate your overall attitude about the navigation controls (i.e., playback controls and table of contents) provided by the web lecture interface?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly Positive

Attitudes about the Course Format

11. Based on what you know about the course format for this course (e.g. web lectures and in-class activities), how would you rate your initial attitude toward the course format?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly Positive

12. Do you think the lecture homeworks help you focus on the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

13. Do you think the lecture homeworks help you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

14. If you compare the new course format of web lectures and in-class activities with the traditional in-class lecturing format, how would you rate the new course setup in comparison?

1	2	3	4	5
Much Worse	Worse	About the Same	Better	Much Better

15. Please RANK the following item from 1 to 5, where 1 is the most useful and 5 is the least useful.

______ Textbook Readings

______ Web Lectures

______ In-Class Lectures

______ In-Class Activities

______ Web Lectures Forum

Attitudes about the Web Lectures Forum

16. Based on your experience with the web lectures forum, how would you rate your attitude toward the forum so far?

1	2	3	4	5
Very Negative	Somewhat Negative	Neutral	Somewhat Positive	Very Positive

17. How useful do you consider the web lectures forum in general?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

18. Do you think the web lectures forum is a useful tool for asking questions while viewing web lectures?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

19. Do you think the web lectures forum helps you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Helps	Definitely Helps

Open-Ended Questions

20. What do you like/dislike about the web lectures forum integrated with the web lectures? How do you feel about making part of the lecture homeworks require posting to the web lectures forum? Do you have any suggestions for how this could be done better, or for other ways to encourage student participation on the forum?

21. What do you like/dislike about using web lectures as part of this course?

22. Do you have any suggestions for improving the web lectures, course format, or any other aspect of this course?

Survey 3: CS3750 Spring 2007

Please take a few minutes to complete this survey. Thank you for you valuable feedback!

Attitudes about HCI

1. How relevant do you view HCI to your education?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

2. How relevant do you view HCI to your career?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

3. How likely is it that you will seek out a job that specifically uses HCI?

1	2	3	4	5
Very Unlikely	Unlikely	Neutral	Likely	Very Likely

4. How relevant do you view HCI to your life?

1	2	3	4	5
Very Irrelevant	Somewhat Irrelevant	Neutral	Somewhat Relevant	Very Relevant

Attitudes about Web Lectures

5. How would you rate your overall attitude about the web lectures?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly Positive

6. How do you feel about web lectures for use in education in general?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

7. How do you feel about studying web lectures *in advance of class*, for spending class time on other activities?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

8. Do you think that reviewing web lectures to study for exams was useful?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

9. How would you rate your overall attitude about the navigation controls (i.e., playback controls and table of contents) provided by the web lecture interface?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly Positive

Attitudes about the Course Format

10. Based on what you know about the course format for this course (e.g. web lectures and in-class activities), how would you rate your initial attitude toward the course format?

1	2	3	4	5
Strongly Negative	Negative	Neutral	Positive	Strongly Positive

11. Do you think the lecture homeworks help you focus on the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

12. Do you think the lecture homeworks help you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Help	Definitely Help

13. If you compare the new course format of web lectures and in-class activities with the traditional in-class lecturing format, how would you rate the new course setup in comparison?

1	2	3	4	5
Much Worse	Worse	About the Same	Better	Much Better

14. All other things being equal, in comparison to other courses you have taken, how much do you think you *learned* from this course?

1	2	3	4	5
A Lot Less	Less	About the Same	More	A Lot More

15. All other things being equal, in comparison to other courses you have taken, how much would you say you *enjoyed* this course?

1	2	3	4	5
A Lot Less	Less	About the Same	More	A Lot More

16. Please RANK the following item from 1 to 5, where 1 is the most useful and 5 is the least useful.

______ Textbook Readings

______ Web Lectures

______ In-Class Lectures

______ In-Class Activities

______ Web Lectures Forum

Attitudes about the Web Lectures Forum

17. Based on your experience with the web lectures forum, how would you rate your attitude toward the forum so far?

1	2	3	4	5
Very Negative	Somewhat Negative	Neutral	Somewhat Positive	Very Positive

18. How useful do you consider the web lectures forum in general?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

19. Do you think the web lectures forum is a useful tool for asking questions while viewing web lectures?

1	2	3	4	5
Totally Useless	Quite Useless	Neutral	Quite Useful	Very Useful

20. Do you think the web lectures forum helps you learn the material being presented?

1	2	3	4	5
No Help At All	Not Much Help	Neutral	Helps	Definitely Helps

Open-Ended Questions

21. What do you like/dislike about using web lectures as part of this course?

22. Did you notice the "Pause and email question" link in the web lecture UI? If yes, what reasons did you have for *not* using this feature?

23. What do you like/dislike about the web lectures forum integrated with the web lectures? How do you feel about making part of the lecture homeworks require posting to the web lectures forum?

24. As the semester progressed, did your use or attitude about web lectures change? If yes, in what ways and why?

25. Do you have any suggestions for improving the web lectures, course format, or any other aspect of this course?

APPENDIX C

Student Responses to Open-ended Survey Questions Throughout the 2nd Classroom Quasi-experiment

Early Survey

Question: What do you like/dislike about using web lectures as part of this course?

I like we have fewer in class lectures and can view the web lectures on our schedule. It's much more tedious to "pause and email" a question than to raise a hand and ask. Maybe add a live chat with the TA at the normal lecture time?

Sometimes too long. If lectures are more shorter, then will be good. Shorter but more.

Being able to go back for repeated explanations and elabortation on the PPT slides is helpful when I'm studying the web lectures. It allows me to go at my own pace if it's faster or slower than my current level of understanding. The only thing I don't like is having to use a PC, because I'm a Mac person.

A lot of web lectures assigned at once. I put off and then ended up sitting for over 2 hours studying them all.

Techology is too locked to MS.

I can learn on my own time. If I get sleepy in a lecture (which happens often) I end not paying attention in class. With the web lectures, I can pause to take a break and come back and finish. This way I get all the information, unlike a traditional class.

Con: It seems to take a little longer to get through the material. Pro: If I don't get something the first time I can rewind and review until I understand it.

This format seems to work well, but I also feel like it takes more time.

They are good.

I like being able to study the lectures at my own convenience and I don't have to sit and listen in class as much.

Feels mundane, despite the forum. Very useful for reviewing with pause and rewind.

I like this a lot, except that I have to use MS products.

Like being able to review lectures at any point in time and that there is video. Dislike HW for lecture. A grade for in-class participation during discussion would be better I think.

Like: Can watch on my own time. Dislike: Takes a lot of time at once to study all assigned lectures.

I like being able to watch them at any time. Also, I like being able to repeat. Don't like the syllabus layout on the web…very hard to follow.

I like the ability to easily review the lectures, and I like not having class every once in a while.

The flexibility and effectiveness of in class interaction seems promising.

I like the freedom online lectures provide, and I like this idea to mix online and in class so I get the best of both. Because of the video in the lecture, I feel sort of like I'm in class anyway.

I think it's really convenient to watch the lectures on the web. I can watch them over again and make sure I learn all the things Prof. Foley is teaching.

I feel like I learn more from this format because I get both lecture and discussion. More than in other classes I've taken, and I like the on-my-own-time nature of online lectures for that kind of necessary teaching.

I don't like the load time or the requirement of IE.

I like having the profs words to refer back to.

Some web lectures are too long.

Likes: I can stop or review past video things I missed or forgot without hesitation or disrupting the class. If I am tried, I can study the web lectures at a better time for me as far as paying

attention / learning. In class, I tend to read/copy lecture notes making me lose focus on the actual lecturer...this helps with the ability to rewind. Dislike: Not as much opportunity for alternative explanation that lecturing in class allows.
Good: May watch at my leisure. Can watch multiple times. Can pause when taking notes or tired. More control over when I want to "attend class."
Good idea. I like the A/V and being able to pause the prof.
If you missed a piece of information, you can easily use the playback controls to review. I like being able to study more at home but still have time with the prof in class for things other than simply listening to lecture.
Like: Being able to view them on my own time. Being able to view them from the comfort of my room. Dislike: Delay in answers to questions relative to in-class discussions and lectures.
Like: I get the advantages of both in class and out of class instruction. If I miss something, I can easily go back by using the web lecture interface. Dislike: A lot assigned at once.
I like them in that you are free to watch them in a time that more appropriately fits your schedule as opposed to being forced to be somwhere at a designed time. I really like how the PPT slides appear along side the video. It's makes the presentation much easier to understand.
I love being able to pause and rewind!! The video image is a bit small though and I can get a little bored.
I really like that our time in class is less about me sitting and listening. More classes should be like this.
Seems a bit impersonal.
Dislike: The amount of "lecture" time is more than an in-class lecture. There could be more to the video to make it more entertaining. It took me about 2 hours to go through the assigned lectures and take notes. Like: I really think the outline at the bottom left helps organize the lecture for me. Also, it is really easy for me to take notes because I can pause the lecture, unlike in class where I often get behind. Finally, this approach makes the time in class better because the professor is dedicated fully to interacting with us instead of simply talking at us.
I like it because I feel that we accomplish more than with a traditional class. I don't, however, like the homework. I would prefer a short quiz at the beginning of the class to assure we studied the web lectures.
The interface looks nice, but I would like to be able to use other browser than IE.
I like them because it gives us the leisure of being able to take them whenever we want.
Dislike: Some of the lectures are a bit too long, or maybe assign fewer at a time. I really like the flexibility of this though.

Question: Do you have any suggestions for improving the web lectures, course format, or any other aspect of this course?

Syllabus and class communication is making it hard to tell when / what is due.
Make them shorter…about 10 minute chunks.
The communication of the class is very poor. I don't know what's due when. This major confusion is causing grumbling from the whole class.
Better compatibility.
Would like better organization for the class and syllabus. A better way to pick project groups would also be nice.
Syllabus format sucks.
I want to use Firefox.
The syllabus needs dates.
Need better communication about assignment due dates and what not.
Firefox
The syllabus needs DATES…so confused about what is due when right now!
In the web lectures, the highlighting of the info was inconsistent. Also, it requires Office, which is expensive.

Keep it the same as it is now. Really good!
The syallabus is terrible. I think we all agree that this class would be better if the admin / schedule stuff was taken more seriously.
Please use a cross-platform/browswer application.
I'd like to see links to related, optional material provided in the web lecture.
I'd like to do more with in class time.
Cross platform and browser would be nice.
The syllabus was very unclear b/c dates were missing. I think this is being fixed, but it was very frustrating up to this point.
Less abbreviations on the syllabus.
Bigger video image.
Require a summary of the web lecture material rather than specific homework questions.
No, this seems like it will work well.
Make the web lectures a little shorter. Add animations or music or something to make the video more entertaining.
I think it would be nice to have quiz questions built into the web lectures themselves.

Midway Survey

Question: What do you like/dislike about the web lectures forum integrated with the web lectures? How do you feel about making part of the lecture homeworks require posting to the web lectures forum? Do you have any suggestions for how this could be done better, or for other ways to encourage student participation on the forum?

Good. I wish more people used it seriously, and the TA/Prof would post.
The forum needs to be motivated in other ways beyond the LHW. Nobody uses it other than that…probably because the TA/Prof never had a presence on there.
Students only do what is required. We should discuss the forum postings more in class and the TA or instructor should post too.
I don't like being required to post for HW.
I think idea is great, but I feel like most of us just post some question because we need to and then find a really easy one to answer.
There seems to be too much of a separation between the forum and the class/web lectures.
It can be helpful sometimes, but other times it feels like busy work.
I don't like being forced to use the forum. Newsgroups would be better. I have used them in other classes. But, I do like the post/answer a question exercise…some good insights can be gained from seeing and answering other students questions.
Being forced to use the forum discourages me to use it any other time. Perhaps motivate posting/answering questions with extra credit?
Too forced. I just prefer to email the TA directly.
I do not like the idea of being forced to post. At that point, my understanding of the material may not be complete, so I don't want to post a stupid question / answer.
It's a nice thought, but there isn't enough traffic on there to motivate my attention and participation beyond the required HW.
It's another website to remember. I'm tired of all the websites professors are encouraging students use.
Not good.
I feel rather ambivilent about the integration of the forum.
Requiring posts is fine.
I think forums are not the way to go because students are not motivated to chem them.
I feel like the forum integration is too cumbersome; the feedback was too slow if you had a question and not usually from a professor or TA--from a student. It would be nice to have the

forum for a topic directly connected to the slides if conincided with. There would be fewer threads to dig through if you have a question.

I don't believe the forum is very useful. I think that some students came up with good questions that brought about good discussion in class, but many others questions were not good. I think it's done as well as it can be now, just not really needed.

The web lecture forum is not used at all unless the LHW requires it. The forum otherwise seems to be a good idea that is not encouraged enough or introduced the right way at the beginning of the semester.

No one would post anything if it wasn't required for our homework. Doesn't feel like posting questions there will be answered.

The only thing anyone uses it for is the homework.

Not really motivated beyond requirement to view/post in the forum.

Posting to the forum as part of the HW seems like busy work to me.

I don't like the forum. Don't get much out of it. Might use it more if I could tell the TA checked it or they commented there.

The forum is pretty useless. I like to just wait to hear the teacher discuss our questions when I get to class. That is much more meaningful.

Question: What do you like/dislike about using web lectures as part of this course?

Hate using IE, but otherwise all good.

I like the flexibility and the interface.

Sometimes too much rehash of web lecture in class.

I like the way parts of the slides are highlighted as Jim talks about them. I really enjoy the web lectures overall--I feel like they help with my learning.

I feel like I have better interaction with the professor even in a big class because of the web lectures taking care of much of the usual talking.

I think they are very useful, and I like the way they have been integrated into class meetings.

I really like being able to repeat the lecture over and over again so I can understand all the material.

Sometimes it feels like I do double the work with this class, even though I know the cancelled classes make up for it.

I think it's my personality to prefer normal in-class lectures. I can see why a lot of the other students like this class though.

LHWs are a lot of work.

I like being able to replay parts of the lecture so I can understand better. In class, I would often not as the professor to repeat because it disrupts the other students.

I like being able to watch the lectures when I have time and at my own pace. Also, when we do other things in class besides lecture it's really helpful and fun. It happens more with this course schedule.

No real preference either way…sometimes I just like to come to class and hear a lecture like other classes. Just used to it.

I like not having class sometimes.

I still really like being able to watch the web lectures on my time and that I can pause and review easily. And I like that the lectures have video…better than normal PPT.

Question: Do you have any suggestions for improving the web lectures, course format, or any other aspect of this course?

I would like the video to be bigger, and a live chat with the TA might be helpful.

There's still a lack of communication with assignments. Need better course organization.

The web lectures are good.

LHW grading seems too harsh sometimes.
A little shorter web lectures would be nice.
I think this format would be better suited for a MWF vs TR schedule.
Drop manditory postings, have TA show presence on forum and I'd probably post on my own.
Put all of the websites at one location…too spread out on different sites now.
I'd like to have a slider-type video control so I can navigate more refined than the outline topics.
The web lectures are good, but need to make sure we don't just repeat the same lecture in class.
Less homework, more focus on project.
The lectures should be available in multiple OS/browser compatibility. It would also be nice to have suggested resources / reading links directly on the web lecture.

Final Survey

Question: What do you like/dislike about using web lectures as part of this course?

Very well done.
Sometimes the web lectures seemed too time consuming and a little boring.
I love being able to pace the lecture at my own learning speed and convenience.
I felt like this class was too much work.
The web lectures are very good. I prefer this mixed class format to the normal lecture.
Good.
Not very personal.
I feel like I learned a lot more in this course because I had both repeatable access to all the lectures and interaction in the classroom--other than just sitting there.
I really like this format. For the web lectures, the ability to navigate using the table of contents and most of the screen dedicated to the slides was very nice.
I really liked the table of contents nav at the botton left…for going both forward and back, and for outlining the lecture.
I like the professor and how he presents the material in the web lectures. I like the order of the course material too. The semester long project has really helped my understanding of the material. I disliked how the prof and the TA always contradicted each other. It was very confusing. I also disliked the vague project description. We lost a lot of points because of this.
I like the idea.

Question: Did you notice the “Pause and email question” link in the web lecture UI? If yes, what reasons did you have for *not* using this feature?

I felt like I wouldn't get feedback in a reasonable amount of time.
Yes, but I never used it. I didn't have many questions anyway, so I just waited to ask in class. And, I use an email client other than Outlook.
I didn't need it.
Too slow of a response mechanism
Saw it, but it would take too long for a response.
Takes too long to respond.
Not instantaneous.
I did not use. Too slow.
I noticed it, but I just prefered to wait and ask in class.
Just googled or took more time with web lecture. Couple times got answers from the book.
Yes, but I understood the lectures and didn't need to ask anything.
I just prefer to ask in person.

No, I didn't even notice it. We should have taken more time at the start of the class to cover ALL this type of stuff.

Too much trouble. I will have to wait too long for a reply.

Yes, but I never had any questions that couldn't wait until class met next. Most of the time, any questions I had could be answered simply by going back over a section of the web lecture after I watched through the first time.

Didn't need it.

Yes, I didn't know who the email would be going to and to me email feels like an emergency or essential form of communication for a small question about a lecture.

Yes. I did not use it because I am too impatient to wait for an email response. I would rather search for the answer independently.

Noticed, but no need.

Yes. I usually know we'll discuss the lecture in detail in class, so most of my questions are always answered anyway.

Yes. It was clear. If I had questions, though, I just asked in class. Nice that we have that option in this format, so didn't need to use the link to email questions.

Not necessary.

I noticed, but if it's like other things in this course I probably wouldn't get an answer for days.

Just didn't want to.

I've never had a question burning enough to need to email the prof about it.

Just get answer in class. Nice to have the option there just in case, but nicer to be able to rely on class even though using online lectures.

Question: What do you like/dislike about the web lectures forum integrated with the web lectures? How do you feel about making part of the lecture homeworks require posting to the web lectures forum?

It just felt tacked on, and without prof or TA involvement there just wasn't much motivation. This is the only part of this new course type that did not help me.

I think it's useless.

One good thing about post/answer a test question HW is that it makes me want to post the BEST question. So, I reviewed the material more for those HWs where we did this exercise. Overall though, not enough buy-in across the teacher/TA/class for this to be fully realized.

Too much going on already. No need for more assignments.

It makes us think, even when we don't want to.

The few times a good discussion or posted question came up, I really liked it. The problem was that this was rare, so this feature was underused in my opinion.

Seemed pointless to me.

Only used when I had to.

Can become tedious.

I didn't like using it.

Trying to generate high quality questions was really hard, which made it a good assignment. But, I don't feel like enough people took it seriously to make the forum useful overall.

Not enough posts.

The forum questions/answers were really good for reviewing for the test. I was initially against the forum, but now I like it for some things. Needs to be more active.

I disliked the forum.

Not integrated with class well enough.

Negative about posting. Maybe have the TA post or answer some questions once in a while?

I like to hear other classmates opinions. I would appreciate the forum more if it were a larger part of the class. No one uses it enough to be an effective learning too, unfortunately.

Not keen on requiring, but good for extra assistance.

I think it's a great idea, but it needs to be more thoroughly integrated; a direct link from the

lecture to the associated lecture would make it much easier to use and navigate through.
Having us come up with our own test-like question on the forum was a good exercise. I liked doing that, and I liked seeing what others thought of.
The forum could be more active, but the idea helps people get out on the forums and thinking in new ways.
It was OK. Not my favorite part.
The forum was annoying.
It is completely useless.
Waste of my time.
Test question was a good idea, just needed more interaction from teacher and TA I think so we felt like we were being noticed for our work.
I don't think the TA even looks at this, so why should we?

Question: As the semester progressed, did your use or attitude about web lectures change? If yes, in what ways and why?

I was a little skeptical at first because it's a new idea, but I really started to like it as we went on.
I started wishing other profs would do this towards the end of the semester.
Got more and more used to the idea. Would definitely take another class like this if offered.
I started to enjoy the flexibility of this format more. I learned a lot more in this class than I think I would have the same class taught with normal lectures.
Liked the whole way, a little more as it became part of my routine.
I liked them from the start, but I my attitude about them did become more even more positive as the semester progressed and I got used to this setup.
It was cool.
At first, it seemed like a burden. It frees up class time though for other activities and lets you decide when you want to study the lectures, instead of being an obligatory period of time in your day. I learn better some times than others, and this class let me take advantage of that more than others.
Stayed about the same. They were very useful all semester.
I've liked this class from the beginning. I enjoy doing web lectures and I find it useful to have them available anytime for studying.
Yes, I liked it better. I was more familiar with the interface and what to expect.
Yes, at the beginning I thought it would be more work, but I realized that the time equaled out and we actually got more out of the class this way.

Question: Do you have any suggestions for improving the web lectures, course format, or any other aspect of this course?

More explanation of project expectations. I'd like to see videos of structured interviews / focus groups. Try to find a less boring text book.
Add an option for editing the PPT to add notes when necessary.
I know most other students really like the web lectures and this class, but for some reason it just doesn't work with me as well. Sorry.
As I'm sure you've heard a million times, non-Microsoft dependence would be good.
I really liked this class, but I definitely got frustrated with the lack of guidance with the project. We were graded unfairly I think.
Be more prompts in returning feedback. Give better descriptions for all requirements initially (not clarifications sent out the day before it's due!).
Nope. Besides better forum use, this approach is very beneficial in my eyes.
I prefer tests to groupwork.
It is a solid, good course.

Get more organized. Get back project reports before the next ones are due!
The idea of watching the lectures beforehand and doing discussions or activities during class is great!
Web lectures are formatted in a great way. I do not have any suggestions for improvement, as it is already good.
I would have come to more classes if we had them, even though it would have meant a little more work than normal.
Don't put the syllabus in that library. Too complicated.
Please make sure the TA and prof are on the same page. Project report expectations need to be made clear!
I think having quizzes when we come to class instead of LHWs sometimes would be a nice change and accomplish the same thing.
I'm not very interested in HCI, but I think the way this class was taught helped me stick with it more than I would have otherwise.

APPENDIX D

Details of the Statistical Analysis of Data from the 2nd Classroom Quasi-experiment

Grades Analysis

```
CROSSTABS
  /TABLES=Sex Age Year Major BY Section
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ CORR
  /CELLS=COUNT
  /COUNT ROUND CELL
```

Crosstabs

Sex * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
Sex	Male	30	25	55
	Female	9	8	17
Total		39	33	72

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.013[a]	1	.908		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.013	1	.908		
Fisher's Exact Test				1.000	.563
Linear-by-Linear Association	.013	1	.908		
N of Valid Cases[b]	72				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.79.

b. Computed only for a 2x2 table

Symmetric Measures

	Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.

Interval by Interval	Pearson's R	.014	.118	.114	.909[c]
Ordinal by Ordinal	Spearman Correlation	.014	.118	.114	.909[c]
N of Valid Cases		72			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Age * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
Age	19	2	1	3
	20	8	4	12
	21	18	9	27
	22	6	9	15
	23	1	6	7
	24	1	1	2
	25	1	3	4
	27	1	0	1
	29	1	0	1
Total		39	33	72

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.417[a]	8	.179
Likelihood Ratio	12.642	8	.125
Linear-by-Linear Association	1.302	1	.254
N of Valid Cases	72		

a. 12 cells (66.7%) have expected count less than 5. The minimum expected count is .46.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	.135	.125	1.143	.257[c]
Ordinal by Ordinal	Spearman Correlation	.255	.114	2.205	.031[c]
N of Valid Cases		72			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Year * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
Year	Freshman	1	0	1
	Sophomore	1	0	1
	Junior	18	11	29
	Senior	18	19	37
	Other	1	3	4
Total		39	33	72

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.246[a]	4	.374
Likelihood Ratio	5.052	4	.282
Linear-by-Linear Association	3.920	1	.048
N of Valid Cases	72		

a. 6 cells (60.0%) have expected count less than 5. The minimum expected count is .46.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	.235	.102	2.023	.047[c]
Ordinal by Ordinal	Spearman Correlation	.216	.112	1.852	.068[c]

N of Valid Cases		72			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Major * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
Major	Computer Science	32	26	58
	Computer Engineering	0	1	1
	STAC	1	0	1
	Computational Media	4	6	10
	Electrical Engineering	1	0	1
	Management	1	0	1
Total		39	33	72

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.552[a]	5	.473
Likelihood Ratio	6.069	5	.300
Linear-by-Linear Association	.000	1	.984
N of Valid Cases	72		

a. 9 cells (75.0%) have expected count less than 5. The minimum expected count is .46.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	-.002	.117	-.019	.985[c]
Ordinal by Ordinal	Spearman Correlation	.028	.118	.236	.814[c]
N of Valid Cases		72			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	-.002	.117	-.019	.985[c]
Ordinal by Ordinal	Spearman Correlation	.028	.118	.236	.814[c]
N of Valid Cases		72			

a. Not assuming the null hypothesis.

c. Based on normal approximation.

```
CROSSTABS
  /TABLES=Absences1 BY Section
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ CORR
  /CELLS=COUNT
  /COUNT ROUND CELL

  /BARCHART.
```

Crosstabs

Absences * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
Absences	0	13	9	22
	1	14	9	23
	2	7	7	14
	3	4	3	7
	4	0	3	3
	5	1	1	2
	6	0	1	1
Total		39	33	72

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.495[a]	6	.482
Likelihood Ratio	7.015	6	.319

Linear-by-Linear Association	2.434	1	.119
N of Valid Cases	72		

a. 8 cells (57.1%) have expected count less than 5. The minimum expected count is .46.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	.185	.112	1.576	.119[c]
Ordinal by Ordinal	Spearman Correlation	.150	.117	1.271	.208[c]
N of Valid Cases		72			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

```
T-TEST GROUPS=Section(1 2)
  /MISSING=ANALYSIS
  /VARIABLES=Absences2
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
Absences	Experimental	39	1.15	1.159	.186
	Control	33	1.67	1.594	.278

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference 95%
Confidence Interval of the Difference
Lower Upper
Absences Equal variances assumed 3.963 .050 -1.576 70 .119 -.513 -1.162
.136
Equal variances not assumed -1.536 57.372 .130 -.513 -1.181
.156

```
MEANS TABLES=CourseGrade Exams Project LHW HW InGPA BY Section
  /CELLS MEAN COUNT STDDEV.
```

Means

Report

Section		Final Course Grade	Exams Combined	Project Combined	LHW Total Grade	HW Combined	Incoming GPA
Experimental	Mean	8.22808861508861E1	83.71	7.65614809131018E1	8.57692307692308E1	90.5448718	2.9659
	N	39	39	39	39	39	39
	Std. Deviation	4.334514626936318E0	5.142	6.949531291939456E0	9.963779887698232E0	13.74457278	.48164

Control	Mean	8.06639233241506E1	83.89	7.61675357061890E1	8.27705627705628E1	89.2992424	2.9915
	N	33	33	33	33	33	33
	Std. Deviation	6.213391009596204E0	4.783	8.484907322321686E0	1.454399068492860E1	13.25607225	.57044
Total	Mean	8.15397781886323E1	83.79	7.63809226932668E1	8.43948412698413E1	89.9739583	2.9776
	N	72	72	72	72	72	72
	Std. Deviation	5.302244217602259E0	4.947	7.637766044885293E0	1.227739249664030E1	13.44241230	.52056

```
T-TEST GROUPS=Section(1 2)
  /MISSING=ANALYSIS
  /VARIABLES=InGPA
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
Incoming GPA	Experimental	39	2.9659	.48164	.07712
	Control	33	2.9915	.57044	.09930

Independent Samples Test

Levene's Test for Equality of Variances   t-test for Equality of Means

F   Sig.   t   df   Sig. (2-tailed)   Mean Difference   95% Confidence Interval of the Difference

Lower   Upper

Incoming GPA   Equal variances assumed   .890   .349   -.207   70   .837   -.02562   -.27286   .22162

Equal variances not assumed   -.204   62.958   .839   -.02562   -.27688   .22564

```
T-TEST GROUPS=Section(1 2)
  /MISSING=ANALYSIS
  /VARIABLES=HWB HWD HWF HW
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
HW B	Experimental	39	8.56837606837607E1	3.020617614492019E1	4.836859219597335E0
	Control	33	8.34595959595960E1	3.014513591404248E1	5.247594598382438E0
HW D	Experimental	39	90.13	22.522	3.606
	Control	33	92.73	17.945	3.124
HW F	Experimental	39	96.79	11.892	1.904
	Control	33	92.88	17.679	3.078
HW Combined	Experimental	39	9.0544872E1	13.74457278	2.20089306
	Control	33	8.9299242E1	13.25607225	2.30758598

Independent Samples Test

Levene's Test for Equality of Variances   t-test for Equality of Means

F   Sig.   t   df   Sig. (2-tailed)   Mean Difference   95% Confidence Interval of the Difference

Lower   Upper

HW B Equal variances assumed .008 .927 .312 70 .756 2.224164724164737E0
-1.201196415894275E1 1.646029360727222E1
Equal variances not assumed .312 68.086 .756 2.224164724164737E0
-1.201656761959231E1 1.646489706792178E1
HW D Equal variances assumed .608 .438 -.535 70 .595 -2.599 -12.296
7.098
Equal variances not assumed -.545 69.772 .588 -2.599 -12.115
6.917
HW F Equal variances assumed 3.693 .059 1.117 70 .268 3.916 -3.075
10.908
Equal variances not assumed 1.082 54.472 .284 3.916 -3.338
11.170
HW Combined Equal variances assumed .001 .970 .389 70 .698 1.24562937
-5.13384292 7.62510166
Equal variances not assumed .391 68.774 .697 1.24562937
-5.11636231 7.60762106

T-TEST GROUPS=Section(1 2)
/MISSING=ANALYSIS
/VARIABLES=LHW1 LHW2 LHW3 LHW4 LHW5 LHW6 LHW7 LHW8 LHW9 LHW10 LHW11 LHW12 LHW13 LHW14 LHW15 LHW
/CRITERIA=CI(.9500).

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
LHW 1	Experimental	39	7.52	1.729	.277
	Control	33	7.40	2.442	.425
LHW 2	Experimental	39	7.814	1.8025	.2886
	Control	33	7.561	2.2905	.3987
LHW 3	Experimental	39	6.99	2.267	.363
	Control	33	6.42	3.026	.527
LHW 4	Experimental	39	6.00	2.433	.390
	Control	33	5.88	2.770	.482
LHW 5	Experimental	39	8.186	3.2306	.5173
	Control	33	8.098	3.2222	.5609
LHW 6	Experimental	39	7.821	3.1403	.5029
	Control	33	7.455	3.0730	.5349
LHW 7	Experimental	39	8.32	2.699	.432
	Control	33	8.83	2.167	.377
LHW 8	Experimental	39	8.97	2.334	.374
	Control	33	8.97	1.610	.280
LHW 9	Experimental	39	9.13	1.765	.283
	Control	33	8.55	2.514	.438
LHW 10	Experimental	39	9.03	2.422	.388
	Control	33	8.55	2.451	.427
LHW 11	Experimental	39	8.97	2.288	.366
	Control	33	8.91	1.422	.248
LHW 12	Experimental	39	8.41	2.643	.423
	Control	33	7.61	3.181	.554
LHW 13	Experimental	39	9.23	1.980	.317
	Control	33	8.76	2.750	.479
LHW 14	Experimental	39	8.67	2.766	.443
	Control	33	8.33	3.247	.565

LHW15	Experimental	39	7.85	2.987	.478
	Control	33	7.88	3.160	.550
LHW Total Grade	Experimental	39	8.57692307692308E1	9.963779887698236E0	1.595481678337377E0
	Control	33	8.27705627705628E1	1.454399068492860E1	2.531783806673876E0

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means				95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
LHW 1	Equal variances assumed	2.059	.156	.239	70	.812	.118	-.866	1.101
	Equal variances not assumed			.232	56.353	.817	.118	-.898	1.134
LHW 2	Equal variances assumed	.235	.630	.525	70	.601	.2535	-.7089	1.2159
	Equal variances not assumed			.515	60.366	.608	.2535	-.7310	1.2380
LHW 3	Equal variances assumed	1.801	.184	.901	70	.371	.563	-.683	1.809
	Equal variances not assumed			.880	58.493	.382	.563	-.717	1.843
LHW 4	Equal variances assumed	.166	.685	.198	70	.844	.121	-1.102	1.344
	Equal variances not assumed			.196	64.336	.846	.121	-1.117	1.360
LHW 5	Equal variances assumed	.040	.843	.115	70	.909	.0874	-1.4348	1.6096
	Equal variances not assumed			.115	68.099	.909	.0874	-1.4352	1.6100
LHW 6	Equal variances assumed	.002	.963	.498	70	.620	.3660	-1.1010	1.8329
	Equal variances not assumed			.498	68.499	.620	.3660	-1.0989	1.8308
LHW 7	Equal variances assumed	.974	.327	-.878	70	.383	-.513	-1.678	.652
	Equal variances not assumed			-.894	69.826	.374	-.513	-1.657	.631
LHW 8	Equal variances assumed	.401	.529	.010	70	.992	.005	-.955	.965
	Equal variances not assumed			.010	67.437	.992	.005	-.928	.937
LHW 9	Equal variances assumed	1.875	.175	1.151	70	.253	.583	-.427	1.592
	Equal variances not assumed			1.119	56.052	.268	.583	-.461	1.626
LHW 10	Equal variances assumed	.262	.610	.834	70	.407	.480	-.669	1.629
	Equal variances not assumed			.833	67.774	.408	.480	-.670	1.631
LHW 11	Equal variances assumed	.253	.617	.142	70	.887	.065	-.850	.981
	Equal variances not assumed			.148	64.622	.883	.065	-.818	.949
LHW 12	Equal variances assumed	.901	.346	1.172	70	.245	.804	-.565	2.173
	Equal variances not assumed			1.154	62.374	.253	.804	-.589	2.197
LHW 13	Equal variances assumed	2.271	.136	.847	70	.400	.473	-.642	1.588
	Equal variances not assumed			.824	56.984	.413	.473	-.677	1.623
LHW 14	Equal variances assumed	.365	.548	.471	70	.639	.333	-1.080	1.746
	Equal variances not assumed			.464	63.272	.644	.333	-1.101	1.768

LHW15 Equal variances assumed .004 .948 -.045 70 .964 -.033 -1.480
1.414
Equal variances not assumed -.045 66.616 .964 -.033 -1.488
1.423
LHW Total Grade Equal variances assumed 3.386 .070 1.033 70 .305
2.998667998667997E0 -2.790252826769247E0 8.787588824105242E0
Equal variances not assumed 1.002 55.140 .321 2.998667998667997E0
-2.998239699380904E0 8.995575696716898E0

```
T-TEST GROUPS=Section(1 2)
 /MISSING=ANALYSIS
 /VARIABLES=P1 P2 P3 P4 Project
 /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
Project Part 1	Experimental	39	73.391	11.6909	1.8720
	Control	33	67.636	16.9453	2.9498
Project Part 2	Experimental	39	74.851	17.3941	2.7853
	Control	33	74.432	14.6004	2.5416
Project Part 3	Experimental	39	71.808	11.7544	1.8822
	Control	33	74.318	12.4786	2.1722
Project Part 4	Experimental	39	85.96	7.272	1.165
	Control	33	88.09	6.756	1.176
Project Combined	Experimental	39	7.65614809131018E1	6.949531291939456E0	1.112815615588947E0
	Control	33	7.61675357061891E1	8.484907322321690E0	1.477032777671096E0

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference 95%
Confidence Interval of the Difference
Lower Upper
Project Part 1 Equal variances assumed .775 .382 1.697 70 .094 5.7547
-1.0072 12.5165
Equal variances not assumed 1.647 55.400 .105 5.7547 -1.2457
12.7550
Project Part 2 Equal variances assumed .684 .411 .110 70 .913 .4195
-7.2118 8.0507
Equal variances not assumed .111 69.998 .912 .4195 -7.1008
7.9397
Project Part 3 Equal variances assumed .105 .747 -.878 70 .383 -2.5105
-8.2142 3.1932
Equal variances not assumed -.873 66.515 .386 -2.5105 -8.2483
3.2273
Project Part 4 Equal variances assumed .096 .758 -1.279 70 .205 -2.129
-5.451 1.192
Equal variances not assumed -1.287 69.361 .203 -2.129 -5.431
1.172
Project Combined Equal variances assumed 2.292 .135 .217 70 .829 .393945206912775
-3.233478937265360E0 4.021369351090910E0
Equal variances not assumed .213 61.856 .832 .393945206912775
-3.302964417633348E0 4.090854831458898E0

```
T-TEST GROUPS=Section(1 2)
 /MISSING=ANALYSIS
 /VARIABLES=Midterm Final Exams
 /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
Midterm Grade	Experimental	39	7.55924630924631E1	7.725198141369788E0	1.237021716156035 E0
	Control	33	7.83057851239669E1	7.267196696194969E0	1.265056566242612 E0
Final Exam Grade	Experimental	39	9.00946275946276E1	5.326575245157873E0	8.529346601110095 E-1
	Control	33	8.82756132756132E1	4.154651171531556E0	7.232319372538073 E-1
Exams Combined	Experimental	39	83.71	5.142	.823
	Control	33	83.89	4.783	.833

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference 95% Confidence Interval of the Difference
Lower Upper
Midterm Grade Equal variances assumed .103 .749 -1.526 70 .132 - 2.713322031503864E0 -6.260427166728571E0 .833783103720843
Equal variances not assumed -1.534 69.185 .130 -2.713322031503864E0 -6.242905277195163E0 .816261214187435
Final Exam Grade Equal variances assumed 1.554 .217 1.593 70 .116 1.819014319014329E0 -4.577060193928991E-1 4.095734657421556E0
Equal variances not assumed 1.627 69.576 .108 1.819014319014329E0 -4.115742174438116E-1 4.049602855472469E0
Exams Combined Equal variances assumed 1.513 .223 -.149 70 .882 -.175 -2.525 2.175
Equal variances not assumed -.150 69.345 .881 -.175 -2.511 2.161

```
T-TEST GROUPS=Section(1 2)
  /MISSING=ANALYSIS
  /VARIABLES=CourseGrade
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
Final Course Grade	Experimental	39	8.22808861508862E1	4.334514626936318 E0	6.940778248524586E-1
	Control	33	8.06639233241506E1	6.213391009596208 E0	1.081612542486715E0

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference 95% Confidence Interval of the Difference
Lower Upper
Final Course Grade Equal variances assumed 4.683 .034 1.295 70 .199 1.616962826735573E0 -8.724248626808148E-1 4.106350516151961E0
Equal variances not assumed 1.258 55.811 .214 1.616962826735573E0 -9.577092880626343E-1 4.191634941533781E0

```
UNIANOVA CourseGrade BY Section WITH Age Year Sex InGPA
  /METHOD=SSTYPE(3)
```

/INTERCEPT=INCLUDE
/EMMEANS=TABLES(OVERALL) WITH(Age=MEAN Year=MEAN Sex=MEAN InGPA=MEAN)
/EMMEANS=TABLES(Section) WITH(Age=MEAN Year=MEAN Sex=MEAN InGPA=MEAN) COMPARE ADJ(BONFERRONI)
/PRINT=ETASQ HOMOGENEITY OPOWER
/CRITERIA=ALPHA(.05)
/DESIGN=Age Year Sex InGPA Section.

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Section	1	Experimental	39
	2	Control	33

Levene's Test of Equality of Error Variancesa
Dependent Variable:Final Course Grade

F	df1	df2	Sig.
3.715	1	70	.058

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Age + Year + Sex + InGPA + Section

Tests of Between-Subjects Effects
Dependent Variable:Final Course Grade

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Powerb
Corrected Model	382.204a	5	76.441	3.126	.014	.191	15.630	.850
Intercept	1817.130	1	1817.130	74.312	.000	.530	74.312	1.000
Age	3.118	1	3.118	.128	.722	.002	.128	.064
Year	22.550	1	22.550	.922	.340	.014	.922	.157
Sex	76.577	1	76.577	3.132	.081	.045	3.132	.415
InGPA	84.993	1	84.993	3.476	.067	.050	3.476	.451
Section	30.184	1	30.184	1.234	.271	.018	1.234	.195
Error	1613.875	66	24.453					
Total	480705.030	72						
Corrected Total	1996.079	71						

a. R Squared = .191 (Adjusted R Squared = .130)
b. Computed using alpha = .05

Survey Analysis

Descriptives

Descriptive Statistics

	N	Mean	Std. Deviation
HCI Education 1 (Control)	34	4.50	.615
HCI Education 2 (Control)	32	4.38	.707
HCI Education 3 (Control)	29	4.21	.675
HCI Education 1 (Experimental)	37	4.54	.650
HCI Education 2 (Experimental)	33	4.52	.834
HCI Education 3 (Experimental)	33	4.15	.834
HCI Career 1 (Control)	34	4.44	.660
HCI Career 2 (Control)	31	4.32	.653
HCI Career 3 (Control)	29	3.97	.823
HCI Career 1 (Experimental)	37	4.35	.824

HCI Career 2 (Experimental)	33	4.33	.924
HCI Career 3 (Experimental)	33	3.82	1.131
HCI Seek Job 1 (Control)	34	3.44	1.021
HCI Seek Job 2 (Control)	32	3.44	.914
HCI Seek Job 3 (Control)	29	3.14	1.026
HCI Seek Job 1 (Experimental)	37	3.86	.976
HCI Seek Job 2 (Experimental)	33	3.94	.933
HCI Seek Job 3 (Experimental)	33	3.39	1.248
HCI Life 1 (Control)	34	4.18	.758
HCI Life 2 (Control)	32	4.28	.683
HCI Life 3 (Control)	29	4.17	.711
HCI Life 1 (Experimental)	37	4.16	.800
HCI Life 2 (Experimental)	33	4.30	.684
HCI Life 3 (Experimental)	33	4.03	1.015
LHW Focus 1 (Control)	34	3.53	.825
LHW Focus 2 (Control)	32	3.69	.859
LHW Focus 3 (Control)	29	3.62	.820
LHW Focus 1 (Experimental)	37	3.95	.780
LHW Focus 2 (Experimental)	33	3.94	.609
LHW Focus 3 (Experimental)	33	3.94	.704
LHW Learn 1 (Control)	34	3.76	.923
LHW Learn 2 (Control)	32	3.84	.723
LHW Learn 3 (Control)	29	3.79	.774
LHW Learn 1 (Experimental)	37	3.78	.821
LHW Learn 2 (Experimental)	33	3.97	.728
LHW Learn 3 (Experimental)	33	4.09	.631
Forum Attitude 2 (Control)	32	2.50	.880
Forum Attitude 3 (Control)	29	2.00	.886
Forum Attitude 2 (Experimental)	33	2.76	.792
Forum Attitude 3 (Experimental)	33	2.27	.876
Forum Learn 2 (Control)	32	2.34	.971
Forum Learn 3 (Control)	29	1.86	.990
Forum Learn 2 (Experimental)	33	2.45	1.121
Forum Learn 3 (Experimental)	33	2.30	1.015

Comparison Learn (Control)	29	3.00	.598
Comparison Learn (Experimental)	33	4.09	.678
Comparison Enjoy (Control)	29	2.72	.841
Comparison Enjoy (Experimental)	33	3.91	.980
Valid N (listwise)	29		

```
T-TEST GROUPS=Survey(1 3)
  /MISSING=ANALYSIS
  /VARIABLES=RateA RateB RateC Nav RateD CourseA CourseB HCIa1e HCIb1e HCIc1e HCId1e LHWa1e LHWb1e
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Survey	N	Mean	Std. Deviation	Std. Error Mean
Education in General	Early	37	3.70	.702	.115
	Final	33	3.94	.747	.130
In Advance of Class	Early	37	3.51	.651	.107
	Final	33	4.15	.755	.131
Exam Preparation	Early	37	3.84	.834	.137
	Final	33	3.67	.990	.172
Navigation Controls	Early	37	3.46	.730	.120
	Final	33	3.64	.783	.136
Attitude about Web Lectures	Early	37	3.65	.676	.111
	Final	33	3.67	.595	.104
Attitude about Course Format	Early	37	3.81	.616	.101
	Final	33	3.91	.631	.110
Format Comparison	Early	37	3.51	.607	.100
	Final	33	4.18	.727	.127
HCI Education	Early	37	4.54	.650	.107
	Final	33	4.15	.834	.145
HCI Career	Early	37	4.35	.824	.135
	Final	33	3.82	1.131	.197
HCI Seek Job	Early	37	3.86	.976	.161
	Final	33	3.39	1.248	.217
HCI Life	Early	37	4.16	.800	.131
	Final	33	4.03	1.015	.177
LHW Focus	Early	37	3.95	.780	.128
	Final	33	3.94	.704	.123
LHW Learn	Early	37	3.78	.821	.135
	Final	33	4.09	.631	.110

Independent Samples Test
Levene's Test for Equality of Variances   t-test for Equality of Means
F   Sig.   t   df   Sig. (2-tailed)   Mean Difference   Std. Error Difference
95% Confidence Interval of the Difference
Lower   Upper
Education in General   Equal variances assumed   .156   .694   -1.366   68   .176   -.237   .173
-.582   .109

Equal variances not assumed -1.361 65.893 .178 -.237 .174 -.584
.111
In Advance of Class Equal variances assumed .166 .685 -3.797 68 .000 -.638 .168
-.973 -.303
Equal variances not assumed -3.765 63.622 .000 -.638 .169 -.977
-.299
Exam Preparation Equal variances assumed 1.093 .300 .785 68 .435 .171 .218
-.264 .606
Equal variances not assumed .778 62.929 .440 .171 .220 -.269
.611
Navigation Controls Equal variances assumed .257 .614 -.978 68 .332 -.177 .181
-.538 .184
Equal variances not assumed -.974 65.724 .334 -.177 .182 -.540
.186
Attitude about Web Lectures Equal variances assumed 1.078 .303 -.118 68 .907 -.018
.153 -.323 .287
Equal variances not assumed -.119 67.992 .906 -.018 .152 -.321
.285
Attitude about Course Format Equal variances assumed .178 .675 -.659 68 .512 -.098
.149 -.396 .199
Equal variances not assumed -.658 66.710 .513 -.098 .149 -.397
.200
Format Comparison Equal variances assumed .267 .607 -4.192 68 .000 -.668 .159
-.986 -.350
Equal variances not assumed -4.148 62.617 .000 -.668 .161 -.990
-.346
HCI Education Equal variances assumed .195 .660 2.190 68 .032 .389 .178
.035 .744
Equal variances not assumed 2.159 60.314 .035 .389 .180 .029
.749
HCI Career Equal variances assumed 2.071 .155 2.272 68 .026 .533 .235
.065 1.002
Equal variances not assumed 2.232 57.932 .030 .533 .239 .055
1.011
HCI Seek Job Equal variances assumed 4.145 .046 1.767 68 .082 .471 .266
-.061 1.003
Equal variances not assumed 1.743 60.448 .086 .471 .270 -.069
1.011
HCI Life Equal variances assumed .007 .935 .607 68 .546 .132 .217 -.302
.565
Equal variances not assumed .599 60.705 .552 .132 .220 -.309
.572
LHW Focus Equal variances assumed .193 .662 .037 68 .971 .007 .178
-.350 .363
Equal variances not assumed .037 67.986 .971 .007 .177 -.347
.361
LHW Learn Equal variances assumed 5.650 .020 -1.739 68 .087 -.307 .177
-.660 .045
Equal variances not assumed -1.765 66.596 .082 -.307 .174 -.654
.040

```
T-TEST GROUPS=Survey(1 3)
  /MISSING=ANALYSIS
  /VARIABLES=HCIa1 HCIb1 HCIc1 HCId1 LHWa1 LHWb1
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Survey	N	Mean	Std. Deviation	Std. Error Mean
HCI Education	Early	34	4.50	.615	.106
	Final	29	4.21	.675	.125
HCI Career	Early	34	4.44	.660	.113
	Final	29	3.97	.823	.153
HCI Seek Job	Early	34	3.44	1.021	.175

	Final	29	3.14	1.026	.190
HCI Life	Early	34	4.18	.758	.130
	Final	29	4.17	.711	.132
LHW Focus	Early	34	3.53	.825	.142
	Final	29	3.62	.820	.152
LHW Learn	Early	34	3.76	.923	.158
	Final	29	3.79	.774	.144

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference Std. Error Difference
95% Confidence Interval of the Difference
Lower Upper
HCI Education Equal variances assumed .022 .881 1.802 61 .076 .293 .163
-.032 .618
Equal variances not assumed 1.789 57.328 .079 .293 .164 -.035
.621
HCI Career Equal variances assumed .215 .645 2.545 61 .013 .476 .187
.102 .849
Equal variances not assumed 2.501 53.496 .015 .476 .190 .094
.857
HCI Seek Job Equal variances assumed .439 .510 1.173 61 .245 .303 .259
-.214 .820
Equal variances not assumed 1.172 59.353 .246 .303 .259 -.214
.821
HCI Life Equal variances assumed .328 .569 .022 61 .983 .004 .186 -.368
.376
Equal variances not assumed .022 60.423 .983 .004 .185 -.366
.374
LHW Focus Equal variances assumed .006 .939 -.439 61 .662 -.091 .208
-.507 .325
Equal variances not assumed -.439 59.558 .662 -.091 .208 -.507
.325
LHW Learn Equal variances assumed 1.331 .253 -.131 61 .896 -.028 .217
-.462 .405
Equal variances not assumed -.133 60.987 .895 -.028 .214 -.456
.399

```
T-TEST GROUPS=Section(1 2)
  /MISSING=ANALYSIS
  /VARIABLES=HCIa1e HCIa2e HCIa3e HCIb1e HCIb2e HCIb3e HCIc1e HCIc2e HCIc3e HCId1e HCId2e HCId3e
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
HCI Education 1	Experimental	37	4.54	.650	.107
	Control	34	4.50	.615	.106
HCI Education 2	Experimental	33	4.52	.834	.145
	Control	32	4.38	.707	.125
HCI Education 3	Experimental	33	4.15	.834	.145
	Control	29	4.21	.675	.125
HCI Career 1	Experimental	37	4.35	.824	.135
	Control	34	4.44	.660	.113
HCI Career 2	Experimental	33	4.33	.924	.161
	Control	31	4.32	.653	.117
HCI Career 3	Experimental	33	3.82	1.131	.197
	Control	29	3.97	.823	.153

HCI Seek Job 1	Experimental	37	3.86	.976	.161
	Control	34	3.44	1.021	.175
HCI Seek Job 2	Experimental	33	3.94	.933	.162
	Control	32	3.44	.914	.162
HCI Seek Job 3	Experimental	33	3.39	1.248	.217
	Control	29	3.14	1.026	.190
HCI Life 1	Experimental	37	4.16	.800	.131
	Control	34	4.18	.758	.130
HCI Life 2	Experimental	33	4.30	.684	.119
	Control	32	4.28	.683	.121
HCI Life 3	Experimental	33	4.03	1.015	.177
	Control	29	4.17	.711	.132

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference Std. Error Difference
95% Confidence Interval of the Difference
Lower Upper
HCI Education 1 Equal variances assumed .038 .847 .269 69 .788 .041 .150
-.260 .341
Equal variances not assumed .270 68.930 .788 .041 .150 -.259
.340
HCI Education 2 Equal variances assumed .005 .943 .730 63 .468 .140 .192
-.244 .524
Equal variances not assumed .732 61.915 .467 .140 .192 -.243
.523
HCI Education 3 Equal variances assumed .331 .567 -.285 60 .777 -.055 .194
-.444 .333
Equal variances not assumed -.289 59.628 .774 -.055 .192 -.439
.328
HCI Career 1 Equal variances assumed .647 .424 -.504 69 .616 -.090 .178
-.445 .266
Equal variances not assumed -.509 67.784 .613 -.090 .177 -.442
.262
HCI Career 2 Equal variances assumed .961 .331 .053 62 .958 .011 .201
-.391 .413
Equal variances not assumed .054 57.655 .957 .011 .199 -.388
.409
HCI Career 3 Equal variances assumed 3.878 .054 -.579 60 .564 -.147 .254
-.656 .361
Equal variances not assumed -.591 58.087 .557 -.147 .249 -.646
.351
HCI Seek Job 1 Equal variances assumed 1.100 .298 1.787 69 .078 .424 .237
-.049 .897
Equal variances not assumed 1.784 67.853 .079 .424 .238 -.050
.898
HCI Seek Job 2 Equal variances assumed .000 .985 2.190 63 .032 .502 .229
.044 .960
Equal variances not assumed 2.191 62.994 .032 .502 .229 .044
.960
HCI Seek Job 3 Equal variances assumed 2.581 .113 .875 60 .385 .256 .293
-.329 .841
Equal variances not assumed .886 59.749 .379 .256 .289 -.322
.834
HCI Life 1 Equal variances assumed .002 .968 -.077 69 .939 -.014 .185 -.384
.355
Equal variances not assumed -.077 68.931 .939 -.014 .185 -.383
.354
HCI Life 2 Equal variances assumed .008 .929 .128 63 .898 .022 .170 -.317
.361
Equal variances not assumed .128 62.943 .898 .022 .170 -.317
.361
HCI Life 3 Equal variances assumed .222 .639 -.630 60 .531 -.142 .226 -.593
.309

Equal variances not assumed -.644 57.283 .522 -.142 .221 -.584 .299

```
CROSSTABS
  /TABLES=HCIa1e HCIa3e HCIb1e HCIb3e HCIc1e HCIc3e HCId1e HCId3e BY Section
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ
  /CELLS=COUNT

  /COUNT ROUND CELL.
```

Crosstabs

HCI Education 1 * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
HCI Education 1	3	3	2	5
	4	11	13	24
	5	23	19	42
Total		37	34	71

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.622[a]	2	.733
Likelihood Ratio	.623	2	.732
Linear-by-Linear Association	.074	1	.786
N of Valid Cases	71		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.39.

HCI Education 3 * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
HCI Education 3	2	2	0	2
	3	3	4	7
	4	16	15	31

	5	12	10	22
Total		33	29	62

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.108[a]	3	.550
Likelihood Ratio	2.872	3	.412
Linear-by-Linear Association	.082	1	.774
N of Valid Cases	62		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .94.

HCI Career 1 * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
HCI Career 1	2	2	0	2
	3	2	3	5
	4	14	13	27
	5	19	18	37
Total		37	34	71

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.141[a]	3	.544
Likelihood Ratio	2.911	3	.406
Linear-by-Linear Association	.257	1	.612
N of Valid Cases	71		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .96.

HCI Career 3 * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
HCI Career 3	1	1	0	1
	2	5	2	7
	3	3	4	7
	4	14	16	30
	5	10	7	17
Total		33	29	62

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.845[a]	4	.584
Likelihood Ratio	3.265	4	.514
Linear-by-Linear Association	.339	1	.560
N of Valid Cases	62		

a. 6 cells (60.0%) have expected count less than 5. The minimum expected count is .47.

HCI Seek Job 1 * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
HCI Seek Job 1	1	1	1	2
	2	3	4	7
	3	5	14	19
	4	19	9	28
	5	9	6	15
Total		37	34	71

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.466[a]	4	.076

Likelihood Ratio	8.711	4	.069
Linear-by-Linear Association	3.097	1	.078
N of Valid Cases	71		

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .96.

HCI Seek Job 3 * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
HCI Seek Job 3	1	4	2	6
	2	3	4	7
	3	8	14	22
	4	12	6	18
	5	6	3	9
Total		33	29	62

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.210[a]	4	.266
Likelihood Ratio	5.280	4	.260
Linear-by-Linear Association	.768	1	.381
N of Valid Cases	62		

a. 6 cells (60.0%) have expected count less than 5. The minimum expected count is 2.81.

HCI Life 1 * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
HCI Life 1	2	1	0	1
	3	6	7	13
	4	16	14	30

	5	14	13	27
Total		37	34	71

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.123[a]	3	.772
Likelihood Ratio	1.507	3	.681
Linear-by-Linear Association	.006	1	.938
N of Valid Cases	71		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is .48.

HCI Life 3 * Section

Crosstab

Count

		Section		Total
		Experimental	Control	
HCI Life 3	1	2	0	2
	3	4	5	9
	4	16	14	30
	5	11	10	21
Total		33	29	62

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.043[a]	3	.564
Likelihood Ratio	2.807	3	.422
Linear-by-Linear Association	.401	1	.527
N of Valid Cases	62		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .94.

```
T-TEST GROUPS=Section(1 2)
  /MISSING=ANALYSIS
  /VARIABLES=LHWa1e LHWa2e LHWa3e LHWb1e LHWb2e LHWb3e
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
LHW Focus 1	Experimental	37	3.95	.780	.128
	Control	34	3.53	.825	.142
LHW Focus 2	Experimental	33	3.94	.609	.106
	Control	32	3.69	.859	.152
LHW Focus 3	Experimental	33	3.94	.704	.123
	Control	29	3.62	.820	.152
LHW Learn 1	Experimental	37	3.78	.821	.135
	Control	34	3.76	.923	.158
LHW Learn 2	Experimental	33	3.97	.728	.127
	Control	32	3.84	.723	.128
LHW Learn 3	Experimental	33	4.09	.631	.110
	Control	29	3.79	.774	.144

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference Std. Error Difference
95% Confidence Interval of the Difference
Lower Upper
LHW Focus 1 Equal variances assumed 1.457 .232 2.187 69 .032 .417 .190
.037 .797
Equal variances not assumed 2.181 67.634 .033 .417 .191 .035
.798
LHW Focus 2 Equal variances assumed 8.727 .004 1.367 63 .176 .252 .184
-.116 .620
Equal variances not assumed 1.360 55.766 .179 .252 .185 -.119
.623
LHW Focus 3 Equal variances assumed 2.544 .116 1.646 60 .105 .319 .194
-.069 .706
Equal variances not assumed 1.630 55.623 .109 .319 .196 -.073
.710
LHW Learn 1 Equal variances assumed .121 .729 .092 69 .927 .019 .207
-.394 .432
Equal variances not assumed .092 66.303 .927 .019 .208 -.396
.434
LHW Learn 2 Equal variances assumed .203 .654 .699 63 .487 .126 .180
-.234 .486
Equal variances not assumed .699 62.962 .487 .126 .180 -.234
.486
LHW Learn 3 Equal variances assumed 1.248 .268 1.669 60 .100 .298 .178
-.059 .655
Equal variances not assumed 1.647 54.106 .105 .298 .181 -.065
.660

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T-TEST GROUPS=Section(1 2)
 /MISSING=ANALYSIS
 /VARIABLES=ForumA2e ForumA3e ForumB2e ForumB3e
 /CRITERIA=CI(.9500).
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T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
Forum Attitude 2	Experimental	33	2.76	.792	.138
	Control	32	2.50	.880	.156
Forum Attitude 3	Experimental	33	2.27	.876	.152
	Control	29	2.00	.886	.165

Forum Learn 2	Experimental	33	2.45	1.121	.195
	Control	32	2.34	.971	.172
Forum Learn 3	Experimental	33	2.30	1.015	.177
	Control	29	1.86	.990	.184

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference Std. Error Difference
95% Confidence Interval of the Difference
Lower Upper
Forum Attitude 2 Equal variances assumed 1.195 .279 1.241 63 .219 .258 .207
-.157 .672
Equal variances not assumed 1.239 61.852 .220 .258 .208 -.158
.673
Forum Attitude 3 Equal variances assumed .402 .529 1.217 60 .229 .273 .224
-.176 .721
Equal variances not assumed 1.216 58.790 .229 .273 .224 -.176
.722
Forum Learn 2 Equal variances assumed 1.520 .222 .425 63 .672 .111 .260
-.410 .631
Equal variances not assumed .426 62.227 .671 .111 .260 -.409
.630
Forum Learn 3 Equal variances assumed .304 .583 1.726 60 .089 .441 .255
-.070 .952
Equal variances not assumed 1.729 59.326 .089 .441 .255 -.069
.951

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T-TEST GROUPS=Survey(2 3)
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  /VARIABLES=ForumA2e ForumB2e
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Survey	N	Mean	Std. Deviation	Std. Error Mean
Forum Attitude	Midway	33	2.76	.792	.138
	Final	33	2.27	.876	.152
Forum Learn	Midway	33	2.45	1.121	.195
	Final	33	2.30	1.015	.177

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference Std. Error Difference
95% Confidence Interval of the Difference
Lower Upper
Forum Attitude Equal variances assumed .503 .481 2.359 64 .021 .485 .206
.074 .895
Equal variances not assumed 2.359 63.359 .021 .485 .206 .074
.896
Forum Learn Equal variances assumed .430 .514 .576 64 .567 .152 .263
-.374 .677
Equal variances not assumed .576 63.384 .567 .152 .263 -.374
.677

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DATASET ACTIVATE DataSet8.
T-TEST GROUPS=Survey(2 3)
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  /VARIABLES=ForumA2 ForumB2
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Survey	N	Mean	Std. Deviation	Std. Error Mean
Forum Attitude	Midway	32	2.50	.880	.156
	Final	29	2.00	.886	.165
Forum Learn	Midway	32	2.34	.971	.172
	Final	29	1.86	.990	.184

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference Std. Error Difference
95% Confidence Interval of the Difference
Lower Upper
Forum Attitude Equal variances assumed .892 .349 2.209 59 .031 .500 .226
.047 .953
Equal variances not assumed 2.208 58.326 .031 .500 .226 .047
.953
Forum Learn Equal variances assumed .004 .952 1.917 59 .060 .482 .251
-.021 .984
Equal variances not assumed 1.915 58.166 .060 .482 .252 -.022
.985

```
T-TEST GROUPS=Section(1 2)
  /MISSING=ANALYSIS
  /VARIABLES=LearnE EnjoyE
  /CRITERIA=CI(.9500).
```

T-Test

Group Statistics

	Section	N	Mean	Std. Deviation	Std. Error Mean
Comparison Learn	Experimental	33	4.09	.678	.118
	Control	29	3.00	.598	.111
Comparison Enjoy	Experimental	33	3.91	.980	.171
	Control	29	2.72	.841	.156

Independent Samples Test
Levene's Test for Equality of Variances t-test for Equality of Means
F Sig. t df Sig. (2-tailed) Mean Difference Std. Error Difference
95% Confidence Interval of the Difference
Lower Upper
Comparison Learn Equal variances assumed 3.112 .083 6.676 60 .000 1.091 .163
.764 1.418
Equal variances not assumed 6.732 59.999 .000 1.091 .162 .767
1.415
Comparison Enjoy Equal variances assumed .574 .452 5.073 60 .000 1.185 .234
.718 1.652
Equal variances not assumed 5.124 59.972 .000 1.185 .231 .722
1.648

Log Analysis

```
DESCRIPTIVES VARIABLES=TotalViewTimeMinutes

  /STATISTICS=MEAN STDDEV MIN MAX.
```

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Total View Time (Minutes)	20	255.1000	1.4276E3	5.544592E2	288.3134145
Valid N (listwise)	20				

```
CROSSTABS
  /TABLES=TotalViewTimeMinutes BY Avg
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ CORR
  /CELLS=COUNT
  /COUNT ROUND CELL

  /BARCHART.
```

Crosstabs

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.800E2[a]	361	.236
Likelihood Ratio	119.829	361	1.000
Linear-by-Linear Association	.714	1	.398
N of Valid Cases	20		

a. 400 cells (100.0%) have expected count less than 5. The minimum expected count is .05.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	.194	.174	.838	.413[c]
Ordinal by Ordinal	Spearman Correlation	.308	.201	1.375	.186[c]
N of Valid Cases		20			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

APPDENDIX E

Materials Used as Part of the Multimodal Learning Experiment

Entrance Survey

Please answer the following questions about your background experience. If at any point you have a question, please ask the study administrator.

Demographic Data

1. What is your age? _______

2. What is your gender?   Male / Female

3. What year are you?

Freshman   Sophomore   Junior   Senior   Other:____________

4. What is your major? ____________________

5. Have you taken or are you taking any Human-Computer Interaction (HCI) or related courses (e.g. CS/PSYC4750, CS/PSYC6750, etc.) ?

   Yes   No

6. Have you taken or are you taking a course with Prof. Jim Foley?

   Yes   No

7. How much exposure / interaction / use of multimedia educational materials have you experienced?

1	2	3	4	5
None	Not Very Much	Some	Quite a Bit	A Lot

Retention Portion of the Posttest

1. The principles presented were from what branch of psychology?

   Cognitive   Gestalt   Educational   Developmental   Organizational

2. "Our eyes/brain logically group together visual elements that are close to one another." This is the definition for which of the following:

Common Fate | Proximity | Situatedness | Similarity | Closure

3. "Our eyes/brain logically group together visual elements that are alike to one another." This is the definition for which of the following:

   Situatedness | Similarity | Common Fate | Proximity | Congruency

4. "Our eyes/brain associate elements that are aligned alike to one another." This is the definition for which of the following:

   Common Fate | Congruency | Proximity | Closure | Similarity

5. "Our eyes/brain logically group together visual elements that approximate a whole shape, to for that whole shape." This is the definition for which of the following:

   Extension | Similarity | Common Fate | Proximity | Closure

6. Which Gestalt principle causes you to group the "h" at the end of the first word in this sentence with the first word as opposed to seeing it as part of the second word?

   Closure | Continuation | Proximity | Extension | Similarity

7. Indentation can provide structure representative of which principle? ___________

8. How many principles of visual structure were presented? _________

9. Grids can provide structure representative of which principle? ____________

10. Use visual structure to ____.

11. Which two principles can be combined to create a *stronger* typographical hierarchy? _____________ and ________________

12. T / F . If combined, Gestalt principles always complement one another.

13. T / F . Visual design principles are good to use for dialog boxes, but not for web page design.

14. T / F . Items close together appear to have a relationship.

15. T / F . Gestalt principles cannot be combined.

16. T / F . Grids avoid disconcerting irregularities.

17. T / F. The mantra for visual design for user interface design is, “Use visual structure to reinforce logical structure.”

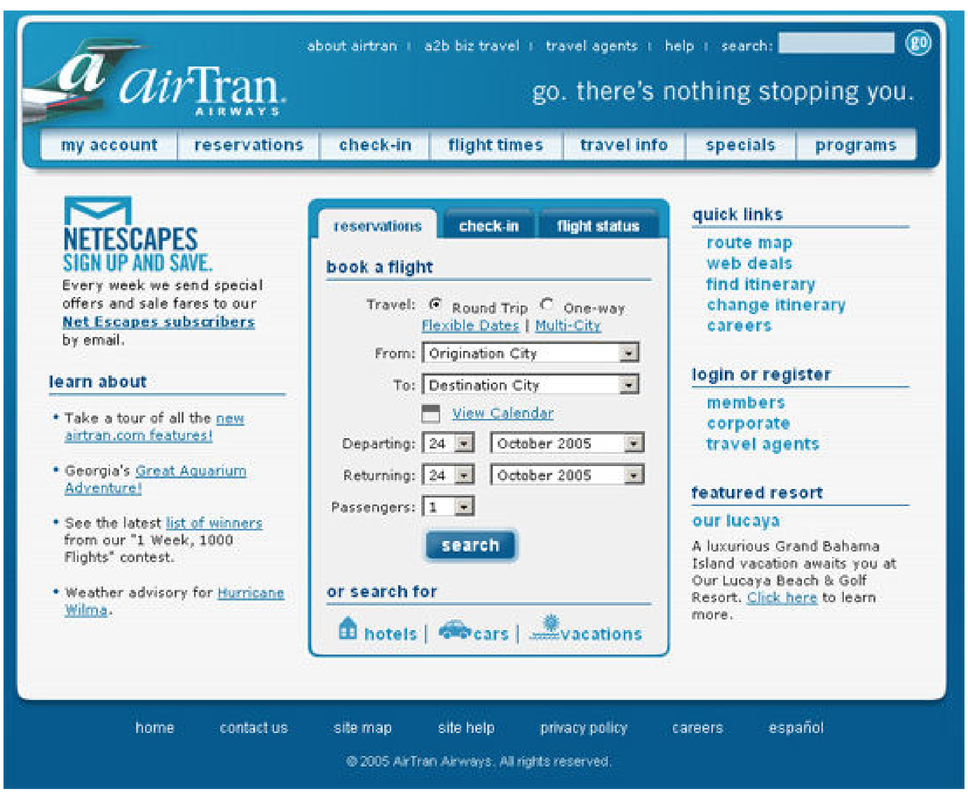
18. T / F. The Closure principle provides guidelines for logical placement of “Close” and “Exit” buttons in dialog boxes.

Transfer Portion of the Posttest

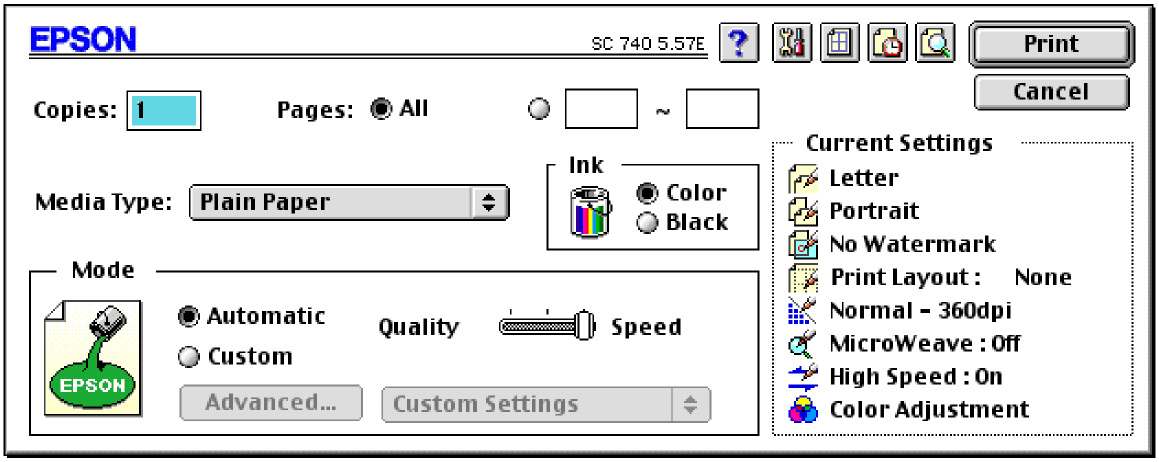
1. Sketch a simple representative example (not used in the PowerPoint presentation) of one of the four principles discussed in the presentation. Identify the principle and explain your example.

2. Sketch a simple representative example (not used in the PowerPoint presentation) of one of the three remaining principles discussed in the presentation. Identify the principle and explain your example.

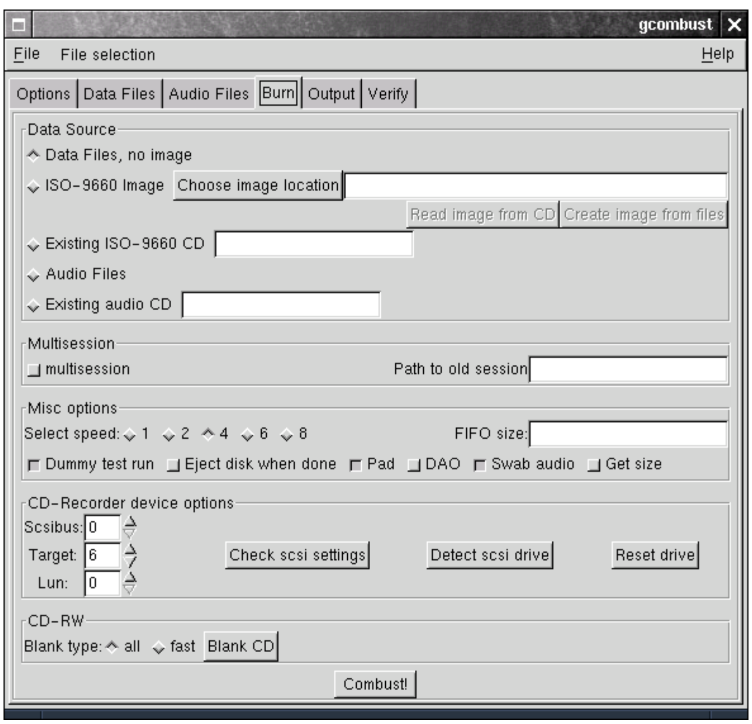
3. In terms of visual structure, would you consider the UI screenshot below good, bad, or a little of both? Use the four principles of visual structure discussed in the presentation to **justify your answer**.



4. In terms of visual structure, would you consider the UI screenshot below good, bad, or a little of both? Use the four principles of visual structure to **justify your answer**.



5. In terms of visual structure, would you consider the UI screenshot below good, bad, or a little of both? Use the four principles of visual structure to **justify your answer**.



Exit Survey

Please answer the following questions about your experiences while participating in this study. If at any point you have a question, please ask the study administrator.

1. In terms of your general learning, how would you rate the effectiveness of the educational materials you were provided?

1	2	3	4	5
Very Ineffective	Ineffective	Neutral	Effective	Very Effective

2. In terms of preparing you for the test, how would you rate the effectiveness of the educational materials you were provided?

1	2	3	4	5
Very Ineffective	Ineffective	Neutral	Effective	Very Effective

3. How likely is it that you would choose to use the kind of educational material you were provided?

1	2	3	4	5
Very Unlikely	Unlikely	Neutral	Likely	Very Likely

4. What did you like best about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

5. What did you like least about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

6. Please describe any ideas you have about what would make the educational material more effective:

7. How much does your opinion of the effectiveness of the educational material you were provided depend on the mode of delivery?

1	2	3	4	5
Not at All	Not Very Much	Some	Quite a Bit	A Lot

8. Think about the mode of delivery of the educational material independently of the content again. How does the mode of delivery affect your comprehension of the content?

1	2	3	4	5
Greatly Decreases Comprehension	Decreases Comprehension	No Affect on Comprehension	Increases Comprehension	Greatly Increases Comprehension

9. Consider the following course format: students are assigned educational material such as you were provided to study *before* coming to class, so less class time is needed for lecture and students come into class with some basic knowledge. Freed up class time is used to engage students with real-world application activities, discussion, and other active learning.

   a. In terms of educational effectiveness, how would you rate this course format in comparison to the traditional in-class lecture format?

1	2	3	4	5
Much Worse	Worse	About the Same	Better	Much Better

   b. In terms of overall course enjoyment, how would you rate this course format in comparison to the traditional in-class lecture format?

1	2	3	4	5
Much Worse	Worse	About the Same	Better	Much Better

10. Please provide any other feedback you might have here.

APPENDIX F

Participant Responses to Open-ended Questions on the Multimodal Learning Experiment Exit Survey

Video+Audio+PPT (*i.e.,* web lecture) Participants

Question: What did you like best about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

Opportunity to go back and review parts of the presentaion
That there was auditory and visual. Also, that you could stop It at any time and the freedom to go at your own pace. Skip things you understand and review the things you did not catch
Auditory and visual stimuli
Getting to listen and see it
The delivery (the teacher speaking) helped me pay attention more. The voice kept me alert
the indepth explanation and examples
the presentation as we as audio delivery
I liked how the presentation could be viewed. It was very nice to not just listen to a presentation that you watched, but that you actually had a person to look at - like in an actual lecture.
The delivery was really straightforward and easy to understand. It was helpful that I could listen to and read at the same time
I liked the fact that the slides were presented orally to clear up any misconception drawn from them
Easy to follow and stay focused, or did not need to read entire word to get meaning
The simultaneous flow of text and visual/audio
The idea of a video and ppt really good. It is like going to class, but at your own pace, and better when you can watch things you missed
Multiple sensory is nice, While hearing the presentation you can also visualize the text and example
I liked being able to weatch the speaker talk because if I was having trouble focusing on what he was saying, I could look at him to refocus
both seeing the professor (not just hearing him) as well as viewing the powerpoint.
I enjoyed the audio linked with the powerpoint. The headings were also useful as they assisted me in determining where I was in the presentation.
I liked the fact that the speaker did not have a monotone voice. He was easy to understand, and his voice changed to provide emphasis for important points.
There was visual aid to what the person on the video was saying so I could follow along with good examples.
I think that both, the presentation and the video, make a great combination rather than just reading a presentation. It is a good way to learn.
I like the fact that I was getting the information using two senses: I could hear Jim Foley explaining it to me, while at the same time, I saw the words on the powerpoint screen ans also the illustrations. To be honest, I retained, or remembered, a lot more than I anticipated.
I liked how the teacher was expressive and how the slides accurately followed him.
you can stop the presentation at any time or go back if you missed something. good organization and flow.
you could hear what he was saying while simultaneously reading the same material
It was easy to navigate and the powerpoint correlated very well with the topics.
I enjoyed the fact that I could control what I watched of the video and could easily reverse it if I wanted to to.

The way the presentation was presented. There was the video and the slides. The things that were mentioned in the video were bolded at the same time on the slides. This made it easier to pay attenntion and focus on what he was talking about.
how there was someone talking and a visual presentation at the same time and then i was allowed to go back and look over the content again
well structured, and contained good illustrative examples that fit with the concept described
The video lecture

Question: What did you like least about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

Cannot look at the speaker and the slide simultaneously
Volme was too loud
Watching the professor I could have done only with hearing him, as watching him move tended to distract me from the reading material
The teacher covered the material fast
the repetition was too much sometimes
the presentation could have been delivered a little more slowly.
I thought it was well put together
It seemes that the guy speaking was going a little fast but it was not too bad
Nothing
Nothing really
A tad bit too fast pace
sometimes the slied foies too fast an I would have to rewatch the part.
It can be dificult to focus on the text (what is written out) when trying to listen to something different
Some of the writing was kind if long on the slides, so if he did not read it word for word, I had trouble listenging to him and trying to read the slides
nothing
The video did more to distract me from the material in the powerpoint than anything else. I didn't focus so much on the video as much as I focused on the audio and powerpoint, while referencing the Table of Contents to see where I was.
The slides that didn't have examples.
The presentation was extremely monotone and it became rather boring at times.
Nothing, I think everything was pretty good and there was nothing wrong with it.
It moved very fast. At times I felt it neccesary to pause the material in order to retain any of the information.
I didn't like that the "GUI" was so plain. lol.
a little too brief on some of the slides
it seems fairly easy to get lost quickly
The speaker spoke very fast, but being able to repeat and go back to the slide was very helpful in providing a solution to this problem.
All good
The educational material.
some of the slides i did not fully understand what he was talking about before he moved on, so i had to go back and try and figure out what was going on after
could be a little more animated.
Maybe go a little slower

Question: Please describe any ideas you have about what would make the educational material more effective.

Some interaction during the presentaion. Multiple choice at examples before explanation

Speaker was a little fast
More examples
interactive quiz/activity
slow down audio
Make the presentation interactive…allow the student to answer a question in the presentaion to make sure he/she is paying attention; make a short review at the very end
I really do not have any
Considering that each part can be done independently, none
Highlight in yellow text when the professor talks
Ask questions to the ppt as you go into the next section to make sure the subject has the information down.
If you could somehow include motion that helps get attention
it's great as is
Change the presenter
The powerpoint could have been more eye captivating (incorporated more colors or fonts) to better hold the reader's attention.
I think there should be more problem questions embedded into the actual presentation instead of asking the questions after the presentation is over.
I don't have any ideas. I it all ready effective.
It might be better if the speaker took up a little more of the window... perhaps if it were split screen, I know I sit in the front of my classes because sometimes it simply helps to see the words coming out of the lecturer's mouth. This keeps my mind from wandering and allows me to stay focused.
Just emphasise that definitions are important
more explanation on some of the slides; the presentation moves a little fast at times
more written material to go along with the spoken material
Asking a few questions throughout the presentation to make it interactive.
Nothing I can think of
More examples related to what one would come across on a daily basis.
i think the material was effective in terms of getting the points accross
Have more animation within the slides as the instructor is talking, so that his words guide the movement
Altering the layout would be helpful so the two main elements (PPT and video) don't conflict with one another.

Question: Please provide any other feedback you might have here.

I think it would make my study time less, because I would have auditory and visual reinforcement at the same time rather thatn at separate times
I would be pleased to see this used in the classroom
this seems very interesting it may be very usefull
great job!
Really, I thouhgt it was very effective learning experence. GooD!!
I enjoyed learning this material. And I hope that youcan convince some proffesors to use this presentation to teach us
that was fun and informative, really works
This is a good experiment to test the effectiveness of educational media.
I would love to see this type of technology utilized in classrooms. I'd be able to take more hours, and have a more flexible schedule. A lot of class time is wasted in lectures, for the most part, professors are only lecturing on what is already in the book anyway. This would make class time for real-world application and really being able to work with the material.
I actually enjoyed this study. It didn't make me want to kill myself, and I learned something!
This is a very interesting study, and even if you can't use this for learning-in-advance. It would still be great if professors could post material such as this for students to download.

Great concept. I would love to have this type of education provided before lecture, so that during lecture, more time can be provided for individual questions of the material.
I had very little knowledge of Gestalt principles, but the video reinforced the knowledge I had and made the concepts more clear.

Audio+PPT Participants

Question: What did you like best about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

Visual illustrations
The visual information was deeply explained with exmaples
The presentation was good and it was very informative
the interactive nature of the slideshow. The ability to go back and review the visual activity of the screen (vs staring at a notes sheet)
A PPT was effective and setting was good
The ability to control the voice and lecture slide movement.
Was not too long, consis, showed valid examples. Repeated what the main principles were throughout the presentation
I liked the slides foloowing very closely with the speaker so you were reading over and haering the same thing with the reader explaining a little more
Being able to listen to the information on the screen helped instead of having to read it all
The bolded highlighted terms, where Foley was talking
It was good to have the key points of the speech highlighted in on the text as the statements were made
PPT highlighted lecture. Lecture explained ppt
I liked the voice not a computer one, although if it was a computer one it was superb. The slides were well organized and progresses in an ordered fashion. Also, no extraneous information, just short, concise and clear
the organization of materials was good
interesting, nice how you could go back and check things that you missed before
The audio part of the presentation made it easy to follow along. The visual diagrams however were the most effective form of the delivery of the material though the use of examples.
The presentation alone was ok. It was a little monotone, which made it boring at times. And I just couldn't see myself sitting in front of the computer all day trying to learn information.
The presentation contained many examples
The mix of visual and auditory forms of presentation helped reinforce the material. I also liked having the ability to skip parts that seemed redundant and review parts that I did not fully understand.
it helped to listen as well as read the information
I like that it combines audio and visual cues to help people remember the material. That way people who are better auditory learners and people who are better visual learners, and those who are both, all get something out of this.
The organization and linearity of the presentation.
The function allowing the user to replay or revisit sections when desired was most useful.
Slower rate, a little more time to digest the information
clearity
every slide/section was labelled so it gave you insight/information about what you were learning about, helped me stay more organized in my head and when I was learning rather then when a professor just talks and you write down in one lump sum
I liked that it was presented both visually and spoken. Also, there was repition of the material by giving examples which was helpful.
Slides were well-designed: simple but containing necessary info...so made learning effective. Additionally, the use of examples to demonstrated a key point helped significantly in

understanding subject matter.
The ability to navigate between the slides, so that I could go back to infomation that I had missed.

Question: What did you like least about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

Spoke too fast
The audio along with the visual was good
The speed
I liked the entire presentation
The audio was too loud A better distinction of material being presented on side bar/outline. Better color text or more obvious bolding/text size.
needs more … in the slides
Nothing really, if one wnt to onle use presentationalone he could turn off volume.
Speech was a little fast and sometimes the slides did not match up exactly
When the man was speaking ad it moved to the next bullet point the color change did not match and I did not like it
Sme of the information was talked about more than other information
Boring
It would have been nice to have had more examples
While listening attention had to be diverted to read, whereas in visual examples it did not
The list on the left was kinda hard to read, maybe use some commo fate techniques on that
The voice was a little annoying. Hard to Listen and read at content at the same time
personaly i did not like the speaker,   sometime sluring his words and not giving a very enthusiastic presentation
At some points the verbal instruction masked the information presented as text on the screen. most of the time it aligned but on a few occasions i found the slide changing as i was still reading the box.
I didn't like that I had to just listen and read off the computer.
The narrator talked quickly and didn't give much time to look at the examples to take them in
I would rather have actually seen the person speaking, and had the oppurtunity to ask questions
the speaker went a little fast
The voice could have been more engaging. The sound was turned up a little too high, but I could have fixed that. I just didn't want to mess things up for the next person to take the experiment.
The voice of the narrator was not clear enough.
The largest problem with the presentation was the speed with which the speaker moved from point to point, often without enough time for the user to focus on what he had said in relation to what was being displayed.
I would have liked to see the person who speaking over the slides.
sound is clear. brief
hard to sit and watch it- I got distracted and tired of staring at the screen
I least liked that sometimes the voiceover would say almost the sentence written on the screen, but not quite, confusing me a for a second when that happened. Also, the voiceover screwed up a few times.
The presentor's voice was not very appealing...so did not want one to actively partake in learning process.
I did not like that I could only navigate the speach within ten second intervals, but that was a very minor thing.

Question: Please describe any ideas you have about what would make the educational material more effective.

Speak slower
I liked the audio. But not the guys's voice. And hate looking at a computer screen for laong periods of time
Nothing
It was effective enough as is
Better color text, in the outline or more obvious bolding/text so it would be easier easier to follow along. Also, more room dedicated to outline, I could not see some of the information
A less monotone speaker. More usual effects
It would be even better to know what part of the lecture slide the prefessor is referring to…like having a laser pointer type feature that the professor use in real lecture.

Only next to chanfe color during the slide
The information was quite easy maybe to make it something that is a little harder
More interesting material
I would have learned more if there had been a wndow on panel where I would have implemented what I had learned
Give time to read and listen, or read and then explain. Use examples more than text
More visual stimuli (videos, aimations) would bore the reader less, but otherwise it was good
Not have any sound
more examples with the repitition of the names of each method more often
I would add a second or so of time to each slide at the end of just silence. This way the material could be absorbed fully for a moment with out having to concentrate on the audio portion of the presentation.
I'm not sure I could come up with any. I just learned that this isn't how I learn. The best anyway.
Talk slower and allow time for audience to look at slide examples
having a way to ask questions
the speaker could slow down a little
I would add more pictures, and possibly some visual segments. More colors, and perhaps a few effects would also serve to grab attention and make it more interesting.
Use a narrator that has a clearer voice and use colors as a relation for the learning materials.
The speaker must focus more on the material the user is looking at. In cases where there is a large picture or a lot of visual information, it would also be helpful if the speaker had some method of pointing out specific aspects of what is shown, so the user does not waste time wondering what part of the picture the speaker is referring to.
Voice, and the formatting of the web page with the survey... put more friendly colors there and make it cleaner, esp. the side panel
it is a little boring.
make it more interactive- the fact that i plays on its own makes it easier for me to stop paying attention because I did not have to do anything
Rerecord when the voiceover guy misreads it.
Have a woman speak since women's voice are a tad bit more welcoming than men. If a man is used to be the presentor, ensure that he has a 'radio voice' and speaks eloquently.
Interactive examples (such as multiple choice questions) within the presentation.

Question: Please provide any other feedback you might have here.

Job well done on experiment and presentation
A better outline would have been desirable since that allows me to better interact with my material
This is great for people who don’t fo to class.
The table of contents jumps around and is a little disstracting
This type of learning would work great in Physics. I am strugling in that class and I feel a lecture

with not pictures, but animations would bolster my pre and post class preparation
This should not replace actual human contact between teacher and stdent, but it could help the student with additional study
interesting information presented, i never put that much thought into it but see how much it effects me very cool
This was my first ever experiment. This was really cool.
I think that having students study this before coming to class would be a terrible idea. It takes discipline to sit down and study something before class, especially if the student isn't being tested on it. I think many students would be apathetic, and wouldn't study it. However, if it were presented in the lecture they might go out of habit, and therefore at least learn some of the material.
Educational technology can be helpful or hurtful to the overall education process depending on how it is used. I do not belive that technology can replace direct instruction, but I do believe that it can be a great asset to it. The presentation I saw had some positive aspects (such as ease of navigation) and some negative (such as lack of engagement with the student).
I liked taking the written test better because when I was given questions on the computer survey the blanks made me feel restricted or channeled in my answering but when I had a paper test I felt easier about writing down everything and felt that I had learned more because I was not restricted by multiple choice or answer blanks

PPT+Transcript Participants

Question: What did you like best about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

I liked that it allowed me to read the material at my own pace. Rereading whichever parts I needed
I am a visual learner, so the exmples helped me
good
I liked the visual example, combined with the detailed notes and explations at the bottom.
Visual examples being able to go back to material I missed
Good options on the diagrams, understood most infromation through those
Visual depiction of theories with pictures
I liked the ongoing outline on the side , it helped keep up with where the presentaion was and help relate it
I could look back over it and the timing was good
The integration of slides and written material
I like how PPT slides present the material effectively, the user can see right to the crux of the informaton without wasted effort. I also like the script at the bottom, which gave a different perspective on the same material
The presentation allowed me to move ahead when I was ready which I liked
It was organized well, and I could go back whenever I wanted
There were titles on the side with a table of content
I liked the organiztion of the screen
I liked how well-organized it was and easy to follow. It didn't really lose me anywhere.
There was alot of information covered in a fairly concise manner.
I could read what the professor said about each slide on the bottom. I could also go back to a slide if I did not have enough time to read it
I thought it was presented in a very good manor.
visual examples
pictures
The use of relevant examples.
I liked that there were a lot of examples for each point.

The delivery was in timed slides and I enjoy a structured study
Very informative the side notes were helpful
It showed the contrast between a well designed visual presentation and badly designed one.
The mode of delivery allowed display of examples which might be time consuming to draw out on a board in class.
Very easy to read, very dynamic, many examples.
I really liked the examples. They helped a lot to remember the materials.
If I needed to revisit what the speaker "said" it's presented right below the slide for easy re-reading.

Question: What did you like least about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

I would have liked to be able to control the slide transition on my own so I could spend more time on some, less on others
I needed a little more in depth explanations in the text form
having to fill this out by hand
That if changed slides on its own before I was done
Having to read all the content of the presentation
the small information bar at the bottom of the site, I realized it was there near the end of the presentation
No sound. Otherwise good mode
The text (lecture text) at the bottom, it was too hard ti pay attention to that and the slide
Some of the slides examples were not intuitive. I guess that is content though
The speed at which it was presented
Presentaion moved to quicky, I had to review by hand what I found more important. Script at the bottom was too small - tough to read
My mouse was not very "user friendly" and was sort of frustrating to use to navigate through the PPT
It could have showed more slides
That I coudnt go at my own pace
I disliked how the presentation could be either too fast or too slow at points
nothing really. there were good examples and everything.
It went way too fast.
I would prefer if I actually saw the professor talk, or if the pictures were moving. All I was doing is reading, and i prefer if i am doing more then one thing with info when I am getting it (reading, writing; reading, hearing)
I thought that if I just went there it as if I was in class I would not have retained very much info. I felt it moved to fast and I could not catch most of the material.
only sorce of stimuls was through reading
sometimes wordy
Didn't really attract attention to the slides.
I didn't like how the top was very large and the information was very small at the bottom.
The delivery was just a little to fast
the pace was too fast
It was difficult to pay attention to both the presentation and the script. Having an A/V presentation would have been better.
That I wasn't 100% in control of the pace. When it advanced itself, when I wasn't ready, I was flustered.
There was nothing that I disliked about the delivery of the material.
Tyhe explanation about the terms was not clear enough or was not highlighted to get the attention.
No sound as I had to read what the speaker originally said then read the slide. Normally, I can look at the slide while the speaker is presenting, simultaneously gathering information. With the

time limit, I didn't have enough time to read all the presented information.

Question: Please describe any ideas you have about what would make the educational material more effective.

More colors, moving objects, text
More indepth text explanations
if it were all in the computer with multiple choice questions.
Make the notes at the bottom either more noticable or easier to find
Sound - oral explanation with visual exapmles
More visual Cues
play with nother sense like hearing.
Maybe some animation with the lecture text on the slide -more real time
Sound maybe, or movies

1) Move slower key slides to allow user to study them. 2) Make scripted comment at the bottom more accessible
More detailed descriptions. Some of the material seemed together and did not distinguish well the distinctions between areas
More slides and examples
Give the slides a little more time to playout
Have the option of listening to the presentation instead of having to read the slide and the presentation
the only thing i can think of is make some of the slides have longer time. other than that, I can't think of anything.
If there was an audio/video component, I think I would have learned a bit more from it.
Audio that did not simply repeat the slides, but give more information. Feedback on my ideas
I feel if you took more time explaining it and maybe make it a little more similar.
some type of interactive tool
color!!! -more pictures
Maybe more color.
I would have put the information on the top and the examples at the bottom of the page.
I would have listed out the four types of Gestalt's phychology so that applying the types would be easier
more examples and slower pace
Along with the visual presentation, audio should also be included. The script at the bottom makes it confusing to decide what should be read first, the slide or the script.
The material needs to be spellchecked. Also, a few of the gestalt principles needed to be applied to the 1st slide and maybe others.
Different types of examples.
Use a method to show the important terms to get the attention of the students, and use more visualized examples to explain t5he terms and information. Because examples help a lot ot understand materials.
A time limit on the length of each slide. It would be beneficial to know how long you have to read the speaker's information as well as the slide's.

Question: Please provide any other feedback you might have here.

I would have liked this test to b on the computer because I really do not like writing
I thouhgt theer has to be visual stuff here to get this stuff. Words will not have been as useful
Nice study
The presentation was a good intro tool for learning two topics of disscussion
when i said worse for 10 and 11, i meant it's not as good or fun. I'm not saying this isn't helpful,

it's just better to have a teacher to interact with.
I feel it would be more helpful to engage students with real world application activities instead of lecturing the entire time.
The format of the powerpoint was distracting. Also, the time for reviewing the material was not enough time to review for the questions.
I simply forgot one of the four types and other than that learning through application will always improve knowledge of a subject
The organisation of the slides was very good. Helped me retain alot of information in a very short span of time!

PPT-Only Participants

Question: What did you like best about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

Representative of the Principles by visual examples
It was quick
it was to the point the images examples
The material was organized well The outline was very helpful in reviewing material
It was set up with good examples
Liked it because I can go back and forth in the slides or slide names or list it making navigation easy
it had a lot of examples for the types of gestalt learning.
The stuff was on the left to see what had been covered
The examples with text and pictures
There were plenty of easy to understand examples
Its visual aspects since I am a visual learner
it had a statement and then it gave examples
I got images of material in my head when recalling. It was clear and concise. I like structure of the overview. Each item with provided explanation exmaples, linking it all together. Planned well.
Allow to go back or stay in a slide if needed by clicking on the left part of the screen with designated slide
Simple slides with examples
I liked that there were a few examples for each principle.
I know that I am a visual learner, so the fact that it was visual. I especially liked the pictures that enforced the content.
provided plenty of time to return to previous slides if I did not fully understand what was on it
I found the examples on the presentation to be very helpful in understanding the concepts.
It was easy to move forwards and backwards in the presentation.
I liked that each item was presented in terms of an explanation and then followed up by a visual example.
The slides were simple and easy to follow
It was neatly and logically organized with clear points and easy-to-understand material.
Its the standard presentation that I have a familiarity with
The visual aspect of it.
The pace at which the presentation was delievered made it easy to comprehend the material. All too often powerpoint slides are presented too quickly, making it hard to comprehend the material.
The examples that were given.
Each slide contained ample information- the slides were not overloaded with a lot of information to take in at once.
The presentation gave good examples

visual examples

Question: What did you like least about the mode of delivery (the presentation alone, considered independently of the content) of the educational material?

Needed to be like a video teaching that showed you all the necessary steps and how to analyse
nothing
Some things could have been explained better
I like to hear it along with seeing it
Maybe adding audio that read the slide contents would be helpful for some people, not for me
it did not seem to connect all of the things together so I did not know how the information went together that well.
The timing was not very good, sometimes it was very wrong
At times there was too much text
It was somewhat boring
It was good overall, so nothing really
it was confusing towards the end when two principles are put together.
No audio
wish to be given practice exmaples where the subjects actually had to participate in determining similarity, proximity, closure or common fate
I did not like the screenshots with infromation about these principles
The information on each slide showed up all together as opposed to transitioning it in.
Nothing.
nothing, it was pretty good
Some of the combination of concepts were difficult to understand without someone directly explaining them.
The timed slides. It would move to the next slide while I was still studying the previous.
I did not like that there was no interactive activities.
just plain slides are kind of dull so can lose focus sometimes
Some of the examples were difficult to understand at first.
it really plane
There was no audio or video.
Most people are visual learners, and in terms of communication, written text is the most ineffective. Personally, a better way to present the material would have been to use a combination of written text and either a movie clip or interactive program.
I would say the lack of explanation i would have rather it been explained in greater detail.
I did not like the automatic timing of the slides.
I did not pick up on the terms, and main divisions of Gestalt.
wordy explanation. it makes even hard to understand rather than helping understand

Question: Please describe any ideas you have about what would make the educational material more effective.

Add audio or even better video
Use an introduction video describing exactly what was going on
more pictures
More details and examples
sound
Maybe adding audio that read the slide contents would be helpful for some people, not for me
To put more focus on thte main topics so I could organize the information better.
Video or sound. More color. Seeing a real person giving the real world examples would be helpful
Possibly apply the visual principles to the design of the presentation

Include more visual material instead of just text
explain more when the two prinicples are mixed together.
Audio explanations to some slides
Good example given thoughout
Simple slides and examples, more slides with less information
Transitioning in some of the data as opposed to seeing it all at once
Separating when the data appears on the screen. For example, having one point appear after another.
Having links to more examples in case the given examples were not sufficient.
An interactive component e.g. arrange these boxes into a grid.
If there was some way to get the student more involved, such as through an interactive activity, while they learn.
provide audio with the slides to make it more engaging
It would be more effective if the examples were to be animated, showing the effect of it before it had been visually organized, and after it was visually organized, to give the student a better understanding of the difference.
maybe sound will help in the headphones and it would be easier to remember also
I would have liked audio to go along with the slides.
I think that an interactive game would be an effective way to make the material presented more effective. More information would be retained in this method. Also, using video clips to further expand the points covered in the text would help.
Describe the topic in more detail.
More ordered, arranged definitions in the slides to comprehend easier.
Have different slides labeled: PROXIMITY, GRIDS, etc.
highlight some word or terms that are very important. video or audio system would help for the better understanding

Question: Please provide any other feedback you might have here.

the ppt was effective.
I think there was a typo on the first slide of my study (deseibe -describe)
This tool was very similar to ppt. It was definitely helpful
great experiment
Using as many possible different activities elp me learn. I always do better on tests when I can -read; -write;-do online quizzes;-flashcards, make rhymes, create examples and practice
Interesting study!
Most people are visual learners. In my opinion, for a presentation to be effective there should be some visual content (ie. short film clip). Having a user actively participate in learning the content via an interactive game of sorts would be the most effective at retaining information.
Great idea for teaching a class. Would make it more enjoyable, and would allow for knowledge of how the material is actually played out in the real world, not just in theory.
it was a good experience

APPENDIX G

Details of the Statistical Analysis of Data from the Multimodal Learning Experiment

```
ONEWAY RScore TScore SumScore BY Cond
  /STATISTICS DESCRIPTIVES EFFECTS HOMOGENEITY
  /PLOT MEANS
  /MISSING ANALYSIS

  /POSTHOC=TUKEY SCHEFFE BONFERRONI ALPHA(0.05).
```

Oneway

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Retention Score	4.764	3	116	.004
Transfer Score	3.374	3	116	.021
Total Test Score	5.092	3	116	.002

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Retention Score	Between Groups	199.367	3	66.456	13.385	.000
	Within Groups	575.933	116	4.965		
	Total	775.300	119			
Transfer Score	Between Groups	371.508	3	123.836	11.529	.000
	Within Groups	1245.983	116	10.741		
	Total	1617.492	119			
Total Test Score	Between Groups	1104.775	3	368.258	16.770	.000
	Within Groups	2547.317	116	21.960		
	Total	3652.092	119			

Post Hoc Tests

Dependent Variable		(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.
Retention Score	Tukey HSD	VAP	AP	1.667*	.575	.023
			PT	2.700*	.575	.000
			PO	3.433*	.575	.000

	AP	VAP	-1.667*	.575	.023
		PT	1.033	.575	.280
		PO	1.767*	.575	.014
	PT	VAP	-2.700*	.575	.000
		AP	-1.033	.575	.280
		PO	.733	.575	.581
	PO	VAP	-3.433*	.575	.000
		AP	-1.767*	.575	.014
		PT	-.733	.575	.581
Scheffe	VAP	AP	1.667*	.575	.043
		PT	2.700*	.575	.000
		PO	3.433*	.575	.000
	AP	VAP	-1.667*	.575	.043
		PT	1.033	.575	.362
		PO	1.767*	.575	.028
	PT	VAP	-2.700*	.575	.000
		AP	-1.033	.575	.362
		PO	.733	.575	.655
	PO	VAP	-3.433*	.575	.000
		AP	-1.767*	.575	.028
		PT	-.733	.575	.655
Bonferroni	VAP	AP	1.667*	.575	.027
		PT	2.700*	.575	.000
		PO	3.433*	.575	.000
	AP	VAP	-1.667*	.575	.027
		PT	1.033	.575	.450
		PO	1.767*	.575	.016
	PT	VAP	-2.700*	.575	.000
		AP	-1.033	.575	.450
		PO	.733	.575	1.000

		PO	VAP	-3.433*	.575	.000
			AP	-1.767*	.575	.016
			PT	-.733	.575	1.000
Transfer Score	Tukey HSD	VAP	AP	3.0333*	.8462	.003
			PT	3.5500*	.8462	.000
			PO	4.7833*	.8462	.000
		AP	VAP	-3.0333*	.8462	.003
			PT	.5167	.8462	.929
			PO	1.7500	.8462	.170
		PT	VAP	-3.5500*	.8462	.000
			AP	-.5167	.8462	.929
			PO	1.2333	.8462	.467
		PO	VAP	-4.7833*	.8462	.000
			AP	-1.7500	.8462	.170
			PT	-1.2333	.8462	.467
	Scheffe	VAP	AP	3.0333*	.8462	.007
			PT	3.5500*	.8462	.001
			PO	4.7833*	.8462	.000
		AP	VAP	-3.0333*	.8462	.007
			PT	.5167	.8462	.946
			PO	1.7500	.8462	.239
		PT	VAP	-3.5500*	.8462	.001
			AP	-.5167	.8462	.946
			PO	1.2333	.8462	.549
		PO	VAP	-4.7833*	.8462	.000
			AP	-1.7500	.8462	.239
			PT	-1.2333	.8462	.549
	Bonferroni	VAP	AP	3.0333*	.8462	.003
			PT	3.5500*	.8462	.000
			PO	4.7833*	.8462	.000
		AP	VAP	-3.0333*	.8462	.003
			PT	.5167	.8462	1.000

			PO	1.7500	.8462	.245
		PT	VAP	-3.5500*	.8462	.000
			AP	-.5167	.8462	1.000
			PO	1.2333	.8462	.886
		PO	VAP	-4.7833*	.8462	.000
			AP	-1.7500	.8462	.245
			PT	-1.2333	.8462	.886
Total Test Score	Tukey HSD	VAP	AP	4.7000*	1.2099	.001
			PT	6.2500*	1.2099	.000
			PO	8.2167*	1.2099	.000
		AP	VAP	-4.7000*	1.2099	.001
			PT	1.5500	1.2099	.577
			PO	3.5167*	1.2099	.022
		PT	VAP	-6.2500*	1.2099	.000
			AP	-1.5500	1.2099	.577
			PO	1.9667	1.2099	.368
		PO	VAP	-8.2167*	1.2099	.000
			AP	-3.5167*	1.2099	.022
			PT	-1.9667	1.2099	.368
	Scheffe	VAP	AP	4.7000*	1.2099	.003
			PT	6.2500*	1.2099	.000
			PO	8.2167*	1.2099	.000
		AP	VAP	-4.7000*	1.2099	.003
			PT	1.5500	1.2099	.651
			PO	3.5167*	1.2099	.042
		PT	VAP	-6.2500*	1.2099	.000
			AP	-1.5500	1.2099	.651
			PO	1.9667	1.2099	.453
		PO	VAP	-8.2167*	1.2099	.000
			AP	-3.5167*	1.2099	.042
			PT	-1.9667	1.2099	.453
	Bonferroni	VAP	AP	4.7000*	1.2099	.001

		PT	6.2500*	1.2099	.000
		PO	8.2167*	1.2099	.000
	AP	VAP	-4.7000*	1.2099	.001
		PT	1.5500	1.2099	1.000
		PO	3.5167*	1.2099	.026
	PT	VAP	-6.2500*	1.2099	.000
		AP	-1.5500	1.2099	1.000
		PO	1.9667	1.2099	.641
	PO	VAP	-8.2167*	1.2099	.000
		AP	-3.5167*	1.2099	.026
		PT	-1.9667	1.2099	.641

*. The mean difference is significant at the 0.05 level.

```
UNIANOVA SumScore BY Cond WITH Age Year PresTime TestTime
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /EMMEANS=TABLES(OVERALL) WITH(Age=MEAN Year=MEAN PresTime=MEAN TestTime=MEAN)
  /EMMEANS=TABLES(Cond) WITH(Age=MEAN Year=MEAN PresTime=MEAN TestTime=MEAN) COMPARE ADJ(BONFER
RONI)
  /PRINT=ETASQ OPOWER
  /CRITERIA=ALPHA(.05)

  /DESIGN=Age Year PresTime TestTime Cond.
```

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Condition	1	VAP	30
	2	AP	30
	3	PT	30
	4	PO	30

Tests of Between-Subjects Effects

Dependent Variable:Total Test Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Power[b]
Corrected Model	1292.613[a]	7	184.659	8.765	.000	1.000
Intercept	695.768	1	695.768	33.027	.000	1.000
Age	117.157	1	117.157	5.561	.020	.647

Year	139.791	1	139.791	6.636	.011	.724
PresTime	32.071	1	32.071	1.522	.220	.231
TestTime	2.404	1	2.404	.114	.736	.063
Cond	1028.561	3	342.854	16.275	.000	1.000
Error	2359.478	112	21.067			
Total	116076.500	120				
Corrected Total	3652.092	119				

a. R Squared = .354 (Adjusted R Squared = .314)

b. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Dependent Variable:Total Test Score

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
30.608[a]	.419	29.778	31.439

a. Covariates appearing in the model are evaluated at the following values: Age = 19.67, Year = 2.23, Presentation Time = 15.74, Total Test Time = 17.53.

2. Condition

Estimates

Dependent Variable:Total Test Score

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
VAP	35.432[a]	.852	33.745	37.120
AP	30.499[a]	.849	28.816	32.182
PT	29.022[a]	.845	27.348	30.695
PO	27.480[a]	.853	25.791	29.169

a. Covariates appearing in the model are evaluated at the following values: Age = 19.67, Year = 2.23, Presentation Time = 15.74, Total Test Time = 17.53.

Dependent Variable:Total Test Score

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]
VAP	AP	4.933*	1.214	.001
	PT	6.411*	1.202	.000
	PO	7.952*	1.210	.000
AP	VAP	-4.933*	1.214	.001
	PT	1.477	1.196	1.000
	PO	3.019	1.210	.084
PT	VAP	-6.411*	1.202	.000
	AP	-1.477	1.196	1.000
	PO	1.541	1.209	1.000
PO	VAP	-7.952*	1.210	.000
	AP	-3.019	1.210	.084
	PT	-1.541	1.209	1.000

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

```
CROSSTABS
  /TABLES=Cond BY Sex Age Year Major TechUse
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ
  /CELLS=COUNT

  /COUNT ROUND CELL.
```

Crosstabs

Condition * Sex

Crosstab

Count

		Sex		Total
		Male	Female	
Condition	VAP	15	15	30
	AP	15	15	30
	PT	15	15	30
	PO	16	14	30

Crosstab

Count

		Sex		Total
		Male	Female	
Condition	VAP	15	15	30
	AP	15	15	30
	PT	15	15	30
	PO	16	14	30
Total		61	59	120

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.100[a]	3	.992
Likelihood Ratio	.100	3	.992
Linear-by-Linear Association	.060	1	.807
N of Valid Cases	120		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 14.75.

Condition * Age

Crosstab

Count

		Age	Total								
		18	19	20	21	22	23	24	26	27	
Condition	VAP	13	6	9	0	1	0	0	0	1	30
	AP	10	6	4	7	2	0	0	0	1	30
	PT	7	5	8	5	3	1	1	0	0	30
	PO	10	8	3	3	4	1	0	1	0	30
Total	40	25	24	15	10	2	1	1	2	120	

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	26.027[a]	24	.352

Likelihood Ratio	30.561	24	.167
Linear-by-Linear Association	1.359	1	.244
N of Valid Cases	120		

a. 24 cells (66.7%) have expected count less than 5. The minimum expected count is .25.

Condition * Year

Crosstab

Count

		Year					Total
		Freshman	Sophomore	Junior	Senior	Other	
Condition	VAP	13	8	7	1	1	30
	AP	10	6	9	5	0	30
	PT	8	7	9	6	0	30
	PO	13	6	4	6	1	30
Total		44	27	29	18	2	120

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.132[a]	12	.604
Likelihood Ratio	12.344	12	.418
Linear-by-Linear Association	.790	1	.374
N of Valid Cases	120		

a. 8 cells (40.0%) have expected count less than 5. The minimum expected count is .50.

Condition * Major

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	70.630[a]	78	.711
Likelihood Ratio	81.108	78	.383
Linear-by-Linear Association	.293	1	.588
N of Valid Cases	120		

a. 104 cells (96.3%) have expected count less than 5. The minimum expected count is .25.

Condition * Use of EduTech

Crosstab

Count

		Use of EduTech					Total
		None	Not Very Much	Some	Quite a Bit	A Lot	
Condition	VAP	1	10	12	7	0	30
	AP	5	6	10	5	4	30
	PT	3	10	7	9	1	30
	PO	2	12	9	7	0	30
Total		11	38	38	28	5	120

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.293[a]	12	.178
Likelihood Ratio	16.749	12	.159
Linear-by-Linear Association	.309	1	.579
N of Valid Cases	120		

a. 8 cells (40.0%) have expected count less than 5. The minimum expected count is 1.25.

```
CROSSTABS
  /TABLES=EQ1 EQ2 EQ3 EQ5 BY Cond
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ BTAU
  /CELLS=COUNT ROW COLUMN TOTAL
  /COUNT ROUND CELL

  /BARCHART.
```

Crosstabs

General Learning * Condition

Crosstab

Condition Total

VAP AP PT PO

General Learning 2 Count 0 0 1 1 2

% within General Learning .0% .0% 50.0% 50.0% 100.0%

% within Condition .0% .0% 3.3% 3.3% 1.7%

% of Total .0% .0% .8% .8% 1.7%

	3	Count	0	11	15	15	41
		% within General Learning	.0%	26.8%	36.6%	36.6%	100.0%
		% within Condition	.0%	36.7%	50.0%	50.0%	34.2%
		% of Total	.0%	9.2%	12.5%	12.5%	34.2%
	4	Count	20	14	12	12	58
		% within General Learning	34.5%	24.1%	20.7%	20.7%	100.0%
		% within Condition	66.7%	46.7%	40.0%	40.0%	48.3%
		% of Total	16.7%	11.7%	10.0%	10.0%	48.3%
	5	Count	10	5	2	2	19
		% within General Learning	52.6%	26.3%	10.5%	10.5%	100.0%
		% within Condition	33.3%	16.7%	6.7%	6.7%	15.8%
		% of Total	8.3%	4.2%	1.7%	1.7%	15.8%
Total		Count	30	30	30	30	120
		% within General Learning	25.0%	25.0%	25.0%	25.0%	100.0%
		% within Condition	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	25.0%	25.0%	25.0%	25.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	28.673[a]	9	.001
Likelihood Ratio	38.451	9	.000
Linear-by-Linear Association	22.439	1	.000
N of Valid Cases	120		

a. 8 cells (50.0%) have expected count less than 5. The minimum expected count is .50.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	-.381	.063	-5.915	.000
N of Valid Cases		120			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Posttest Preparation * Condition

Crosstab

			Condition	Total					
			VAP	AP	PT	PO			
Posttest Preparation		2	Count	0	0	3	4	7	
		% within Posttest Preparation			.0%	.0%	42.9%	57.1%	100.0%
		% within Condition		.0%	.0%	10.0%	13.3%	5.8%	
		% of Total	.0%	.0%	2.5%	3.3%	5.8%		
	3	Count	1	5	8	11	25		
		% within Posttest Preparation			4.0%	20.0%	32.0%	44.0%	100.0%
		% within Condition		3.3%	16.7%	26.7%	36.7%	20.8%	
		% of Total	.8%	4.2%	6.7%	9.2%	20.8%		
	4	Count	16	21	16	13	66		
		% within Posttest Preparation			24.2%	31.8%	24.2%	19.7%	100.0%
		% within Condition		53.3%	70.0%	53.3%	43.3%	55.0%	
		% of Total	13.3%	17.5%	13.3%	10.8%	55.0%		
	5	Count	13	4	3	2	22		
		% within Posttest Preparation			59.1%	18.2%	13.6%	9.1%	100.0%
		% within Condition		43.3%	13.3%	10.0%	6.7%	18.3%	
		% of Total	10.8%	3.3%	2.5%	1.7%	18.3%		
Total	Count	30	30	30	30	120			
	% within Posttest Preparation			25.0%	25.0%	25.0%	25.0%	100.0%	
	% within Condition		100.0%	100.0%	100.0%	100.0%	100.0%		
	% of Total	25.0%	25.0%	25.0%	25.0%	100.0%			

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	32.046[a]	9	.000
Likelihood Ratio	34.433	9	.000
Linear-by-Linear Association	25.707	1	.000
N of Valid Cases	120		

a. 4 cells (25.0%) have expected count less than 5. The minimum expected count is 1.75.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	-.409	.065	-5.974	.000
N of Valid Cases		120			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Likelihood of Use * Condition

Crosstab

			Condition	Total					
			VAP	AP	PT	PO			
Likelihood of Use		2	Count	0	1	2	4	7	
		% within Likelihood of Use			.0%	14.3%	28.6%	57.1%	100.0%
		% within Condition		.0%	3.3%	6.7%	13.3%	5.8%	
		% of Total	.0%	.8%	1.7%	3.3%	5.8%		
	3	Count	1	10	12	10	33		
		% within Likelihood of Use			3.0%	30.3%	36.4%	30.3%	100.0%
		% within Condition		3.3%	33.3%	40.0%	33.3%	27.5%	
		% of Total	.8%	8.3%	10.0%	8.3%	27.5%		
	4	Count	14	15	14	10	53		
		% within Likelihood of Use			26.4%	28.3%	26.4%	18.9%	100.0%
		% within Condition		46.7%	50.0%	46.7%	33.3%	44.2%	
		% of Total	11.7%	12.5%	11.7%	8.3%	44.2%		
	5	Count	15	4	2	6	27		
		% within Likelihood of Use			55.6%	14.8%	7.4%	22.2%	100.0%
		% within Condition		50.0%	13.3%	6.7%	20.0%	22.5%	
		% of Total	12.5%	3.3%	1.7%	5.0%	22.5%		
Total	Count	30	30	30	30	120			
	% within Likelihood of Use			25.0%	25.0%	25.0%	25.0%	100.0%	
	% within Condition		100.0%	100.0%	100.0%	100.0%	100.0%		
	% of Total	25.0%	25.0%	25.0%	25.0%	100.0%			

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	29.561[a]	9	.001
Likelihood Ratio	33.162	9	.000
Linear-by-Linear Association	16.529	1	.000
N of Valid Cases	120		

a. 4 cells (25.0%) have expected count less than 5. The minimum expected count is 1.75.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	-.324	.075	-4.267	.000
N of Valid Cases		120			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Comprehension * Condition

Crosstab

Condition Total

VAP AP PT PO

Comprehension 2 Count 0 4 5 2 11

% within Comprehension .0% 36.4% 45.5% 18.2% 100.0%

% within Condition .0% 13.3% 16.7% 6.7% 9.2%

% of Total .0% 3.3% 4.2% 1.7% 9.2%

3 Count 0 2 6 6 14

% within Comprehension .0% 14.3% 42.9% 42.9% 100.0%

% within Condition .0% 6.7% 20.0% 20.0% 11.7%

% of Total .0% 1.7% 5.0% 5.0% 11.7%

4 Count 14 20 18 22 74

% within Comprehension 18.9% 27.0% 24.3% 29.7% 100.0%

% within Condition 46.7% 66.7% 60.0% 73.3% 61.7%

% of Total 11.7% 16.7% 15.0% 18.3% 61.7%

5 Count 16 4 1 0 21

% within Comprehension 76.2% 19.0% 4.8% .0% 100.0%

% within Condition 53.3% 13.3% 3.3% .0% 17.5%

% of Total 13.3% 3.3% .8% .0% 17.5%

Total Count 30 30 30 30 120

% within Comprehension 25.0% 25.0% 25.0% 25.0% 100.0%

% within Condition 100.0% 100.0% 100.0% 100.0% 100.0%

% of Total 25.0% 25.0% 25.0% 25.0% 100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	45.970[a]	9	.000
Likelihood Ratio	50.519	9	.000
Linear-by-Linear Association	19.464	1	.000
N of Valid Cases	120		

a. 8 cells (50.0%) have expected count less than 5. The minimum expected count is 2.75.

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Kendall's tau-b	-.398	.060	-6.093	.000
N of Valid Cases		120			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

```
CROSSTABS
  /TABLES=Sex Age Year PresTime RTime TTime TestTime EQ1 EQ2 EQ3 EQ4 EQ5 EQ6 EQ7 BY Cond
  /FORMAT=AVALUE TABLES
  /CELLS=COUNT
  /COUNT ROUND CELL

  /BARCHART.
```

Crosstabs

Sex * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Sex	Male	15	15	15	16	61

	Female	15	15	15	14	59
Total		30	30	30	30	120

Age * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Age	18	13	10	7	10	40
	19	6	6	5	8	25
	20	9	4	8	3	24
	21	0	7	5	3	15
	22	1	2	3	4	10
	23	0	0	1	1	2
	24	0	0	1	0	1
	26	0	0	0	1	1
	27	1	1	0	0	2
Total		30	30	30	30	120

Year * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Year	Freshman	13	10	8	13	44
	Sophomore	8	6	7	6	27
	Junior	7	9	9	4	29
	Senior	1	5	6	6	18
	Other	1	0	0	1	2
Total		30	30	30	30	120

Presentation Time * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Presentation Time	8	0	0	0	1	1
	9	1	0	0	1	2
	10	1	1	2	0	4
	11	0	0	1	1	2
	12	2	0	1	5	8
	13	1	4	1	3	9
	14	6	5	3	4	18
	15	5	1	5	5	16
	16	3	5	3	2	13
	17	1	3	3	1	8
	18	2	4	2	2	10
	19	1	2	3	2	8
	20	7	5	6	3	21
Total		30	30	30	30	120

Retention Test Time * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Retention Test Time	2	5	3	2	1	11
	3	10	7	10	8	35
	4	6	7	6	7	26
	5	7	7	6	7	27
	6	1	2	1	3	7
	7	1	2	2	2	7
	8	0	1	3	1	5
	10	0	1	0	0	1
	13	0	0	0	1	1
Total		30	30	30	30	120

Transfer Test Time * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Transfer Test Time	3	0	0	0	1	1
	7	1	0	0	1	2
	8	1	2	1	2	6
	9	0	0	3	1	4
	10	1	1	2	1	5
	11	1	1	2	4	8
	12	6	4	5	2	17
	13	7	4	4	3	18
	14	5	4	2	5	16
	15	4	5	5	3	17
	16	2	5	4	3	14
	17	2	3	1	3	9
	18	0	1	1	1	3
Total		30	30	30	30	120

Total Test Time * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Total Test Time	6	0	0	0	1	1
	11	0	0	1	0	1
	12	1	1	1	2	5
	13	2	1	3	1	7
	14	1	0	2	2	5
	15	1	3	1	0	5
	16	9	1	4	3	17

	17	3	2	0	2	7
	18	5	1	2	3	11
	19	6	7	2	4	19
	20	2	14	14	12	42
Total		30	30	30	30	120

General Learning * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
General Learning	2	0	0	1	1	2
	3	0	11	15	15	41
	4	20	14	12	12	58
	5	10	5	2	2	19
Total		30	30	30	30	120

Preparation for Test * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Preparation for Test	2	0	0	3	4	7
	3	1	5	8	11	25
	4	16	21	16	13	66
	5	13	4	3	2	22
Total		30	30	30	30	120

Likelihood of Use * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Likelihood of Use	2	0	1	2	4	7

	3	1	10	12	10	33
	4	14	15	14	10	53
	5	15	4	2	6	27
Total		30	30	30	30	120

Mode of Delivery * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Mode of Delivery	2	2	0	2	1	5
	3	7	10	10	12	39
	4	15	12	15	11	53
	5	6	8	3	6	23
Total		30	30	30	30	120

Comprehension * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Comprehension	2	0	4	5	2	11
	3	0	2	6	6	14
	4	14	20	18	22	74
	5	16	4	1	0	21
Total		30	30	30	30	120

Format Efficacy * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Format Efficacy	2	1	3	4	3	11
	3	5	5	7	5	22

	4	12	15	14	14	55
	5	12	7	5	8	32
Total		30	30	30	30	120

Format Enjoyment * Condition Crosstabulation

Count

		Condition				Total
		VAP	AP	PT	PO	
Format Enjoyment	1	0	1	0	1	2
	2	1	2	3	2	8
	3	3	5	6	4	18
	4	14	18	16	15	63
	5	12	4	5	8	29
Total		30	30	30	30	120

```
ONEWAY TechUse BY Cond
  /PLOT MEANS
  /MISSING ANALYSIS

  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

ANOVA

Use of EduTech

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.633	3	.211	.195	.899
Within Groups	125.333	116	1.080		
Total	125.967	119			

```
ONEWAY PresTime BY Cond
  /MISSING ANALYSIS

  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

ANOVA

Presentation Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	46.492	3	15.497	1.705	.170
Within Groups	1054.500	116	9.091		
Total	1100.992	119			

```
ONEWAY RTime BY Cond
  /MISSING ANALYSIS

  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

ANOVA

Retention Test Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.267	3	5.422	1.726	.165
Within Groups	364.400	116	3.141		
Total	380.667	119			

```
ONEWAY TTime BY Cond
  /MISSING ANALYSIS

  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

ANOVA

Transfer Test Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20.292	3	6.764	.889	.449
Within Groups	882.633	116	7.609		
Total	902.925	119			

```
ONEWAY TestTime BY Cond
  /MISSING ANALYSIS

  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

ANOVA

Total Test Time

	Sum of Squares	df	Mean Square	F	Sig.

Between Groups	34.758	3	11.586	1.539	.208
Within Groups	873.167	116	7.527		
Total	907.925	119			

```
ONEWAY EQ1 EQ2 EQ3 EQ5 BY Cond
  /MISSING ANALYSIS

  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
General Learning	Between Groups	13.900	3	4.633	11.089	.000
	Within Groups	48.467	116	.418		
	Total	62.367	119			
Posttest Preparation	Between Groups	16.092	3	5.364	11.013	.000
	Within Groups	56.500	116	.487		
	Total	72.592	119			
Likelihood of Use	Between Groups	16.667	3	5.556	9.477	.000
	Within Groups	68.000	116	.586		
	Total	84.667	119			
Comprehension	Between Groups	18.692	3	6.231	12.369	.000
	Within Groups	58.433	116	.504		
	Total	77.125	119			

Post Hoc Tests

Tukey HSD

Dependent Variable	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.
General Learning	VAP	AP	.533*	.167	.010
		PT	.833*	.167	.000
		PO	.833*	.167	.000
	AP	VAP	-.533*	.167	.010
		PT	.300	.167	.280
		PO	.300	.167	.280

	PT	VAP	-.833*	.167	.000
		AP	-.300	.167	.280
		PO	.000	.167	1.000
	PO	VAP	-.833*	.167	.000
		AP	-.300	.167	.280
		PT	.000	.167	1.000
Posttest Preparation	VAP	AP	.433	.180	.082
		PT	.767*	.180	.000
		PO	.967*	.180	.000
	AP	VAP	-.433	.180	.082
		PT	.333	.180	.256
		PO	.533*	.180	.019
	PT	VAP	-.767*	.180	.000
		AP	-.333	.180	.256
		PO	.200	.180	.684
	PO	VAP	-.967*	.180	.000
		AP	-.533*	.180	.019
		PT	-.200	.180	.684
Likelihood of Use	VAP	AP	.733*	.198	.002
		PT	.933*	.198	.000
		PO	.867*	.198	.000
	AP	VAP	-.733*	.198	.002
		PT	.200	.198	.743
		PO	.133	.198	.907
	PT	VAP	-.933*	.198	.000
		AP	-.200	.198	.743
		PO	-.067	.198	.987
	PO	VAP	-.867*	.198	.000
		AP	-.133	.198	.907
		PT	.067	.198	.987
Comprehension	VAP	AP	.733*	.183	.001
		PT	1.033*	.183	.000

		PO	.867*	.183	.000
	AP	VAP	-.733*	.183	.001
		PT	.300	.183	.362
		PO	.133	.183	.886
	PT	VAP	-1.033*	.183	.000
		AP	-.300	.183	.362
		PO	-.167	.183	.800
	PO	VAP	-.867*	.183	.000
		AP	-.133	.183	.886
		PT	.167	.183	.800

*. The mean difference is significant at the 0.05 level.

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