Enriching Everyday Activities through the
Automated Capture and Access of Live Experiences
eClass: Building, Observing and Understanding the
Impact of Capture and Access in an Educational Domain

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**Enriching Everyday Activities though the
Automated Capture and Access of Live Experiences**
*eClass: Building, Observing and Understanding the
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SUMMARY

We spend much of our lives gathering and processing information. In academia, a large portion of the day is spent listening to and recording the surrounding events that occur in meetings and classroom lectures. Unfortunately, we are not always good at capturing information in a meaningful way and often spend our time trying to remember a piece of information presented to us in past because we do not have a sufficient record of that experience. We define the general capture and access problem to be the attempt to capture information so that it can be successfully accessed at a later date. We consider materials 'successfully accessed' when they are found at the proper level of detail with minimal effort.

Automating the capture and access process can help in many situations where the act of taking notes to preserve an experience is either impossible, undesirable, or otherwise interferes with one's ability to pay attention. This research investigates how ubiquitous computing can help solve the capture and access problem in a college classroom. We have observed that many students attempt to capture the lecture experience by jotting down everything of any significance in the classroom. Our research is motivated by the notion that this kind of capture and access of college lectures (via traditional note taking techniques) can be time consuming, difficult, and prone to error. By automating the capture and access of lectures, we hope that students will find value in using these richer artifacts as a more complete aid to their after-class study routines.

By gaining a deep understanding of capture and access in a narrow domain such as college classroom lectures, we hope to generalize our work in capture and access to

other domains. Understanding the dimensions and requirements of capture and access allows us to build capture and access applications for other domains that can be quite different from the classroom. We have learned that the capture and access system that works in the educational domain does not necessarily map well to other domains without modifications. By mapping out the design space of capture and access, we hope to make it easier to build capture and access systems in different domains.

This thesis describes a classroom we built to record the slides and handwriting presented in a lecture along with audio and video and any Web pages visited during the lecture. All of the captured material was made available immediately after the lecture for student access. The technology, originally called Classroom 2000, then later renamed eClass, was used in real classes at Georgia Tech for nearly four years. To help evaluate eClass, at the end of each course, students were asked to fill out surveys regarding their attitudes and opinions of the system. Additionally, access sessions to the on-line captured notes were logged and analyzed. Our analysis shows that both students and teachers find the technology worthwhile and a useful learning tool. We show that eClass helps to encourage more 'summary style' note taking in the classroom, and that its use does not result in decreased attendance. The online notes are mostly used for immediate lecture review and exam study, but continue to be used well after the semester ends. We have found that by allowing students to concentrate more on the material being taught (rather than being copy machines), eClass affects both students and teachers in mostly positive ways.

We believe that in order to properly apply ubiquitous computing research you must first construct a living system that becomes everyday in some domain (college

lectures, in our case). Once you have achieved authentic use, then the system can be evaluated. This thesis helps show that our method is indeed a valid method of research and one that enables a deep understanding of how technology affects both the situation it is used in and the people in it.

CHAPTER I

INTRODUCTION AND MOTIVATION

We spend much of our lives gathering and processing information. In academia, a large portion of the day is spent listening to and recording the surrounding events that occur in meetings and classrooms. In order for the collected information to be useful, it needs to be recorded and preserved for future reference. This typically requires capturing additional context or meta-information so that the material can be properly referenced in the future. Unfortunately, we are not always good at capturing information in a meaningful way and often spend our time trying to remember a piece of information presented to us in past because we do not have a sufficient record of that experience.

We define the general capture and access problem to be the attempt to capture new, non-persistent information (such as speech and the writings on a whiteboard), while integrating it with existing information (such as presentation slides) so that the new information can be successfully accessed at a later date. We consider materials 'successfully accessed' when they are found at the proper level of detail (as defined by the accessor) with minimal effort.

Automating the capture and access process can help in many situations where the act of keeping a record to preserve an experience is either impossible, undesirable, or otherwise interferes with one's ability to pay attention. For example, a dance instruction class offers very little opportunity to jot down detailed notes on new steps learned, or suggestions for style. The information that one would want to capture would be tedious or very difficult to describe with pen and paper, and in most classes there would not be

ample time to write it. As a result, it is common for dance lessons to be video taped by the student for later viewing. However linear recordings do not work as well in the classroom because the captured record is not easily accessible and is not well integrated with the student's personal notes. Videotapes preserve one perspective of the experience, and in the absence of other notes are worthwhile, but they require additional effort to integrate them with other recording methods, such as note taking.

In general, we believe activities where the hands are occupied or where concentration and participation is important can take advantage of automated capture and access. This research shows how ubiquitous computing can help solve the capture and access problem in a specific setting: the college classroom, where success depends largely on the ability to capture and later access information at the salient moment, typically, on the final exam. We have observed that many students attempt to capture the lecture experience by jotting down everything they deem to be significant in the classroom. Our research is motivated by the notion that this kind of capture and access of college lectures via traditional note taking techniques can be time consuming, difficult, and prone to error. It is important to note that we are not arguing against note taking in general, just in trying to reduce instances of copious note taking. By automating the capture and access of lectures, and by augmenting traditional notes with media we can provide a more detailed record of a lecture than is possible with just pen and paper. We believe that providing students with access to these notes can improve their review and study sessions.

In order to test this hypothesis, we must move away from the realm of desktop computing and into a living laboratory, the classroom. To measure the impact of the

technology on the students, professors, and the learning experience, we must use our system in the classroom for an extended period of time, at least as long as a semester (for one-time results) and ideally over several semesters. Long term use and evaluation is the bread and butter of ubiquitous computing research, where a living laboratory is created to explore and understand the impact of technology based on authentic use. Once a system is in place and we have achieved authentic use, then we can fully evaluate the system and its impact on teachers and students.

By gaining a deep understanding of capture and access in a narrow domain, like the college classroom, we hope to generalize our work in capture and access to other domains. Specifying the dimensions and requirements of capture and access allows us to build capture and access applications for other domains that can be quite different from the classroom. For example, classroom presentations are highly structured whereas impromptu or serendipitous meetings are not. Classroom lectures have a well-defined agenda and flow whereas many meetings do not. The linear visualization of classroom lectures can be an easier problem to solve than the visualization of a meeting room history. We have learned that the capture and access system that works in the educational domain does not necessarily map well to other domains without modifications. By helping to map out the design space of capture and access, we hope to make it easier to build capture and access systems in different domains.

Our general research goals are centered on the idea that the automated capture of everyday experiences for later playback or searching is a valuable service for people. Automated support can help computers do what they do best — record an event — in order to free humans to do what they do best: attend to, synthesize, and understand what

is happening around them, with full confidence that specific details will be available for later perusal.

1.1   Reasons for Taking Notes in the Classroom

Note taking is common in university classes, but although all students attending a class listen to the same lecture, the notes taken differ in style and content from student to student. Hartly [39] showed that generally, students take notes because

1. the process of writing information down helps them to remember that information

2. they provide a written record of the lecture content for review at a later date

In effect, the manual capture of a lecture can help student remember the lecture (1) and provide a record of the experience for later review (2). There is little disagreement that repeated review of material helps student recall, but Kiewra [44] found that the benefits of manually taking notes (as opposed to being provided a set of instructor's notes) are inconsistent among other studies.

In later work [45], Kiewra showed that *generative processing*, or actively generating relations among parts of the learning material does enhance recall of information, but that manually taking notes can interfere with that process due to the complex process of note taking. Meanwhile, Bromage [12] showed that *repetition* allows the learner to add more information to memory and to adapt learning strategies to focus on different aspects of the material with each successive presentation.

Therefore, there is a value in taking notes because by having a written record, it provides the opportunity for repetition of the material to be learned, however, the process of taking notes can interfere with generative processing. Hadwin [38] found that students with high working memory (students able to process and hold more material

simultaneously) benefit more from listening to a lecture rather than listening and taking notes (assuming that they can study later from a written record of the class).

Our intent is not to imply that note taking is bad, but based on these results, and our experiences as students trying to copy down everything said in class, our goal was to build a system that assists note taking for the student, allowing them to experience generative processing during the class and then repetition after the class. Such a system may not be ideal for all students, but students who feel that they need to take notes can still take notes and students who feel that they are too busy taking notes can perhaps concentrate more on the lecture. In either case, all students get the benefit of access to media augmented notes.

1.2 Current Approaches to Capture and Access in the Classroom

To understand how automated capture could be used in the classroom, we looked at what is currently captured (and how it is captured) by students manually. Existing approaches for manual capture and access range from using only memory to using computer systems to augment memory. Each approach has its own advantages and drawbacks in either the capture or the access phase. Currently, the best methods we have to preserve classroom lectures are memory, pen, paper, and audio/video tape recorders, and electronic text.

Memory is often the only available method of saving and recalling information. Memory is used typically when there are no other external memory aids present. Memory is always available and is the only truly ubiquitous 'device' for capturing information. Unfortunately, human memories (including the author's) often fail in the absence of external cues [34], and while they are good for storing summary information,

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detailed recovery (access) of presented data is difficult. For example although you might be able to recall a general concept discussed last week, explicit recall of the finer details is unlikely using only memory.

Pen and Paper are the traditional tools for helping us recall the details of everyday events. They have many affordances that are desirable: they are lightweight, small, readily available and usually usable everywhere. The problem with pen and paper is that taking notes in a lecture often interferes with participation in the class. For example, after solving a problem on the board, a calculus professor may turn around and ask the students if there are any questions, only to find them heads down, trying to copy the problem from the board to their personal notes. Another problem is that important points are often not recorded because they are missed or are incorrectly assumed not to be important. Finally, ink on paper bears little resemblance to the rich multimedia content of most classrooms. When paper notes are reviewed, it is usually difficult to search over large amounts of handwriting and reorganizing the notes (to make searching easier) usually means recopying them. The result is that paper notes often are not enough.

Writing on a handout version of a prepared presentation can be used to augment pen and paper notes. This allows the student to take less copious notes (because the important points are typically already written down), but not many instructors provide handouts before the class begins. While this does help to avoid problems in the capture phase, the same access problems remain.

Tape Recorders are often used to capture lectures, sometimes in tandem with paper notes. Audio preserves more meeting information, but obtaining information from it during access creates new access problems because of the lack of integration between

audio and paper notes. Video and audio recordings can also preserve classroom lectures. Initially, video recording seems like the best way to capture a lecture, however, finding information within the video or audio is difficult and obtaining studio-quality videotape currently requires professional help or the use of a special classroom.

Electronic Text, or notes taken with a computer, is another method of note taking. Despite the flaws of paper and pencil, they are common tools for jotting down meeting summaries, classroom lectures, and general day-to-day events. Their computer note equivalents, on the other hand, usually are more difficult to create during a classroom environment because of heavyweight computers or laptops and the inflexibility of keyboard input. Computers that accept handwriting as input have limitations as well: the screen size is typically smaller and has a lower resolution than paper, and is generally not as easy to manipulate as paper. Of course the benefits of on-line documents are that computers can do useful things with them such as searching, editing, and even linking documents to other types of media.

These tools, though useful, are not optimally suited for lecture capture. Jotting down exhaustive notes hinders effective communication and participation in the meeting or in the class. Summarizing important points, while being better than copious note taking, often leads to an incomplete record. Audio/video captures an audio transcript of the meeting, but searching the tape to pick out important points is an arduous task.

1.3 *Automating Note Taking in the Classroom*

Even when note taking with pen and paper is possible and desired (such as in a classroom), it can interfere with the act of paying attention. One reason why we chose the college classroom for our first attempt at building an automated capture and access

support system is because of the obvious need for students to record what goes on in it while at the same time paying attention to the lecturer. Additionally, the items to be recorded in the classroom (what the instructor says and writes) are easy to specify and not too difficult to capture. Cameras and microphones can record what the instructor says, and electronic whiteboards can be built to capture what is presented and written.

Our initial hunch turned out to be correct: students in classrooms do feel that they are paying more attention to copying down information presented in class than the information itself. When asked to "Briefly describe your note taking practices in traditional classrooms utilizing a traditional whiteboard and overhead projector," students answered (with our emphasis):

- "I **copy all the notes** written on the board."

- "Many times I lose what the professor is saying because **I'm too busy writing notes** on what she said previously."

- "I'm usually more **busy trying to write**/decipher what the instructor is writing on the board, **and don't really have the time to understand** the concept."

- "I spend all my time **scribbling frantically without listening** to what the professor is saying."

These responses are from 359 undergraduate and graduate students at Georgia Tech enrolled in classes captured with our capture and access technology. 42% of students indicated that they tried to write down everything said and written in the class; with many of them indicating that they had trouble keeping up while trying to copy down notes. At the same time that students are struggling to keep up with the amount of material presented in traditional classes, an increasing number of professors are starting

to take advantage of technology in the classroom to present *more* information during class. If students feel that they now spend too much time copying notes in a traditional classroom, then the situation grows worse in a class that uses technology to present even more information through Web pages, videos, computer-based slide presentations, and computer demonstrations or animations.

In fact, most of the technology in a classroom (projectors, VCRs, computers) is designed to help the instructor present more information during a lecture than is possible with traditional whiteboards. The premise is that these enhanced display capabilities will help provide a deeper learning experience for the students. Unfortunately, (as is the case with Web pages and videos, for example) the richness of this supplementary information does not lend itself well to being copied or summarized. We feel that students, using only pen and paper, are drowning in information because the tools they have cannot adequately capture the richness of a modern classroom lecture. As a result, many students wind up practicing a "heads down" approach to learning — they are too busy writing down everything presented in the classroom to actually pay attention to the lecture material.

Automated capture can help relieve the students of the burden of copying down everything that goes on in the class, thereby enabling them to concentrate better on the lecture or take fewer, more personalized notes. The whole point of capture, however, is the access to the materials. Access to captured materials aids the students in studying for exams (repetition) or whenever in the future that information is needed again (repository). Access of captured materials can also aid the professors in teaching a course that was previously taught by a different instructor, or in preparing for a new

lecture on a topic already discussed by allowing them to see both the materials and how they were presented.

Although we knew that automated capture would have applications in distance learning and general business meetings, we explicitly focused on the standard university lecture, with access made available to those who had originally attended the lecture. There are some who would argue the effectiveness of this age-old didactic form, but the fact remains that a vast majority of education occurs this way. Producing a system specifically tuned to the traditional lecturing style would allow us to experiment with a large number of users and also put us in a position to observe how automated capture affects the form of the traditional lecture.

1.4 Overview of eClass

eClass (formerly Classroom 2000) is our attempt to solve the capture and access problem in the college classroom. In simplest terms, eClass is a suite of programs enabling a classroom to 'take notes' of live lectures on behalf of its occupants (Figure 1-1). Through the automation of the capture of live courses and then making them available on the Web, we hope to empower students to pay attention in class, free from the obligation of copying everything down. We also hope to create a new approach to multimedia authoring — live teaching as courseware production.
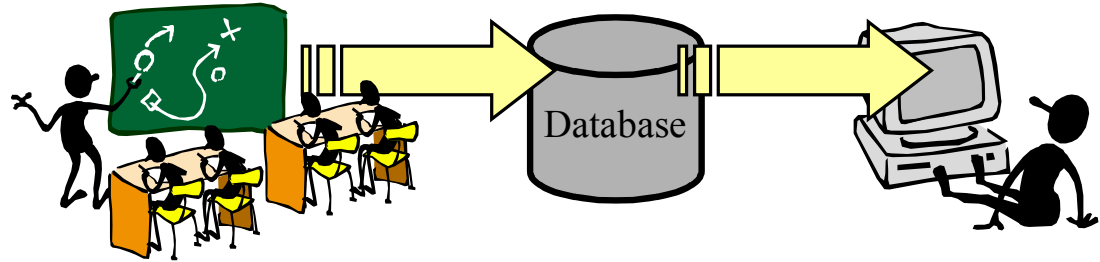
Figure 1-1: A simplified view of eClass. eClass takes everything that is written on the electronic whiteboard, said in class, and shown on the Web, and places it in an on-line database where the materials can be later accessed via a Web browser.

As the project grew, we focused more on supporting the capture and access of live experiences and less on the goal of automatically creating on-line courses. As a result, we feel that the notes for a lecture created by eClass are best suited for those students who were actually in the lecture, though we have seen other effective uses as well. Therefore, we describe our work here as an enhancement for traditional lectures, not as a replacement for them.

eClass began with the goal of producing a classroom environment in which electronic notes taken by students and teachers could be preserved and accessed later, augmented by audio and video recordings. The initial idea was to produce media-enhanced records of a traditional lecture. eClass has since evolved into a collection of capture-enabled programs that attempt to preserve as much as possible of the lecture experience, with little or no human intervention.

To the students enrolled in a course taught using eClass, the in-class experience is not all that different from a typical classroom. A professor lectures from prepared slides or Web pages or writes on a blank whiteboard. Then, shortly after class is over, the students can access the lecture via the Web, choosing to replay the entire lecture, print

out any slides that were created, search for related materials, or just go over a topic that was not well understood.

Figure 1-2: eClass in use. On the right, the instructor annotates PowerPoint slides or writes on a blank whiteboard. Previous slides (or overviews of more than one slide) are shown on the middle and left screens. The screens can also be used to display Web pages.

From the professor's viewpoint, using eClass is not much different from any room equipped with modern presentation equipment. Before class, materials to be shown (if any) are prepared in PowerPoint. Upon entering the classroom (Figure 1-2), the instructor starts some client software from our system and proceeds with the lecture, showing prepared slides on the electronic whiteboard, and writing on it. As the lecture progresses, a partial history of it can be seen on separate displays at the front of the room. After class, the instructor closes our program and a series of Web pages are automatically

created, integrating the video, visited Web pages, and slides. This is normally completed before the instructor leaves the room.

Figure 1-3 shows an example of the captured notes. In the upper left pane, students see a timeline of the class, from start to finish, decorated with significant events that happened in the class such as the instructor visiting a new slide or a Web page. Clicking on the black timeline plays back the audio and video of the class at that point in the timeline. Clicking on the blue slide links takes the student to that slide, and clicking on the red Web links takes the student to that Web page (shown here in a new window). Below the timeline is an embedded video player. The student has the option of using an external or embedded player, both having equivalent functionality. Whichever option used is merely a cosmetic preference.

The right side of the interface is where all of the slides and their annotations are shown in a single scrollable frame. This allows for scanning a lecture to quickly find a topic. For slower network connections, only one slide at a time is loaded into the frame. Clicking on any handwritten annotations will launch the video of the lecture at the time that the annotations were written.

Other features of the notes that are not shown include generating a printable version of them, searching for keywords in the lecture, and editing a collaborative Web page for the course.
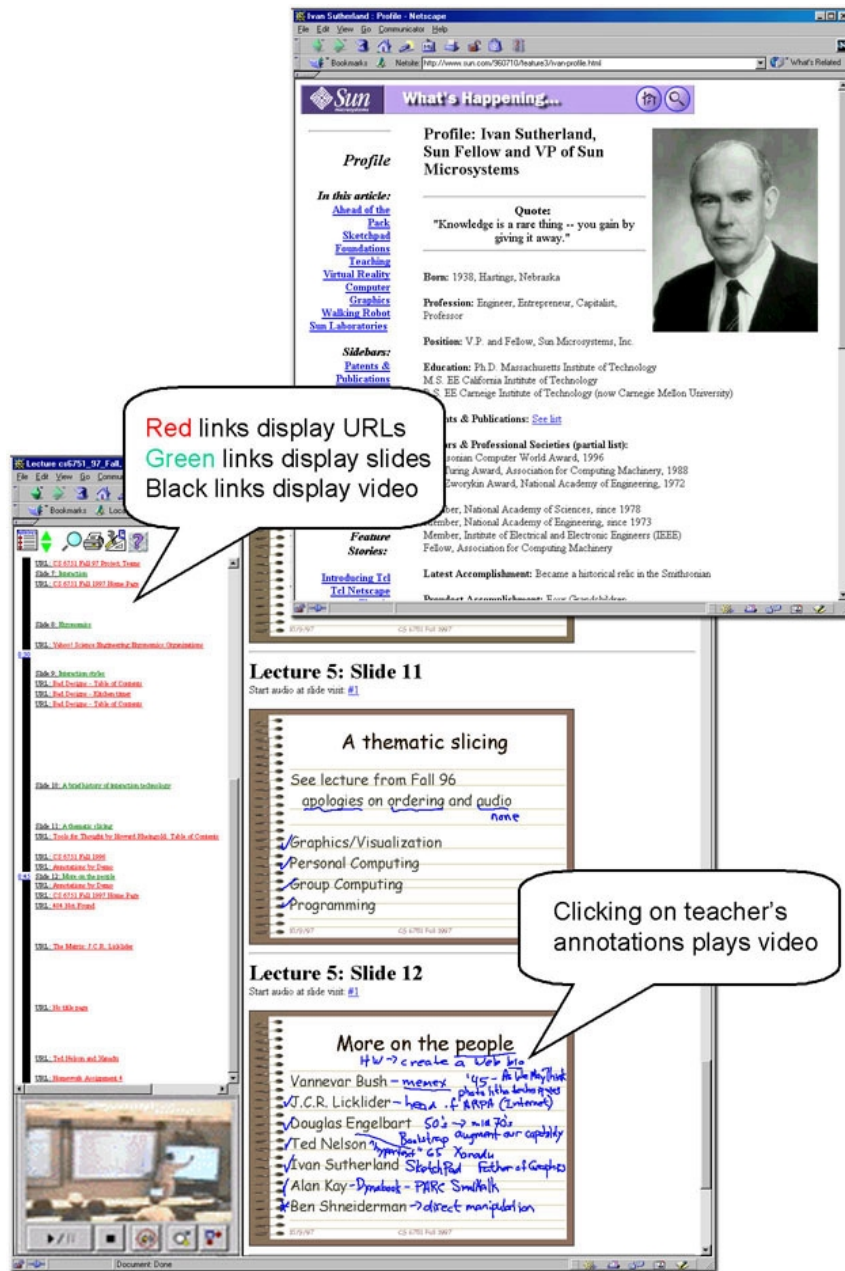
Figure 1-3: An example of the notes taken by our classroom. On the left a timeline is decorated to indicate significant changes of focus, from whiteboard slides to Web pages. The frame beside the timeline contains a scrollable list of slides to facilitate browsing. Web pages are brought up in a separate browser window, as shown. Directly above the timeline is a link that allows students to bring up help on using the system.

1.5   Definition of Terms, Roles, and Activities

Because many different images and preconceptions come to mind when one envisions a classroom, this section makes explicit our definitions and descriptions of a typical classroom environment. Much of this may seem obvious, but we feel that before we describe the tools and services eClass provides, we need to precisely define the underlying classroom model and assumptions that eClass was built upon.

1.5.1 Roles

We have defined three roles in our classroom environment: instructor, student, and outsider. The tools and services of eClass support each role to some degree. A student is any person who wants or is required to learn or study a topic of information and is paying an institution or instructor to teach them about the topic. An instructor is the person who is charged with the task of sharing or giving information about the topic. An outsider is any person who has an interest in what is being taught, but is not paying for the information or would not otherwise be considered a student at the time the information was taught.

1.5.2 Situation

A topic is defined as a collection of knowledge about a particular subject. Topics can be broken down into smaller segments where each segment is discussed in a lecture. A single lecture may cover many segments, or one segment may span many lectures. A lecture is a meeting where at least one instructor and two or more students come together in a scheduled location at regular intervals for dissemination of knowledge from the instructor(s) to the students or, in some cases, from students to students. A course is thus

a collection of these lectures over a period of time and the classroom is simply the location where lectures are taught.

1.5.3 Tools

Both the instructor and students use tools in the classroom to help them with their roles. Two of the most familiar items in the classroom are chalk/markers and the chalkboard/whiteboard. It is hard to imagine a classroom where the instructor does not have some large markable surface to display information. Slowly, these surfaces are becoming electronic, but whatever the technology used, each classroom typically has a large surface where the instructor can write information for the students.

Oftentimes, an instructor has too much information to write during class, or needs to display intricate drawings or photos where physically drawing the information is impossible. In this case, acetate slides and an overhead projector are commonly used. Here, the instructor can write on the projected slides to further explain key points. In some modern classrooms, overhead cameras and television sets are used to achieve the same purpose. Recently, instructors have started using presentation software (such as PowerPoint) to prepare their lectures. During class, a computer with a projected display is used to give the lecture. In all cases, the instructor is using some tool to prepare materials in advance for use in class in order to save time during the lecture.

In classrooms equipped with networked computers and projected displays, some instructors have taken to using the Web as an instructional tool. Essentially this is the same as an overhead projector, but with no marking capabilities. Instructors can use the Web to show either prepared presentations or information created by other people, or in some cases, other students.

The students have traditionally had access to only a few tools to help them learn the material presented in a lecture. Some instructors prepare handouts of their prepared material either before or after the lecture. Paper and pen are the icons of any student and a strong note-taking ability is often the mark of a successful student. Audio recordings are sometimes permitted, but using the audio to study from is often hard enough that it is not worth the effort.

1.5.4 Tasks and Activities

After identifying the tools of the classroom, we are now ready to identify the activities that make use of them. The instructor has one main objective- student learning, typically done through knowledge dissemination among the students and assessing if they have learned it. The instructor has many common activities for doing this: lecturing, meeting with students outside of class time, and assessing performance on assignments (such as projects and homework) and tests.

Homework assigned during a lecture typically consists of work done outside of class designed to reinforce the topic taught in lecture. Projects are typically more lengthy assignments, usually done in teams, and extending for the duration of several lectures. Projects are designed to show competency in several lecture topics, the ability to work as a team, and the ability to integrate knowledge from different subjects.

Tests are the familiar assessment method bemoaned by many students. They are designed to show a comprehensive knowledge over an entire course's worth of material. Tests are the most common method of determining grades, and passing tests are usually a student's main motivation for the class.

Students are also charged with other tasks in the classroom. The most obvious ones are attending the class, taking notes during the class, and studying after the class. Many instructors also insist on discussion from the students and, via assignments, that they review their notes outside of class.

1.5.5 What eClass Supports, and the Assumptions eClass Makes

eClass assumes, not unreasonably, that a course and all of its lectures take place in only one classroom throughout the semester. With a little manual effort, our software can also support courses that consist of two or more classrooms. eClass can also support (but not very well) a lecture given in two different locations if it is given in two parts. We attempted to use eClass with lectures that take place in more than two locations at the same time and were met with mixed success. eClass was not designed to support distributed lectures. The lack of communication tools and the amount of manual effort required to 'force' the system to fit this model made it clear that eClass was not a good solution for distributed classes.

We do not assume that the students or instructor of a course are the only people who will access the on-line notes. We have discovered that access of captured materials can also aid other instructors teaching a course that was previously taught by a different instructor. eClass helps instructors prepare for a new lecture on a topic already discussed by allowing them to see the materials used in class and how they were presented. Students of other courses and outsiders often look at the on-line notes for a captured class that they were not enrolled in. The system supports in some way accesses from instructors and non-students, but our intent was to provide an access service of a course for the actual students of the course.

We do not mean to imply that eClass directly supports all of the roles, tools, and tasks specified above. Recall that the main goal of eClass was to build a classroom that could take quality notes for the students enrolled in a course. In trying to meet this goal, we have noticed our system being used in ways we did not predict. For example, professors have had open-note tests using eClass and have created class projects that require the use of eClass to build publicly critiqued artifacts. In most of these cases, we then refined our system to facilitate and encourage the unexpected behavior(s). This has resulted (for better or worse) in eClass being used to some extent to support the people and activities described above.

1.6 *Purpose of Research and Thesis Statement*

In this thesis, we intend to show how automated capture and access of live experiences can enhance an everyday activity by exploring capture and access in a relevant domain: college lectures—and then generalizing our findings so that they may be applied to other domains. We have already shown why note taking is important for preserving a record of the lecture experience (useful for learning by repetition) but how it also can distract from paying attention to the lecture (bad for generative processing). This is a prime example of why automated capture and access can benefit college lectures.

We now present our thesis statement:

Automated capture in the classroom can provide a detailed record of a lecture in the form of autonomously generated media-enhanced notes that students will regularly access in their review and study of college lectures.

We believe that automated capture can aid the student based on student observations and interviews where we found that students want to capture more information from a lecture than they currently do in the classroom, but with less effort. If the student is confident that the room is capturing all of the details of the lecture, the reasoning follows that they should be able to concentrate more on what is being presented rather than concentrating on recording it. If through access of captured lecture materials we can provide for the students additional studying capabilities, then they should find this service useful in their studies, resulting in significant use of the captured notes.

Automated capture is also useful for the students because augmenting traditional note taking techniques and notes with audio, video, and Web pages provides for a richer learning experience. Instructors can show more information with the knowledge that all of the information can be accessed after class. Integrating the audio and video of the class with the instructor's handwriting increases the value of the handwriting by providing more context of what was going on when the ink was written.

We prove our thesis statement by taking example from ubiquitous computing research [1]. First, an automated capture and access system must be built. Second, it then must be put into real, everyday classes in order to obtain authentic use. Third, the system must be evaluated. In order to be able to determine the real impact of technology in our everyday lives, the technology must first become "everyday." The reason for this is that we as designers cannot anticipate they way our systems will be integrated into

personal lives, so any evaluation that occurs in a lab or trial setting can not tell the complete story. Only after the system has become "everyday" can we then evaluate it.

1.7 Contributions

Because we are applying capture and access research to the classroom domain, a large number of contributions of this thesis will be related to the classroom experience. Some of these expected contributions are:

- Building eClass, an automated note taking classroom and on-line note access system.

- Understanding how the educational experience is impacted by eClass for both students and instructors. Specifically, we show that:

    - eClass does not result in decreased lecture attendance.

    - captured lectures are useful beyond their original semester taught.

    - eClass is perceived as a useful learning tool because:

        - students feel eClass makes the class more interesting, helps increase attention

        - students prefer eClass over other technological solutions

        - eClass is easy enough to use and is adaptable to most courses

        - students report being able to study more efficiently

    - media-enhanced notes are a useful study aid and:

    - audio augmentation is preferred

    - slide level indexing is preferred over ink level indexing

    - students take fewer, more summary style notes.

    - students want to personalize the public captured record.

    - privacy is not that much of a concern, but should be addressed.

o   exam performance is not impacted.

In addition to focusing on the classroom, we will address the larger space of the capture and access as a general ubiquitous computing problem. In this area some of our contributions include

- Identifying four phases to capture/access applications: pre-production, live capture, integration and access.

- Simplifying the access of captured materials by treating captured information as a collection of time-stamped streams.

- Generalizing capture and access to a collection of history preserving devices.

- Advice on building and evaluating ubiquitous computing systems, including designing a system for continuous use.

- Building a framework for creating capture and access applications.

- Building transparent but powerful interfaces into everyday objects.

1.8 Overview of Dissertation

The rest of this thesis is organized as follows. In chapter 2 we present related work in capture and access in the educational and other domains. In chapter 3 we provide some requirements for capture and access systems along with a description of eClass and Zen*, our generalized capture and access system. In chapter 4, we discuss our objectives for evaluation, the methods we used to meet them. Chapter 5 details the results of our evaluation, and in Chapter 6, we discuss how our attempts at extending capture and access into other domains and highlight what could have been improved with eClass. We finish in chapter 7 with our conclusions and future work.

CHAPTER II

BACKGROUND AND RELATED WORK

In this chapter, we discuss some of the related and relevant work in capture and access in and out of the educational domain. This discussion is an introduction to previous work in the field of capture and access and to the tools and techniques which enable it or make it better.

2.1 Capture and Access Overview and Features

The first step to any capture and access application is deciding on what to capture. This of course depends on the domain of the applications. The goal of capture is the preservation of as much of the experience as possible. For a classroom, this includes what the instructor (or student) says, what is shown on an overhead projector, and what is written on a chalk or whiteboard. For a meeting, this might include who said what, the materials discussed, and any assigned action items to be completed.

Many of the systems we will look at will vary in the following ways:

- the material being captured

- whether the capture process being manual or automated

- whether the system captures public or private information or both

- how the material is integrated for access

- whether the integration process is manual or automated

- whether the system shows public or private information or both

Although there is some overlap between classrooms and meeting rooms, in both cases it is impossible to completely capture the experience from the user's perspective. The best that we can do is try to record everything and provide a mechanism for users to playback and access the information based on what they deem are the significant events for that experience.

2.1.1 Definition of Media Streams

We can think of the various experiences to be captured as a stream of information that flows through time [22], [13]. For example, audio can be thought of as a series of discrete samples progressing linearly through time. In the case of CD quality audio we would have 44,100 samples per second. Similarly, TV quality video can be thought of as a sequence of discrete frames played back at 30 frames per second.

We can extend the examples of audio and video to other activities by breaking down the activity into a series of significant events. By recording these events, we can then reconstruct the experience by playing the events back at a later time. To capture Web browsing activity, we record the time and location of each URL visited. To play back the browsing activity, we simply display each URL at the appropriate time. A more comprehensive Web capture utility might also record mouse movements and keyboard activity so that the replay would show where the attention was focused in the Web document. Ink written on the board can be thought of as a stream of strokes, each stroke being broken down into a stream of points, each point having a time and a location on the surface on which it was drawn.

The advantage of treating activities as a series of streams is that all streams have a common attribute – time – that we can use to merge different activities into a single

experience. A common theme in this and related work is taking advantage of the commonality of time to merge together media streams. An example of this is merging audio and ink streams such that clicking on the ink will play the audio at the time the ink was written.

Once the data to be collected has been specified, it needs to be captured. This can be accomplished in two ways: manual or automated.

2.1.2 Manual vs. Automated Capture and Access

Manual capture of experience is commonplace, yet requires some expertise. For example, a classroom can be treated as a movie studio with "actors" (the students and instructor) and "props" (the materials shown in class). Such a studio might employ one to four camera operators, a technology assistant (in case the instructor encounters an equipment failure or needs help operating the equipment), and a producer. After the "movie" has been captured, it is manually edited and distributed. We can ease the manual production for this process by automating the capture of raw materials and the creation of finished materials for later access.

A studio production of all of our everyday experiences (similar to the movie, "The Truman Show") is not desirable or feasible. We assume (as we must in most classrooms because of budget constraints) that the only people who can capture and access the meeting or lecture are the actual people present in the meeting. We must then have the members in the meeting be responsible for capturing the material and preparing it for later access. As motivated in the introduction, this often is not desirable. We instead want to automate this process by having a computer do it. Of course the degree of

automation and manual intervention will vary between related projects, and can even vary from the capture phase to the preparation of the materials for later access.

We don't want to remove the human completely from the capture of materials. Although the environment can capture all of the publicly displayed information, personal annotations and insights are still an important part of the capture process. The difference between what is public information and what is private information is discussed in the next section.

2.1.3 Public vs. Private Information Capture and Access

In its simplest definition, public information is information that all members of the group can see; private information is that which only the author (or a small authorized subset of people) can see. Public capture is the capture of public information and private capture is the capture of private information. Public access means that all people can view the captured materials; private access means only the author (or a small authorized subset of people) can view the captured materials.

Information does not need to be consistently public or private as it goes from the capture phase to access phase. For example, the environment can capture public information, but the viewing of the captured material may be private. Alternatively, both public and private capture can occur, but all of the materials can be made public during the access phase.

Whether the information be public or private, collecting it in an unobtrusive manner can be difficult. We do not want the capture process to interfere with the experience, but we cannot provide for rich capture of materials by using traditional devices. In the next section we look at how ubiquitous computing can help us gain

insight into how we might augment traditional devices with capture and access technology.

2.2 The Role of Ubiquitous Computing in Capture and Access

In the late 80s, Mark Weiser and researchers at Xerox Palo Alto Research Center [83] began to merge together two radical ideas to form what has been dubbed "ubiquitous computing." The first idea was the notion of building computer applications that could go beyond the desktop by spreading computers ubiquitously (everywhere), but invisibly, through the environment. In effect, they were trying to provide computational resources to everyday objects while honoring the transparent ease of use of the objects.

The second idea, based on evaluation of computer systems, was to observe the way people really used technology, not just the way they claimed to use technology. This means shifting the focus of research from computer hardware and protocols to the detailed situational use of the technology—understanding the interplay between computers and our everyday environment. Together, these two ideas make up ubiquitous computing.

[a field that]… speculated on a physical world richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives and connected through a continuous network [83].

A secondary goal of this thesis is to show how everyday objects augmented with capture and access capabilities play an integral part in ubiquitous computing research.

2.2.1 Defining Ubicomp

In his seminal paper [82], Mark Weiser characterizes ubiquitous computing systems as having two main attributes.

- *ubiquity*: interaction with the system is available wherever the user needs it.

- *transparency*: The system is non-intrusive and is integrated into the everyday environment.

In the above definition, ubiquity takes on the vague role of always being there when needed. Depending on the domain, this can mean different levels of support. For example, in a classroom setting, the classroom needs to always be ready to record a lecture, and the captured materials must be available whenever the student desires them.

Transparency was a very important goal for us. We wanted many instructors to use eClass, but we realized that most professors are not willing to go through extra effort in preparing for a class. Therefore, we tried to use technology that was as similar as possible to the existing materials and make recording a lecture as easy and transparent as possible. Although we were successful at integrating eClass into the everyday environment, we were not quite as successful on the transparency.

2.2.2 Refining Ubicomp

Salber [63] later took the original two attributes of ubiquitous computing and expanded them to provide for a better characterization of what ubicomp systems really are. He makes the argument that ubiquity can be described in terms of user mobility. The measure of mobility is a scale varying from none, to fixed, to full mobility. PC workstations have no user mobility while systems that work over a small scale, such as a room or building offer fixed mobility- the user is free to roam around within the confines of a defined area. Full mobility is achieved when user mobility is not at all constrained. eClass is an example of a constrained user mobility system. The captured material is accessible from all over the world, but the capture can occur in only one location.

Transparency is further refined to mean interface transparency; how much the user must consciously perceive, understand, and manipulate an interface that is conceptually separate from the task being performed. Interface transparency can be broken down into syntactic and semantic transparency. Syntactic transparency relieves the user of tasks that are introduced by the system itself. Common examples of this include: explicitly saving a file, manually getting new email messages from a server, and scrolling windows in a GUI. Semantic transparency refers to the system being able to anticipate the user's intent and performing the task for him—such as an automatic sliding door. eClass tried to provide syntactic transparency by automating the recording and synchronization process of a lecture. However it is not perfect—upon entering the room, our program still needs to be started. We have not provided in eClass any significant level of semantic transparency, but that is the topic of further research.

2.3 *Automated Capture and Access Tools and Environments*

To enable capture in meetings and classrooms we need to augment the tools used such as chalkboards, pens, paper, overhead projectors, with the ability to provide a digital record of their use. In this section, we'll look at some of the technology employed in our research and related work.

2.3.1 Electronic Whiteboards

There are several approaches to augmenting whiteboards, ranging from making small additions to them to building completely electronic models. The idea in all cases is the same: to provide an electronic version of what is written on the board.

One method to augment a whiteboard used by BrightBoard [70] and ZombieBoard [10] is to use a real whiteboard with real markers in conjunction with a camera focused on the whiteboard. The user writes on the whiteboard just like any other whiteboard. Meanwhile, the camera looks for specific markings or gestures that indicate to the system that the user wants the ink currently on the board to be saved.

These systems are good in that they use existing technology that users are familiar and comfortable with. The disadvantage of these systems is that they require the use to modify their whiteboard behavior by drawing or using special pre-drawn gestures (affixed magnetically). This behavior is not common with whiteboard users and can lead to confusion. Another problem is the granularity of the data captured. Currently, the system only saves ink when the user explicitly indicates it to save, usually, just before a significant portion of the board is to be erased. This results in a page-level granularity of ink, resulting in all the ink on a 'page' to have the same timestamp, as the camera can not determine when strokes were initially written. For many capture applications, such as replaying the ink as it was written, or for handwriting recognition, we need a finer level of granularity for the ink.

A method to achieve better granularity is to convert an existing whiteboard into an electronic one. One way of doing this is to alter the whiteboard so that the surface can detect when objects are pressed against it (and the location), thereby capturing the ink the moment it is written on the board. Many commercial products such as SmartBoard [68], SoftBoard [69], TeamBoard [75], Ibid [49], and PanaBoard [46] use this idea. The whiteboard has a thin electromagnetic film over it and when a pen is used to write on the board, the film contacts the board and gives a location of what is pressed against it. The

advantage of these systems is that they can provide real time ink data and they look and feel just like traditional whiteboards with real pens and erasers. One problem with these systems is that they can not detect what object is doing the pressing, say a pen, or finger, so the user typically must explicitly indicate the color of the marker, or that she is erasing. The SmartBoard attempts to get around this problem by using a special pen tray that detects when markers are lifted from their respective trays. Unfortunately, this often causes confusion because as in the case of an instructor holding two different colored markers drawing a diagram, the most recently picked up marker is not always the marker being used.

Another approach to converting a traditional whiteboard into an electronic one is to augment the board with sensors that can track special pen holders via infrared or sonic emissions. EBeam [29], Mimio [78] and SmartScribe [23] are two such systems. Both systems have a small vertical sensor relay that attaches to the side of a whiteboard (or in the case of SmartScribe, possibly a chalkboard). Real pens are placed in special cradles that the sensors can detect. These systems do not have the same disadvantages as the modified whiteboards since there are different detectable cradles for each marker or eraser which means the system knows what object the writer is using. The only downside to these systems is that they require the use of the cradles or they can not detect the markings.

A final approach to augmenting whiteboards with capture capabilities involves using completely electronic whiteboards. These boards are similar to the modified whiteboards but instead of real pens, they use pens with no ink. They require the use of a projected computer to then digitally display the 'ink' written on them. The screens for

electronic whiteboards can be front- or rear-projected, depending on the type of board. Rear-projected electronic whiteboards are large, cabinet-like systems; front-projected boards tend to look like ordinary whiteboards. Many of the modified electronic whiteboards discussed above can also be used as front-projected electronic whiteboards.

Rear-projected electronic whiteboards such as those made by SmartBoard use the same kind of contact-closure sensing technology as the modified boards. Some whiteboards, like a SoftBoard, use a grid of lasers behind the writing surface to detect when ink is being written. The LiveBoard [30] uses infrared pens to transmit where the ink is being written. Projected electronic whiteboards have the advantage of being able to display, capture, and control computer screens, in essence doubling the functionality of the whiteboard. Advantages of rear-projected boards are that they have no occlusion of ink from the instructor standing in front of the projector. Front-projected whiteboards are generally cheaper and take up less space since the projector is usually ceiling mounted. Both modified and traditional whiteboards can have prepared materials projected on them with an overhead projector, but the projected information cannot easily be captured – each whiteboard comes with its own controlling software that saves data in a proprietary format, and often doesn't save all the information that we want. Integration therefore of several different whiteboards is not possible without writing a generic capture tool.

2.3.2 Personal Note Taking Devices

We now turn our attention from large group-display devices to smaller personal note taking devices. Pen and paper are the most common means of taking notes. We can access pen and paper documents online by scanning them. The problem with notes access in this way is the same as with electronic whiteboards, which only capture when

the user indicates capture should occur; the captured record has no notion of the ink on the page or when it was written. Devices to support digital note taking range from electronic pen and paper tablets to hand-held personal digital assistants (PDAs) to completely electronic pen computers designed to look and feel like a notebook.

Augmenting pen and paper with capture can be done by writing with a special pen that remembers its movements and can then re-create the ink digitally at a later time. Another technique involves having the user write on a normal notepad that rests on a special digitizing tablet. This table can track an ink pen outfitted with an undetectable transmitter. The CrossPad [21] is the first commercial example of this. This has the advantage of being most like pen and paper. The disadvantage of course is that it's just like pen and paper and can not benefit from other technologies in the room like an electronic whiteboard or other CrossPads sharing information.

PDAs, such as Newton, PalmPC, and Palm Pilot, are similar to small pen and paper tablets, but are completely digital. Because of this, they also can function as multi-purpose devices. The advantage of taking notes using PDAs are that when networked, they can be used to share information or notes. Disadvantages include the small size for writing notes and with devices like the Pilot [59], the special alphabet needed to input notes.

Pen tablets are completely electronic versions of notebooks. They are computers with the approximate form of a notebook with a display approximately the size of a standard sheet of paper. The device can either be self-contained, as in Fujitsu's Stylistic Lt [33], or can be a tethered-display for a computer like Wacomm PL-400 [79]. They use special non-marking pens for writing and interacting with the computer, much like a

mouse. The advantage of pen tablets is that they are extremely flexible in what can be done with them. They can be made to look like traditional notebook paper and they can have the professor's notes drawn on them in real time while the student is taking notes. Since they are essentially computers with pen interfaces, anything a computer can do, they can do. The disadvantage to pen tablets is that they are often heavyweight and cumbersome. They often generate large amounts of heat or noise. Writing notes on them feels different than it does with pen and paper, and most programs for taking notes with them are much more complicated to use than simply writing on paper and their ink resolution does not come close to that of pen and paper.

In augmenting whiteboards and notebooks, the goal is to capture what is being written without being too invasive to the user. Whitaker and Schwarz [86] found that a failure to keep the same properties of pen and paper and whiteboards that have made them so useful in more powerful electronic alternatives will result in disuse of the technology. One way to combat this is to provide a value-added service for the users. This is why augmenting these devices with capture works. Even though the replacement technology is not exactly like the alternatives, the benefits of using them outweigh the negatives.

2.3.3 Rooms

Recall the problem of augmenting real-world devices with capture technology. We embed computation power in everyday objects, but we also want to make the interface as transparent as possible. In this section we will look at systems that focus not on capture, but on providing more natural and transparent interfaces to technology-enabled devices.

A number of researchers have looked at making the presentation of materials in a room easier for the presenter. One of the first examples of this, also motivated by Weiser's vision of ubiquitous computing is the University of Toronto's Reactive Environment [19]. The Reactive Environment was designed as a study on how to balance the joint demands of ubiquity and transparency. Cooperstock was concerned with how a presenter could effectively work with the environment to give a multimedia talk with multiple display sources such as videotape and overhead slides. A further goal was to capture the presentation or meeting, and how remote colleagues would view the presentation.

By creating a graphical user interface to control the physical connections (such as directing a Hi-8 video to be shown on a specified screen), they were able to reduce the complexity of using the room. They then turned to automating the room by attempting to detect user intention based on certain actions. For example, when a presenter presses the play button on a VCR, they also want the output to be shown on a screen. The room attempts to provide this sort of service for all of the presentation sources in the room. Flachsbart at Northwestern University [31] has built a similar classroom, using cameras as sensors to detect what the instructor is doing and to respond appropriately.

Having the computer infer user intention is one way to provide a more useful presentation environment. Another method is to have the user simply talk to the room and let the room take over the role of the human controller. The researchers at Northwestern have extended their work to do this. Jabberwocky [32] is a speech-based interface to PowerPoint for navigating between slides and when used to rehearse

presentations, can recognize key phrases and advance the slides automatically based on the actual spoken presentation.

2.4 Automated Capture and Access Applications

We now turn our attention from tools to aid in the capture and access process to first-class capture and access application systems. There is a lot of related work (most current work has been surveyed by Brusilovsky [14]) and we break it up by domain. First, we'll examine capture and access applications in the Classroom environment. Next, we look supporting meetings with capture and access. We then look at capture targeted to specific areas such as the Web and video. Next is an examination of research techniques for aiding in capture access applications. We conclude this section by looking at previous work in evaluation and summarizing the novelty of this work.

2.4.1 Capture and Access in the Classroom

Based on the definitions we gave in section 2.1.3 we break the work on capture and access into the classroom into public, private, and systems that capture both public and private information. For completeness, we'll then look at systems in which the capture is not public, but rather done by an instructor ahead of time and then the material are made available for public access. These are not live capture experiences in that they do not capture a real lecture but can instead be thought of as multimedia authoring tools, with generalized access.

Much of the work in supporting classroom lectures is based on an idea presented in [22], [2] that attempts to solve the huge costs of generating multimedia courseware for distance learning by treating the teaching and learning experience as a form of

multimedia authoring. The concept is simple: it can take years to design one online course using traditional multimedia creation tools, yet the same course is probably being taught several times a year. If we can treat the classroom as a form of multimedia authoring, then we can hopefully increase the ability to generate online courses. A common theme for these systems is to attempt to capture the lecture experience for later replay by persons not in attendance. Because of this goal, these systems focus on the capture of public information.

Systems that capture only private information are not as common as public systems because for the effort and architecture required to capture private information, you almost get for free the ability to capture and share public information. With the capture of public information becoming more and more common, more researchers today are starting to focus on systems that capture both public and private information.

2.4.1.1 Public Capture and Access

BellCore's AutoAuditorium [9], Cornell's Lecture Browser [55], and recent work by Liu et. al. from Microsoft Research [48] use cameras to capture the video of the instructor and the slides presented in an automated, transparent fashion. By using a camera fixed on a whiteboard, another camera that can track people, and an algorithm for switching between the two images, they are able to produce a multimedia document on the web of a presentation automatically. The presentation consists of the video for the presentation alongside the contents of the whiteboard. Lecture Browser differs from AutoAuditorium in that it attempts to structure the presentation by using a timeline for navigating through the lecture in a non-sequential fashion. The work by Li et. al. is promising in that they tried to understand the activities of a studio production crew to

create a system that can produce video productions of lectures that rival those of a professional crew.

STREAMS [22] is another system that supports the recording and playback of presentations. The idea behind STREAMS is to record as many information streams possible and have the user decide on playback which streams are significant. Through manual effort and the use of visualization techniques for video and events, STREAMS allows users to search meetings for significant events.

Rendezvous [3] and Author on the Fly [5], [6] are similar to the above projects except that they do not rely on video cameras to produce their record but instead use electronic whiteboards to guide and structure their presentation of captured materials. Author on the Fly also captures any programs or simulations run on a computer for later playback. Both systems emphasize the importance of creating multimedia content by capturing a live presentation.

Forum [43] and Flatland [84] are systems that try to extend a physical presentation beyond the walls of the classroom by broadcasting the content and allowing for audience-presenter interaction via chat room, interactive question and answers, and video.

2.4.1.2 Private Capture and Access

The AT&T Learning/Teaching Theater [67] is an example of an authentic teaching environment augmented with many desktop computers. It had the luxury of teachers willing to adapt their teaching styles and use new technology for presentation. The traditional classroom was transformed into what looked like a computer lab with a computer at every desk. The theater, however, did not support later access of presented materials so we classify it mainly as a presentation system. Since students were able to

save certain materials from the class, we consider this a system that captures private information.

While we feel that the system was overly obtrusive, they did discover some valuable insights in their research. First, the technology enabled new (unanticipated) teaching styles to emerge. Group activities that weren't feasible before such as group coding and debugging became commonplace. Their work was also key in that they promoted actual use of their own research—an example of living in your environment.

2.4.1.3 Public and Private Capture and Access

In the classroom, capturing all of the public information although valuable is not enough. Students often desire the ability to take their own notes and have them integrated with the public capture record. StuPad [76] and DEBBIE [8] are two such systems that take what an instructor writes or types on an electronic whiteboard and broadcasts it to computers at students' desks. The students can then write their own annotations along with the instructor's and after class, save the notes into an electronic notebook for later study. DEBBIE is a complete system while StuPad is an extension of this work that allows for the personalization of public experiences. Both systems allow students to take notes on a live captured presentation. Both have separate areas for private annotation and public (the instructor's annotations), but StuPad allows students to combine the two forms into one area, integrating the student's notes with the instructor's handwriting.

2.4.1.4 Non-Live Capture and Access

All of the previous work in the section has focused on the live capture of a lecture for later access. For completeness, we now look at some systems that provide access without capturing a live presentation. We first examine systems that are just repositories of lecture information and then look at systems that capture the lecture experience by having the instructor present and prepare materials alone. The presentation is captured and then made available for playback by students.

Blackboard.com [11] and Uzone.com [77] are two commercial companies that store lecture information. Both sites allow instructors to upload presented material and let students upload notes that were taken during class. In reviewing or studying for a class, students can print out copies of the materials and ask questions that other students or the instructor can answer.

Uzone and Blackboard are primarily just storage sites for a collection of student notes. The notes are taken by paid students who write a generalized account of a class they attended. There are no searching facilities, and the notes are transcribed text. Personal customization is supported by allowing students to save sets of notes they find useful into a private space. Supporting an on-line calendar for keeping class schedules provides additional customization. Collaboration is supported via an IRC-style chat room. The notes are not editable, but are free to download.

Manic by University of Massachusetts [71], [58], Carnegie Mellon's Just-In-Time Lectures [24], NZEdSoft's AudioGraph [57], and another system by the same name, AudioGraph by Alex Shafarenko [66] are examples of online lecture authoring programs. They all enable an instructor to privately give a lecture with supporting electronic

sources, record it, and publish it on the Web. These systems produce output which is similar to the systems that capture live lectures, however they are often of a higher quality because of the increased effort in producing them.

2.4.2 Capture and Access in Meetings

Not all work in capture and access is focused on the classroom domain. In this section we will look at systems where the capture and later access of business and everyday meetings is the focus. For simplicity, we again divide existing work into public, private, and mixed information capture and access.

2.4.2.1 Public Capture and Access

Wolf and Rhyne [88] presented a pen-based tool for supporting both group communication and meeting capture and review. They developed We-Met, a program designed for an electronic whiteboard that shows prepared slides and can record ink, allowing the user to replay the meeting back in real time or to see how the group artifacts have changed over time.

In their evaluation of their system, they present some important design consideration for future shared whiteboard programs.

- Pen-based interfaces offer a big win over keyboard and mouse input. Although we found this to be true, our studies show that users still desire the option to type.

- A whiteboard of 640x480 resolution is not large enough. We have found that a whiteboard of 1024x768 resolution is not large enough.

- Users want a private space to jot down personal notes and reminders. We have found this to be true, but that users also want their notes to be integrated with the public capture information.

- User must be trained to use the system, and the system must be very similar to pen and paper technology lest it go unused. We have found that if the system is designed for interface transparency, then users to do not have to be trained, but that if training is provided, users are much more effective at using the tools.

Kmi Stadium [28] is an attempt to capture more than just what is presented, but to also enable (and capture) remote audience participation and mood. Stadium is essentially a virtual reality realization of a stadium or conference hall or a small meeting room. Participants who are not physically present can log in and see a representation of the event. Through the interface they can ask questions, walk and meet with others in the lobby, or even applaud and boo. Their system has many different 'arenas' for presentation: a stadium, audio-only Webcasts, Audiotrium presentations showing the presenter and their slides, or a talk-radio style interview. Theirs is one of the first examples of using different access interfaces depending on the material to be captured.

The Informedia Experience-on-Demand (EoD) project [80] is similar to STREAMS in that it attempts to capture many different streams of information about an experience for later access. What is significant about EoD is that it attempts by using Video Optical Character Recognition, audio analysis, and 3D reconstruction of an environment to understand the video and audio streams to provide more context about the situation.

Where Were We (Minneman et. al.) [50] and I'll Get That Off the Audio (Moran et. al.) [53] are systems designed to let meeting participants "salvage" parts of the meeting during the actual meeting or during later access. Both systems aided participants in creating a detailed summary of a meeting but they were novel in that they were the first to look at using capture *during* the access phase to help aid in future access sessions.

The work of Moran et. al. is important because it focused on understanding how users would later access the captured materials. They identified several types of salvaging profiles and showed how features available during the capture phase (such as time-stamped ink) can lead to specific types of salvaging behavior.

Padhye and Kurose also evaluated access activities through student use of their MANIC-produced Web-based lectures. They focus on media usage during a study session and report that forward skips (jumps) in the audio are seven times more likely than backward skips. They found the average study session for students to be around 30 minutes with 80% of sessions lasting less than 30 minutes, but more importantly, that study sessions that access audio tend to last longer than those that do not.

2.4.2.2 Private Capture and Access

Capture and access can also aid more personal, one-on-one situations in the workplace. Here, the role of audio takes on a more central role, as in the case of preserving private conversations held through phone calls. Phone calls comprise about 20% of the workday and face-to-face meetings account for an additional 25-50% [61]. While computers are getting better at recognizing speech, they still do not understand speech. The problem with the tape recorder approach for audio is that the end product (a tape) results in an ineffective medium for searching (play, go forward, go backward),

rendering the tape nearly useless. The reason for the limited role of computer programs using audio is the way audio has traditionally been used. Audio has been used as a medium for communication and not as a source of data. This is because it is easy for computers to transmit and encode audio but it is difficult to process the audio signal itself for meaning. One example of how computers can use audio without understanding it is presented in PhoneSlave [64]. It used conversational techniques to take a telephone message, asking callers a series of questions and recording the answers. These sound segments could be highly correlated with structured information about the call. For example, the response to "At what number can you be reached" contained the phone number. If a user asks the computer to give him the phone number of the person who called, it simply plays back that portion of the audio. The important idea here is that the computer gave the user the data they needed without knowing exactly what that data was. This use of audio is called audio-as-data.

In her papers on ubiquitous audio [41], [42], Hindus treats audio as a source of data. Rather than trying to interpret the audio data, she structures it using simple techniques to provide an interface for searching and indexing into the audio. Automatic transcription of formal meetings is the holy grail of meeting capture, but since this is not possible, Hindus provides an alternative approach to structuring the audio from a meeting.

The novelty in her work is in the program Xcapture which takes a phone calls and separates the audio into each person speaking. This is easily done with a phone as the two speakers are on physically separate lines. After the call is completed, the program displays a summary of the call by decorating a timeline with the segments of audio

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pertaining to each person. By clicking on a segment, the user can hear that portion of the audio. She also provides for playing the audio back at increased rates allowing for more rapid searching of familiar conversations.

Xcapture demonstrates that for computers to use audio they don't necessarily have to understand the audio. There are however, some problems that were overlooked in this work. While Xcapture provides a reasonable method for searching the audio of phone calls, they don't address the issues of searching through hundreds of phone calls for the one call that is important. Clearly, the indexing of audio also needs to occur at a higher level than the audio itself. Another problem with Xcapture is that it only works for two people. Distinguishing voices in an office environment is still an unsolved problem, so it is not clear if this technology will work in a group capture setting.

Simply recording audio or ink strokes of meeting participants is not enough to provide an accurate record of the meeting. First, different media streams such as audio and video must be recorded simultaneously. Second, these media streams must be integrated with the ink such that the ink can be used as indices into the other media streams. Finally, although computers are very good at recording information, humans are very good at organizing information. Users must be able to provide on the fly organizational indices into the media streams in a low-overhead manner.

Previous work in this area of meeting capture has focused on interview studies on the note-taking practices of meeting room participants as well as implementing systems to support meeting capture.

Whittaker *et al*. [85] examined note-taking practices in meetings and the use of audio in reconstructing events from the meeting. This information was then used to build a prototype system that was used and evaluated in field trials.

Similarly to Hindus, they found that with regard to traditional meeting capture tools (pen, paper, tape recorder), audio users complained that extracting the information from tape was a long a laborious task, often consisting of trial and error when searching for a particular topic. This is due to the lack of navigational and indexing aids on tape recorders. As time-consuming as it would be, most users suggested that having a transcript of the audio would be ideal.

Note-taking surveys showed that notes were used to capture and distil key elements of what was said in meetings. They report that the note-taking process is error prone and 70% of users have problems with their current note-taking practices. Some of these problems were

- Failure to note facts that turned out to be crucial afterwards

- Illegible names or handwriting

- Lack of time to jot down ideas without missing vital spoken information

- Diminished ability to participate in the conversation

- Notes ultimately not being a sufficient record of the meeting

Armed with this information, Whittaker created the Filochat system based on a tablet computer equipped with a soundcard. Participants used individual, private notebooks with each one recording audio of a meeting and the time-ink written during the meeting. User were then tested on recall, speed of access to information and their confidence level in their recall.

Whittaker demonstrates a usable system for capturing meeting activity, but more importantly, he also is able to enumerate additional concerns that future work must address, namely

- Studies to determine what type of meetings work best with the system

- Recording and privacy issues

- Examining the extent to which a system modifies the user's current note-taking practices

- Allowing for automated gesture recognition, enabling a shorthand approach to noting key points and ideas

- Automating audio indexing based on time, other activity, or voice inflection

- Storage issues in recording all of this data and keeping it for future use

- Further research in user-centered indexing

Wilcox *et al.* [87] provide similar work to Whittaker. They first conducted a user survey of workers' note-taking practices and how they use notebooks. Based on these results they built Dynomite with the main goal of emulating all of the important qualities of paper notebooks, improving on these qualities electronically, and using audio to enhance these notes.

In their user study, Wilcox also provides insight into the note-taking practices of meeting participants although their study is limited to a small set of individuals who all work at Xerox. One major problem with paper notebooks is that most notes are arranged chronologically which leads to difficult access of a collection of notes on a particular topic. Dynomite improves on this paper flaw by dynamically organizing the electronic notes based on user queries.

Dynomite gets around handwriting recognition problems (and the lack of searching on the notes that this causes) by allowing users to assign keywords to blocks of ink. Sample keywords include "to do" or "Name", and additional user-defined keywords. Ink may be marked with a keyboard either by gestures or with a keyboard.

Dynomite goes to great lengths to provide an all-purpose note-taking device for individual use. To that end, they have succeeded in providing nearly all of the desirable qualities of paper notes while enhancing them with audio and dynamic organizational techniques.

The AudioNotebook [72], [73], Filochat [85], Dynomite [87] and its video cousin, NoteLook [17] are all examples of personal notebook systems that record and integrate audio with the ink that was written on the notebook. The AudioNotebook attempted to preserve the look and feel of a traditional notebook by using a physical notebook as the interface (seated in a computer cradle). The other systems were built using pen tablet computers.

2.4.2.3 Public and Private Capture and Access

DOLPHIN [74] is an application for capturing free-form meetings. It was designed for small meeting groups with members either in the same room or in different locations taking notes on computers. It is similar to Tivoli [52] in that it implements several stroke and gesture recognition routines but DOLPHIN attempts to treat the entire document not as a linear progression of sheets, but as a hyperlinked set of nodes. DOLPHIN allows publicly shared and private annotations, but it does so by using two separate note taking surfaces, similar to DEBBIE.

Coral [51] is a confederation of tools designed to support the real-time capture and later access of informal collaborative activities. Coral enables capture of the audio, materials presented on a LiveBoard, and individual markings. Users can later access these materials and replay the meeting, or add new information.

NotePals [26], [27] takes a different approach to meeting capture. With NotePals, users take individual notes on hand-held devices. The notes can be classified as public or private, and can further be classified manually into types of notes based on their content. The hand-held device is then docked, and all notes are uploaded to a central note server. Access to the notes is done via a Web browser, with only public notes being viewable by everyone. Private notes are restricted to the author who wrote them.

2.4.3 Capture and Access in Other Areas

In this section, we turn our attention to capture and access systems that do not focus explicitly on meetings or classrooms, but that have applications in both areas. We will begin by looking at electronic note taking systems for video, and then look at a system for taking electronic notes on electronic documents, such as Web pages.

Weber and Poon [81] developed Marquee, an electronic note taking system for annotating and logging an event for later integration with the videotape of the event. Their work is motivated by the fact that videotaping is now so easy that it is commonplace to have large repositories of video. Creating access points into this video is crucial if the video is to be useful.

Marquee was designed based on user studies on note taking practices and on a paper mock up design. One problem with time-stamped ink is that the time that the ink was written is not always the time that the ink refers to. An example is when a user jots

down information many minutes after the information has passed, as many people do when writing summaries. To solve this problem, Marquee used the concept of a *timezone*, a scrolling sheet of (electronic) paper with certain areas corresponding to fixed amounts of time. All notes written in the same area refer to the same time regardless of when they were written.

Another challenge was to simplify the creation of keywords with electronic ink to provide searchable ink. Their solution was to have the user circle the ink to convert it into a keyword. Keywords are then presented as the actual ink in the same way that a recording of a phone number can be presented as a phone number.

A user study of their system concludes with some useful pointers for further development of electronic note taking systems that include

- Ability to take notes and still fully participate in the meeting
- Noting that although a system may support many note-taking styles, the individual style of a user may not support other users of the record in a collaborative setting
- Noting how use of the system changes note-taking behavior
- Noting the need for overviews or summaries of meetings for quick browsing
- Supporting iterative note-taking (during and after a meeting)

MRAS by Microsoft [7] and AntV [20] are two similar systems for taking notes on video. AntV focuses on using annotations in video to provide structure to the video and to promote active watching. MRAS and CoNote [25] are similar in that they both look at how to take collaborative electronic notes using Web documents (MRAS however, has special support for annotation of video documents on the Web). Similar to NotePals,

they use a note repository which is integrated into the Web browser, allowing a user to call up notes for a particular Web page or video.

2.4.4 Techniques for Capture and Access

In this section we examine research that helps solve some problems associated with capture and access systems. These range from systems to augment paper, to systems for handling electronic ink, generalized presentations of multimedia streams, and video summarization.

The previous work we have looked at involves integrating existing paper documents with digital ink as in the case of a professor lecturing from prepared notes or slides. Another example is the ability for students to take electronic notes and have them integrated with their existing paper notebooks. Newman and Wellner [56] approach this difficult task by creating an *augmented reality* desk. The desk has a computer display project on it and a camera is focus on the desk which is able to "read" paper documents and able to determine what the user is pointing at. The table has a digitizing tablet built into it that enables precise pointing and handwriting capture.

LivePaper [62] investigates doing the opposite—taking paper artifacts and augmenting them with an electronic display. In effect, sheets of paper are used as input for the computer which then displays relevant information projected on the desk beside the paper. Both of these systems attempt to blur the boundaries between digital and physical information and are two more examples of how to place computational power into everyday objects.

There is much research on how to handle electronic ink. The idea is that if we are going to go to the trouble of providing electronic notebooks, we should be able to do

more with the electronic ink than simply write and erase. For example, cutting and pasting of ink is a common task with electronic ink—something that cannot be done with regular pen and paper. Tivoli [52] involves creating interaction techniques for sharing electronic ink while Chiu [18] investigates methods for automatically grouping electronic ink. Moran has also reported on work [54] that treats ink as structured domain objects which allow for semantic interpretation and manipulation of the ink by computers.

One problem with the easy collection of video is how we can create automated summaries of the video. Short of actually understanding the video, it is difficult to provide any semantic content from a video, but work done by Mircosoft, IBM, and AT&T attempts to do just that. Methods used include compressing the video by playing it back at a faster rate and removing pauses or periods of inactivity [40], [47]; providing indices by looking for significant changes in the video [60]; and providing a timeline of video events allowing the user to decide what is important [35].

Finally, since the access of captured data streams is of course, the whole reason why we do capture, Bacher [6], Ginsburg [35], and Schnepf [65] have looked at how to provide generalized access and visualization of captured multimedia streams.

2.5 Conclusion

Many functional similarities exist between eClass and other systems. This is not surprising considering the age of the project; we're not the only ones doing capture and access research, nor are we the only ones exploring capture and access in the classroom. The major difference between the work proposed in this thesis and all of the work we've just examined is that in eClass, the central focus of the work was to understand how the introduction of technology impacted the teaching and learning experience.

Because of this goal, we have put our system to use in live classes and have captured more courses and lectures than anyone else, putting us in an excellent position to authoritatively report on the impact of technology in the classroom.

Additionally, because we have used and evolved our system for such a long time, we can use this knowledge to inform the building of capture and access applications in other domains outside of the classroom.

CHAPTER III

DESCRIPTION OF THE ECLASS SYSTEM

Recall our thesis statement.

Automated capture in the classroom can provide a detailed record of a lecture in the form of autonomously generated media-enhanced notes that students will regularly access in their review and study of college lectures.

Again, to prove our thesis statement, and based on how research in ubiquitous computing should be carried out, we have identified three tasks that must be completed.

1. An automated capture and access system must be built.

2. It then must be integrated into real, everyday use.

3. After the system has become 'everyday', it must then be evaluated.

In this chapter, we describe the eClass system and introduce four phases to any capture and access application. They are pre-production, live capture, integration, and access. First, however, we focus on the requirements of capture and access systems in the classroom. After we describe eClass, we then discuss how we met these requirements.

3.1 Requirements of Capture and Access in the Classroom

In this section we examine some requirements for an automated capture classroom. Instructors and students place many requirements on the classroom. Because we are working in a live classroom environment, we must ensure that the capture components of the system are stable and that access to the captured materials is always available. Additionally, any materials generated by the classroom must be available to all

students taking the class. The system must also be easy to use and flexible enough to accommodate a wide variety of teaching styles. Ideally, one should forget that she or he is in an extra ordinary classroom.

eClass needed to be reliable enough for the students to come to depend on the system. In addition, the system needs to be able to evolve over time in the face of changing requirements. In order to determine the impact of eClass the following specifications (shared by most ubiquitous systems) needed to be met.

3.1.1 Convenient, Constant Access to Captured Materials

The notes captured by the classroom must be available for the students anytime, anywhere. The alternative to eClass is using ubiquitous traditional notebooks. If students are to prefer eClass over their current practice, then their access to the captured notes must be as convenient at their access to their own notebooks. If the materials are not as easy to access on-line as they are in a notebook, then we must provide extra value to the captured notes so that the drawback of extra effort is eclipsed by the benefits of the notes.

Because we are operating in an educational environment, teaching real classes, we must ensure that all students have at least some minimal level of access to the classroom record. This means that the presentation of the captured lecture notes must be platform and operating system independent. At Georgia Tech, reasonable minimal requirements for the students to view the captured lecture are a computer, a modem or a network connection, a soundcard, and a browser.

3.1.2 'Everyday' Use

By 'everyday' we mean that the system must be dependable and predictable while being unobtrusive so that authentic use can occur. The system must be used daily and must be viewed as a reliable and dependable service. Notebooks themselves are usually always available, and when they are not, similar alternatives (such as borrowing a piece of paper and later integrating that into the notebook) are easy to find. Teachers too, expect the equipment that they are using for presentation to function and will not tolerate failures.

The equipment used in traditional classrooms is reasonably reliable. Occasionally, the chalk will break in mid-stroke, or a dry-erase marker might dry up during use, but when this happens, the user is able to switch pens or re-adjust the chalk and continue writing without much interruption. More disrupting is when the overhead projector has a failure, or when all of the chalk or pens are missing. In these cases though, most instructors can fix these problems by replacing the overhead projector bulb, or by walking into the next room and borrowing some chalk. Because we want to make the computing power in the room unobtrusive, such problems might not be so readily fixed if they fail, or if their failure causes a disruption of the class, they are not so easily fixed.

A reliability failure is most severe when the class has a hidden failure that impacts the student's assumption that the class will take notes. If the student trusts the system to take notes and it fails, then this would be enough reason for a student or teacher not to trust or want to use the classroom.

Reaching everyday use is difficult but necessary, and it often requires large amounts of manual effort. One of our biggest challenges in building a capture and access system in the classroom was doing all the capture and integration automatically, with minimal additional user effort. In our first attempt at providing a smart classroom, we had a staff of three students supervise the recording of the class, the initialization of an electronic whiteboard, and the merging of all the information streams together into a set of HTML pages for students access. Although all of this human intervention was tedious, it provided us with an immediate and working prototype.

3.1.3 Unobtrusive

No one system will solve all educational problems for all students. Many students may prefer to learn by copying notes, so any system that attempts to take notes on behalf of the student must not interfere with their own needs or traditional note taking strategies. A classroom capture and access system must be a supplement to traditional learning methods, not a replacement.

In effect, the casual observer does not need to know that the room is taking notes. This means that the instructor and students should be able to walk in and use the room as they would any other room. Additionally, special purpose equipment for the room should be as unobtrusive as possible. For example, students might be less likely to ask questions during class if there is a microphone right next to their face or if they hear the whir of a video camera turning and zooming in on them.

3.1.4 Ability to Evolve the System

The system must be adaptable to changing functional and hardware requirements as well as new technological advancements. As technology progresses and new products emerge, parts of the system can often be simplified or improved by using new products. The system also needs to be able to integrate user-requested features as users adapt it to meet their own needs and come up with new requirements for the system.

A key implication of this requirement is that the capture of the data does not influence the access of the data. In almost all cases, capture is meaningless without later access, but capture is not as useful if the data can only be accessed in one way. Separating capture from access has two main benefits: it allows the capture and access parts of the system to evolve independently, and it gives users the chance to access the data in the manner that is best suited for them.

3.1.5 Ability to Evaluate the Impact

The impact of the system must be measurable. Because the introduction of a technological solution for a task often changes the nature of the task, the evaluation of the impact of a ubiquitous system must be performed. In particular, a classroom capture and access system should provide for the observation of the impact of the system on the teachers, students, the material presented in class, and the notes taken. This self-monitoring capability can then be used to provide instructors feedback on how students are accessing materials presented in class.

3.2 Building a Ubiquitous Capture and Access System in the Classroom

As mentioned, fielding a ubiquitous computing system for everyday use in a classroom environment is a challenging prospect because the operational needs of the system need to be solved before serious evaluation can occur. Manual solutions to operational needs are neither desirable nor scalable for a research prototype. In the beginning, the engineering issues can easily outweigh the research challenges.

As discussed in the previous section, the system also must be flexible, so that it can be easily adapted to suit changing (or misunderstood) user requirements and it must be quickly prototyped and implemented so that if the original design was flawed, you learn quickly and can rebuild again. For the system to become ubiquitous, it must become a 'living' system- one that grows with its users and is expandable to adapt to their needs.

In order to instrument any environment for automated multimedia content generation, we need to provide computational services in that environment that are effectively pervasive without being overly intrusive. This is a goal in common with much of the work over the past decade in the area of ubiquitous computing, yet one that is essential for a classroom environment where instructors are not going to want to deviate from their normal teaching styles.

Rather than build new tools for instructors to use, we chose to augment existing classroom tools with capture capabilities. In this way, we hope to have a win-win situation; instructors do not need to change their teaching style or do any extra work, and the students get the benefit of automated capture.

In this section, we will address how we built a capture and access system for the classroom by breaking down the capture and access activities into four phases. We then discuss in detail the tools that comprise eClassr, our classroom capture and access system application, and Zen*, the underlying infrastructure that makes eClass possible.

3.2.1 Phases of a Capture Access System

Our initial work focused on treating a classroom lecture as an example of multimedia authoring [2]. Taking parallels from movie production, we identified four separate phases of the execution of a capture and access system and built or bought tools to support those phases. These phases – pre-production, capture, integration, and access – are described below, and later, we discuss the tools used to support each phase.

Initially, the effort involved to support a single class was so great that we were only able to experiment with one class per term. The chief advantage of adopting this four-phase model of the classroom is that we constructed each phase of the system to be independent and, because of this, over time, we were able to streamline all features of the system to support many enhancements at a time

3.2.1.1 Pre-Production

Before a lecture begins, some lecturers may prepare a presentation as a series of slides or Web pages. In the pre-production phase, we are concerned with providing a simple way to reuse existing classroom material. Since most preparation tools that instructors use allow for the exportation of GIF or JPEG images, we built our system to support the annotation of a series of images. In the degenerate case, the instructor annotates a set of blank images, and this is equivalent to writing on a blank whiteboard.

There is no work required of the students during the pre-production phase. If the instructor's lecture style consists of writing on a blank whiteboard, then there is also no work required of him. If the instructor wishes to lecture from prepared slides, then he must transfer his materials into eClass.

The classroom can be a hostile environment and although there is not much demand on the students and instructor in this phase, there is a small amount of maintenance that needs to be done before each class. Users sometimes turn off machines, or terminate our software, which should be always running on general-purpose computers in the classroom, and these need to be restarted. Users sometimes use the projectors to display other electronic materials and forget to return the projector to a computer that other users expect always to have its display projected. Users sometimes turn down volume settings on recording equipment or move cameras. In an ideal setting, once eClass is running, things just work, but in a dynamic classroom environment where wires are pulled and equipment can by used by anyone, some effort must be spent in returning the room to its 'default' settings. It is this 'small' amount of work that surprisingly accounts for nearly all of the researcher's time in running eClass . It is interesting to note that some 'expert' users have taken it upon themselves to learn how to set up the classroom. Although the room only takes a minute to configure, we feel it is still too complicated to expect instructors to do this.

3.2.1.2 Live Recording / Capture

The capture phase begins when the instructor is ready to give her presentation. Once a lecture starts, we want to record as much information as possible. There are two distinct methods for solving the capture problem. The first is to have the room provide

all the computational needs and the second is to have the user carry with them all of the required computational needs. The former leads to "smart" rooms that record activity in them, and the latter leads to personal electronic notebooks. Our research has experimented with both approaches, but in eClass we augmented the room with the technology, as this seemed the least intrusive method for instructors and students. Indeed, we tried to make eClass "walk up and use" as much as possible for the instructors and students.

In reality, both solutions are desired. Smart rooms provide the luxury of preserving your experience just by being present in the room. Of course, because it is not feasible to augment every room with recording capabilities, a personal solution must also exist. Furthermore, each method must be compatible with the other. That is, a personal notebook must be able to record the activities that a smart room records (and possibly for a group of people) and a smart room should be able to provide personal services to its occupants.

During the capture phase, we focused on recording what was presented (slides, Web pages), written, and spoken. We also record a wide-angle, low-quality video of the instructor focused on the front of the room. Student questions are also recorded, but they are generally out of the camera's field of vision.

In this phase, the work of the instructor should be doing exactly what she would be doing anyway — teaching a class. The work of the students, however, is greatly reduced. They can now focus less on capturing everything and more on paying attention to the lecture.

3.2.1.3 Post-Production / Integration

Once class is complete, there is some effort necessary to provide for the integration between the captured electronic whiteboard activity and the audio/video stream of the class. There is also some post-production work necessary to produce a Web-based interface that makes it easy for the students to access the augmented notes from a class home page. The Web-based interface is the subject of the access phase.

The instructor or students do not need to be concerned with this phase. All work happens invisibly and automatically at the end of a class. Occasionally, system errors occur resulting in a lecture not being properly processed and a student, not finding the lecture, will email our help team. These errors are generally trivial and we can fix them as soon as they are reported (if they are not automatically reported by our software).

The integration phase is itself full of research issues, and we have only touched upon a few of them. For example, one concern is the granularity of integration between handwritten notes and the audio stream. Another issue involves the full semantic integration of the media streams. Because computers cannot understand content from the ink, audio, video, or Web pages, they are dependent on humans to provide semantic structure to the captured lectures. In other words, computers can capture all the details about a classroom lecture, but they cannot understand it, or organize it based on the contents of the lecture. One benefit of this work is to enable the investigation of different data integration techniques without the difficult task of correctly deducing content.

3.2.1.4 Access

In the access phase, students and teachers are provided a Web interface to browse past lectures. Access is the most critical step of any capture application. If the captured

material is not available whenever the user needs or wants it, the system will not be used. Furthermore, since capture applications often deal with personal notes and annotations, each user will want (and expect to be able) to modify the presentation of their materials. We had to compromise in this, as eClass did not initially support personal note taking or modification of captured lectures. Other researchers here at Tech have extended portions of the system to enable these features, but they have not used them on a reliable basis. So in this phase, instructors have no required effort, and students hopefully will be more productive in their study time as a result of the captured notes.

One aspect of access that is often overlooked is that we can take advantage of information specified in the capture phase to help guide the presentation phase. As an example, consider recording a classroom lecture. The goal is to capture the experience. We first assume that we want to capture the focus of the classroom. We then refine this by asking what the students should be attending to, and assume that this is what the instructor is currently doing. Using this knowledge, we can implement an algorithm to recreate the lecture in a more natural presentation. A thorough study of the information to be captured should reveal suggestions on how that information will later need to be accessed, but we stress that by using the approximations above, we can create fairly intelligent capture without understanding the live activity.

3.2.2 The Tools of the eClass System

We have built or bought many tools to help automate the four phases of the capture and access of a classroom lecture. In this section, we will describe the tools and in the following section, explain how they work together to capture and make available access of classroom activity.

eClass is a classroom that captures streams of information during a lecture and then integrates them such that students can quickly review at a later date the information presented in class. Information streams that we currently capture include slides and ink written on an electronic whiteboard, audio, video, and Web pages visited during the lecture. We have captured voice transcripts of the instructor and student notes, but these facilities are not yet implemented for all classrooms or all classes. After a class, all of the information streams are automatically integrated into a set of dynamically generated HTML pages. We take advantage of concurrency and use the time of events in one stream of information to index into other streams. An example of this is clicking on some ink on a slide to display the video of the class at the time the ink was written. We also do some post-processing on streams of information to generate new information streams, such as generating time-stamped transcripts from the audio or performing handwriting recognition on written ink.

We have several eClass-equipped classrooms, but we have been using our system in one particular room for more than three years. What follows is a description of this room. Although it is a typical description of the equipment in an eClass enhanced room, the actual hardware can vary considerably from what is presented here. After describing the physical classroom, we will look at the virtual notes captured by the classroom. These captured notes are independent of the physical equipment used in the classroom.

3.2.2.1 TransferMation

We originally provided for the ability for instructors to manually create slide images and import them into our system. The tool was crude and required instructors to

know how to use an FTP-like browser, but enabled instructors to import content into eClass without our intervention.

The process of converting presentations and then importing them to eClass was time-consuming and tedious. It was also too complicated for new users who were not familiar with file transfer protocols, presentation packages or computers in general. Over time, we found that nearly all instructors were using PowerPoint to prepare lecture presentations. Because of this, we were able to help automate this process by creating a tool called Transfermation, which takes an existing PowerPoint presentation file and automatically extracts slide images and uploads them into eClass.
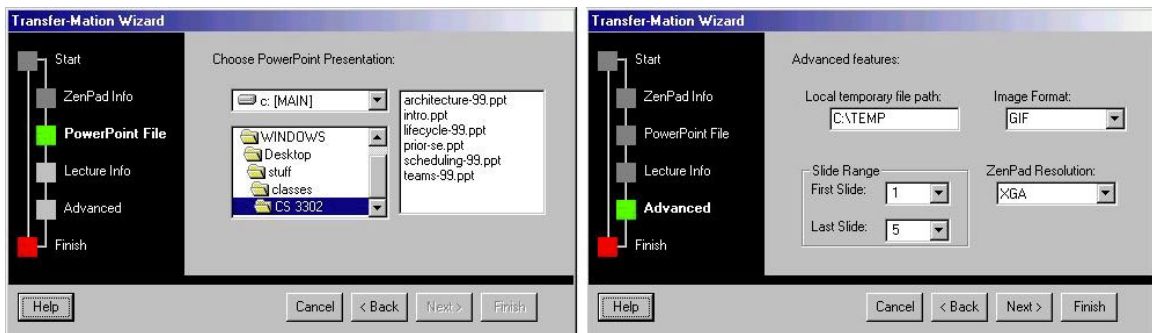
Figure 3-1: Transfermation is a wizard that allows for easy importing of PowerPoint presentations into eClass.

Transfermation was written as a wizard interface using Visual Basic. This was necessary in order to use the PowerPoint libraries needed to create images from slides. As a result, Transfermation only runs on PCs running Microsoft Windows 98. This turned out not to be a great limitation in our work because the most of the machines used to create the presentations could be used to run Transfermation. It was also possible to

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run Transfermation on the electronic whiteboards we used in all of our classrooms at Georgia Tech.

3.2.2.2 Electronic Whiteboards and ZenPad

Because most teachers use some sort of blackboard or whiteboard during a lecture, eClass requires the use of an electronic whiteboard to capture the instructor's handwriting and optionally, to display prepared materials. Electronic whiteboards come in many shapes and sizes. They can be illuminated screens with inkless markers, or modified whiteboards that use real ink markers, or even traditional whiteboards with augmented sensing technology such as cameras and radio-transmitting pens.

Illuminated screens can be front-projected or rear-projected and have the advantage of being able to display, capture, and control dynamic computer screens. Advantages of rear-projected boards (LiveBoard [30], SoftBoard [69], SmartBoard [68], TeamBoard [75], Ibid [49], PanaBoard [46]) are that they are self-contained and have no occlusion from the instructor standing in front of the projector. Front-projected whiteboards are generally cheaper and take up less space since the projector is usually ceiling-mounted. Modified whiteboards (some versions of the SmartBoard, and others) have no computer display and only show the ink physically written on them. Electronic whiteboards built from traditional whiteboards (BrightBoard [70], ZombieBoard [10], eBeam [29], Mimio [78]) are typically the least expensive since all they require is the sensing technology to detect and capture handwriting. Both modified and traditional whiteboards can have prepared materials projected on them with an overhead projector, but the projected information cannot easily be captured.

For our classrooms, we chose a rear-projected electronic whiteboard made by Xerox Liveworks, called the LiveBoard. A LiveBoard is a pen-based computer running Windows with a large, 62" interactive display (Figure 1-2 shows a Liveboard in use during a class). For other eClass installations, the choice of which electronic whiteboard to use was mostly a matter of price and if the instructors would be presenting prepared presentations or simply writing on a blank whiteboard.

Our first electronic whiteboard software program was ClassPad, shown in Figure 3-2. ClassPad was written in Visual Basic and was used for both instructor presentations and student note taking. The instructor would run ClassPad on our Liveboard while students would use handheld tablet computers.

ClassPad was used very much like a slide presentation tool similar to PowerPoint. Simple navigation buttons (arrows in the upper right corner) allow the user to go forward and backward in the presentation one slide at a time. The pen can be used to write on the slide as the lecture progresses. As needed, a new blank slide could be inserted during the lecture and written upon. ClassPad was eventually replaced by our all-Java program, ZenPad.
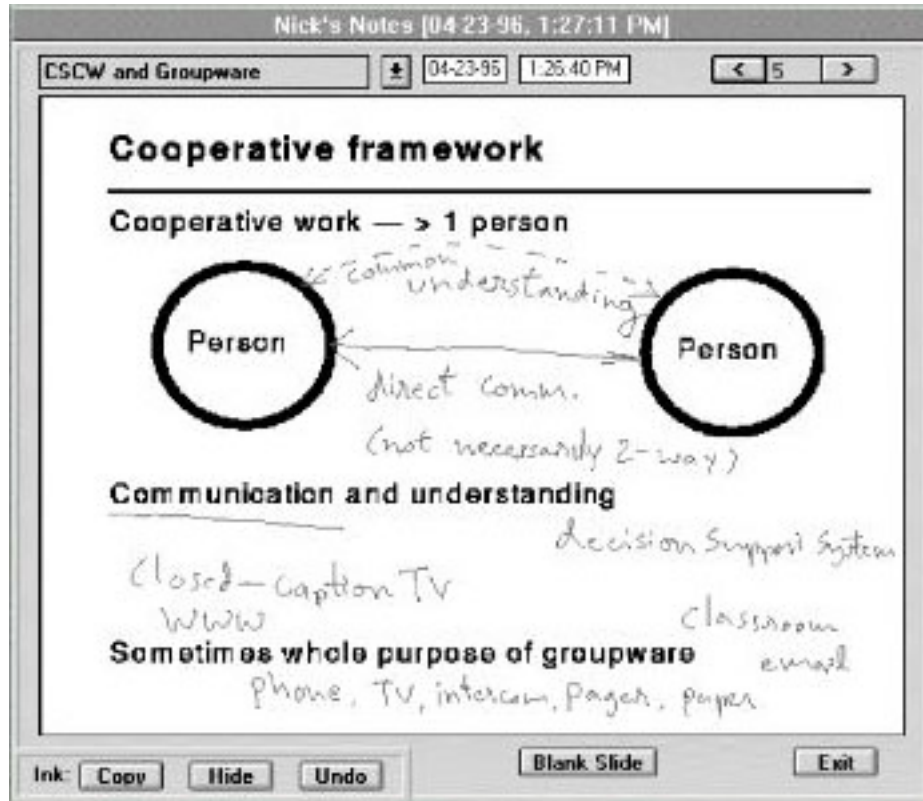
Figure 3-2: The ClassPad interface. Simple navigation and marking tools were used to keep the interface simple and similar to existing presentation tools.

The main capture tool for eClass is ZenPad (Figure 3-3), a program that runs on an electronic whiteboard allowing us to capture what is presented and written. ZenPad, is one part of a client-server Java system, and the main component of what we call Zen*, the collection of generic capture tools that comprise eClass. The eClass servers (described later) coordinate classroom sessions and store and process all of the captured data. Our electronic whiteboards provided two key features that were lacking in commercial counterparts we investigated. First, the artifacts that are produced are easily distributed via the Web. Second, our electronic whiteboards keep information about when various activities occur.
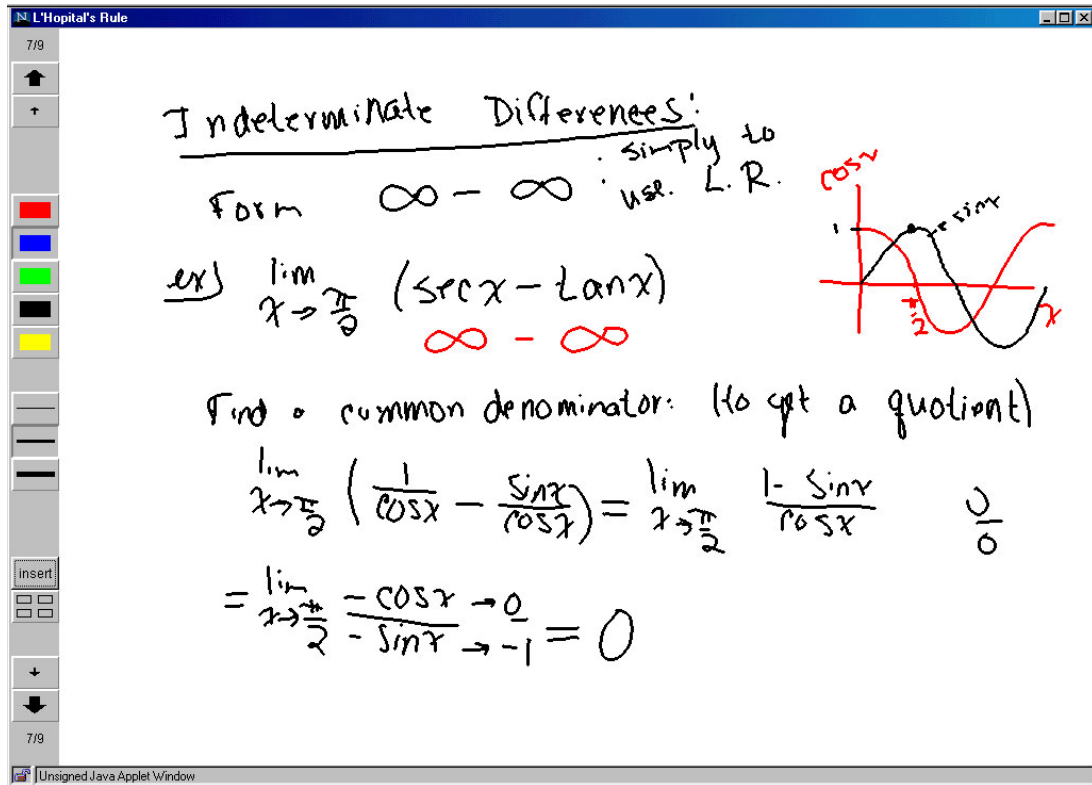
Figure 3-3: Screen shot of ZenPad running on an electronic whiteboard. Navigation and ink marker buttons are on the left panel. The rest of the interface is a blank writing surface.

Like ClassPad, ZenPad provides a very minimal interface that maximizes the actual screen surface for writing. Earlier ZenPad prototypes provided more functionality to the end user, but those features were not used very much and subtracted from the all-important screen real estate teachers wanted for a writing surface.

ZenPad keeps information about when various activities occur. For example, we know when a lecture began, when slides were displayed, when every single pen stroke was created, and when the lecture ended. This information is required for the integration of the teacher's lecture material with the audio or other streams of information, such as audio, video, and Web pages that are recorded during class.

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Recall that the teachers we supported had differing lecturing styles, resulting in the need to support different presentation styles. Teachers with prepared slides wanted to have ZenPad move slide by slide through the lecture with the ability to display a slide and annotate on top of the slide. Other teachers simply wanted ZenPad to provide a continuous scrollable blank writing surface upon which the entire lecture could be handwritten, similar to an overhead projector with a scrollable film.

Beyond fulfilling that simple requirement, ZenPad provides a minimal interface, attempting to conserve screen space. Instructors can change pen thickness, pen colors (depending on the electronic whiteboard, this feature is either automatic, by picking up a colored pen, or manual, by clicking on the software button), and can insert slides if needed. Some users have complained that ZenPad does not provide more support for structured drawing but, in general, we have found that this simple interface has been the best one.

3.2.2.3 Extended Whiteboards and ZenViewer

The LiveBoard is a large display, but it is about one-quarter the width of a traditional classroom whiteboard. Initial use suggested that whereas a LiveBoard is great for small meeting presentations, it was just too small for a classroom. We extended the size of our electronic whiteboard by using two additional computers with their displays projected next to the LiveBoard. When used with ZenPad, this gives the illusion that the electronic whiteboard is really the size of three LiveBoards instead of just one. The extended displays can also be used to display Web pages.

These extended display machines run a Java Applet called ZenViewer that allows viewing of the current or previous slides written on a whiteboard running ZenPad. The

applet displays the slides and the ink written on them in real-time. ZenViewer (shown in Figure 3-4) can be run from anywhere on the Internet and has the ability to display just the current, previous slide, or an overview of many previous slides.

Figure 3-4: ZenViewer running as an extended whiteboard showing the previously visited slide (the screen not being pointed to). Another commonly used configuration of ZenViewer shows the previous four slides tiled in the display.

3.2.2.4 Capturing Visited Web Pages

Since it is difficult to take traditional notes when viewing Web pages, we capture the URLs visited and integrate them with the slides written so that students can revisit them again after class. Originally, we tried to modify existing Web browsers in a Macintosh environment to save their access histories. Now, we can use any commercial browser on any operating system to do this by having the Web browser go though a proxy server (discussed later) which then relays the URLs back to our eClass database where it is integrated with the presented slides and ink.

3.2.2.5 Audio / Video Recording and ZenStarter

Our main classroom employs one video camera, used to capture a low quality video of the instructor and all of the projected displays.   We used six individually adjustable ceiling mounted mini microphones used to record the audio of the instructor and the students. Our second classroom does not record video, but records audio through the use of two microphones mounted in the front and rear of the classroom.   These microphones do a fair job of recording the instructor and students, but we occasionally need higher quality recordings of the professors to generate voice transcripts, used for later searching. For this reason, the instructor has the option of wearing a wireless lapel microphone.   Some instructors prefer to use the wireless microphone just for the increased audio quality alone.

All of these audio and video signals are sent to a computer that encodes the video and audio using RealVideo and RealAudio. Our audio/video medium choice allows us to provide audio and video to students over slower modem connections.

Although using the commercial RealEncoder allows us to easily generate streamable content, the instructor still needs to start and stop this program. To alleviate this problem, we wrote ZenStarter, a general-purpose program that can start and stop other programs (with optional parameters) based on a ZenPad session.   When the instructor starts a class by running ZenPad, all relevant ZenStarters will start any programs that need to run. We have also used ZenStarter to automatically start and stop ZenViewers and turn on the projector for the computer display, but we have not implemented this for everyday use.

3.2.2.6 Ending a Lecture - StreamWeaver

After class, the instructor exits ZenPad and leaves the room. All of the captured data is sent to a central server where it is processed and woven together, using a Java program we have written called StreamWeaver to merge together time-stamped streams of information into classroom notes in the form of HTML documents. These notes (see Figure 1-3) consisted of each slide that was written in class along with a timeline that shows the order in which slides and Web pages were visited. By clicking on a stroke, a RealPlayer is spawned which plays the audio at the time the ink was written. Clicking on the timeline also indexes into the audio at the appropriate point. One minute after class, a syllabus of all the lectures for that class is automatically updated, and the captured notes are automatically made available.

3.2.2.7 Access – From Perl to StreamWeaver to Dynamic Notes

Originally, when we were using ClassPad, the lecturer and student slides were converted into a series of HTML pages (see Figure 3-5). This interface was generated by a series of Perl scripts operating on the annotated slides downloaded from the Liveboard and student units. The top frame provided thumbnail images of all slides for that lecture. The user selected one thumbnail image, and the full-sized image appeared in the lower right frame. The lower left frame contains a list of keywords associated with the slide, the automatically generated audio links representing each time the slide was visited during the lecture, and a link to a form that allows keyword searching across all slides for the entire course. Clicking on an audio link launched our own external streaming audio player at that point in the lecture.

Figure 3-5: The original captured lecture notes interface, a frame-based Web presentation of lecture notes with annotations and audio links.

None of the machines used in the ClassPad prototype were networked, which meant there was as very high overhead both before and after lectures to upload and download materials (about 4 person-hours per lecture).

With ZenPad, we stopped supporting student note taking devices and used network computers to reduce the manual effort of generating an access interface. Additionally, we started using our capture tool as an access tool, thinking that this would allow for a richer access experience. The browse-only interface ZenPad provided (shown in Figure 3-6) allowed students to access and replay lectures.
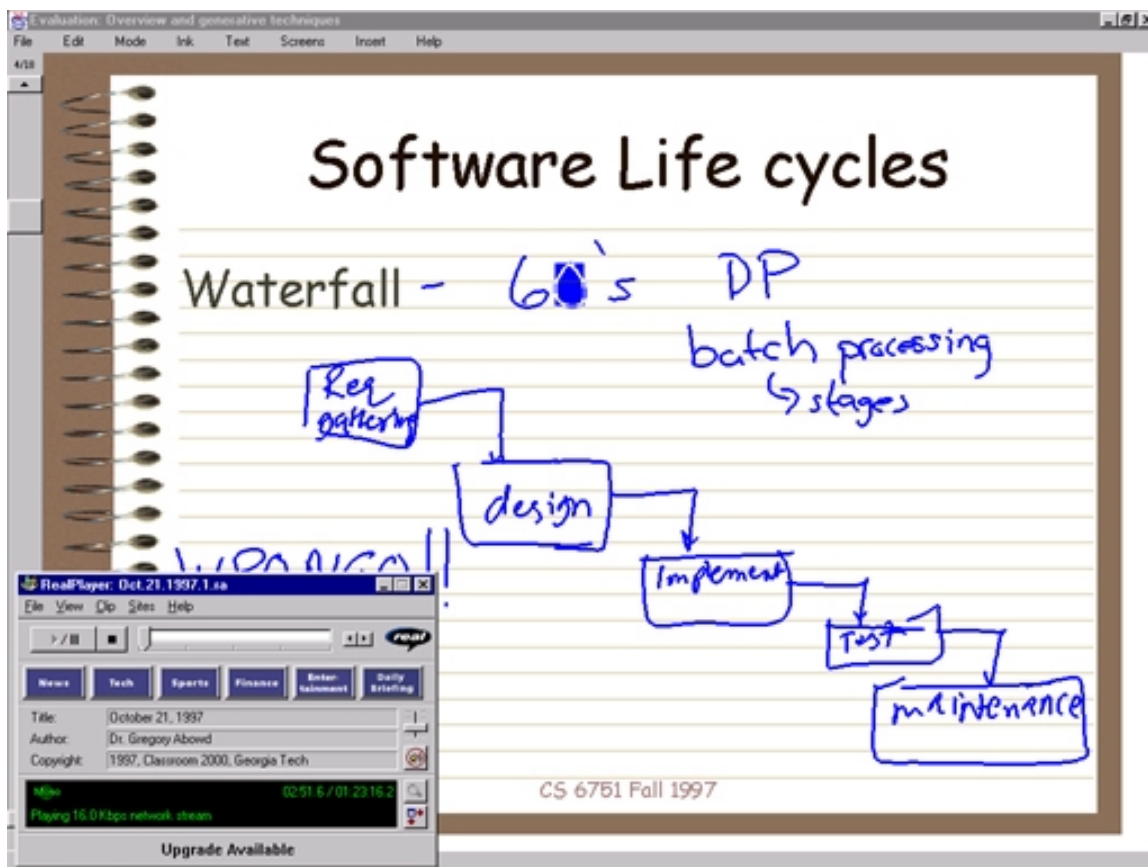
Figure 3-6: ZenPad's browse-only mode. Moving the cursor over ink causes the ink to highlight, and clicking on the ink opens up a RealPlayer window to stream audio. Users could navigate through the slides by moving the scrollbar on the left.

We had to abandon this dynamic interface in favor of static, more constrained HTML documents because at the time, most browsers were not capable of running Java programs robustly and we were running into significant protests from both teachers and students. A small C program was quickly hacked together by a user of the system to read in our ZenPad files and create a set of HTML notes. These notes, shown in Figure 3-7, placed the slides end to end in one scrollable pane. Additionally, navigation bars were placed at the top of each slide. These bars highlighted when in the lecture a slide was shown, and when during the time the slide was being show, ink was being written.

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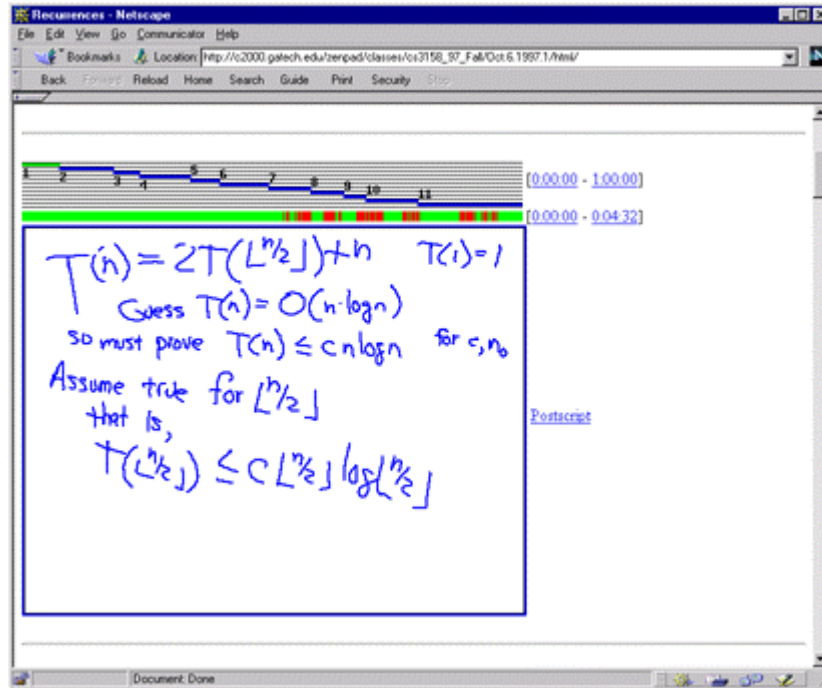
Figure 3-7: Our second attempt at generating HTML notes. This interface placed the slides end to end and provided for the playback of audio by clicking on the ink. Additionally, navigation bars adorned each slide. These bars showed where in the lecture this slide was shown and at what points during the time that slide was show when ink was being written.

Figure 3-8 shows the navigation bar in more detail. The top portion of the navigation bar shows a line for each slide in the presentation. As time progress from left to right, we can see the relative time spent during the lecture on each slide by looking at the horizontal bars. The slide being show is highlighted in green. Below the slide bars is another bar, showing when ink was written. Again, time moves from left to right, and the regions marked in red show ink activity. In this example, some ink was written when the slide was first shown, and then nothing was written for almost half of the slide's exposure before more writing occurred.
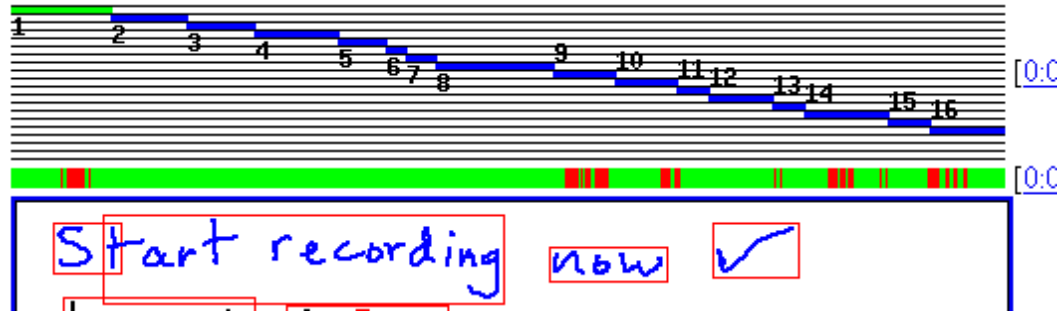
Figure 3-8: Zoom-in of a typical navigation bar.

This interface, later dubbed the "toilet roll interface" turned out to be very popular among students because it was viewable on virtually any HTML browser. Additionally, since we were now streaming audio using RealAudio, students did not have to install our cumbersome audio streaming program which only worked on Unix workstations running SunOs.

From these beginnings, StreamWeaver was written as a Java program to generate enhanced HTML documents of the integrated classroom activities. StreamWeaver was designed to be run automatically at the completion of a lecture so that HTML notes could be generated without manual effort.

Through StreamWeaver, we have also produced a number of HTML interfaces. In all interfaces, there is the ability to jump from the displayed lecture material to the audio/video for that lecture. Different prototypes provided different indexing capabilities. For example, earlier interfaces only allowed the student to index into the audio at time points defined by when slides were visited. Other interfaces were built which allowed indexing down to every pen stroke.

Although StreamWeaver made our on-line notes accessible to virtually everyone, it blurred the line between the integration and access phases making enhancements to the program difficult. For example, if StreamWeaver was enhanced to create a better HTML interface, it would have to again be run on all previous lectures to generate the new HTML code.

As the project matured, we modified StreamWeaver to populate a MySQL database and then used PHP scripts (a Web-based scripting language) to dynamically create the access interfaces for the students (recall Figure 1-3).

Having all of the captured materials stored in a database with a dynamically generated interface allowed us to make many enhancements to the on-line notes. Instructors were now able to add comments to their lectures after the fact, perhaps clarifying a complicated topic. We were able to custom configure browsing interfaces tailored to the student's request, and we were able to generate searchable notes for the first time.
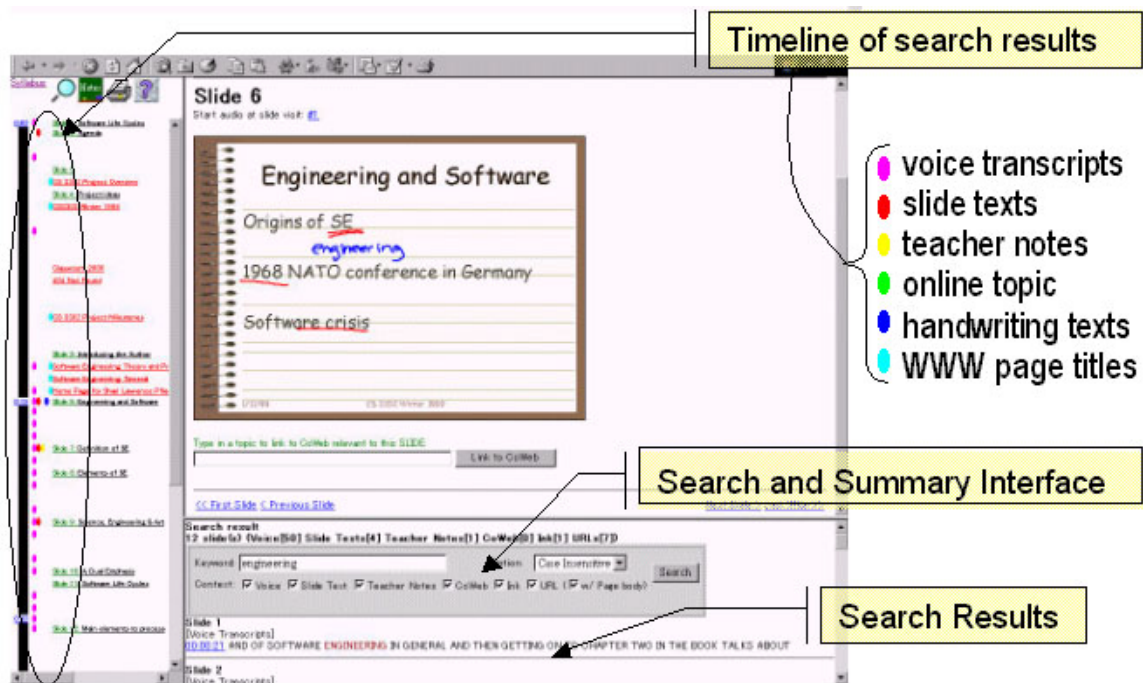
Figure 3-9: Searchable notes interface. The timeline on the left is decorated with color-coded search results. The bottom panel is where keywords are typed and search results are summarized.

Students were able to search the on-line notes by specifying a keyword to find (see Figure 3-9). The data that could be searched depended on the course, but we were able to support the searching of a keyword over what a slide contained, what was written, what was spoken, Web pages, instructor notes, and collaborative Web pages for a course. We were able to generate the searchable content automatically, except for handwriting and speech transcriptions.

Searching over handwriting required that the instructor manually transcribe her writing. In practice, this only took a few minutes per lecture, but only a few instructors bothered to do it. We experimented with automated handwriting recognizers, but they were unable to produce any usable output.

Voice transcription was done using a commercial recognizer trained to one of two instructors. We were able to achieve around 80% word accuracy, which turned out to be sufficient for searching over the audio. The recognizers required that the instructor wear a wireless microphone and much manual effort, so we eventually stopped supporting this feature.
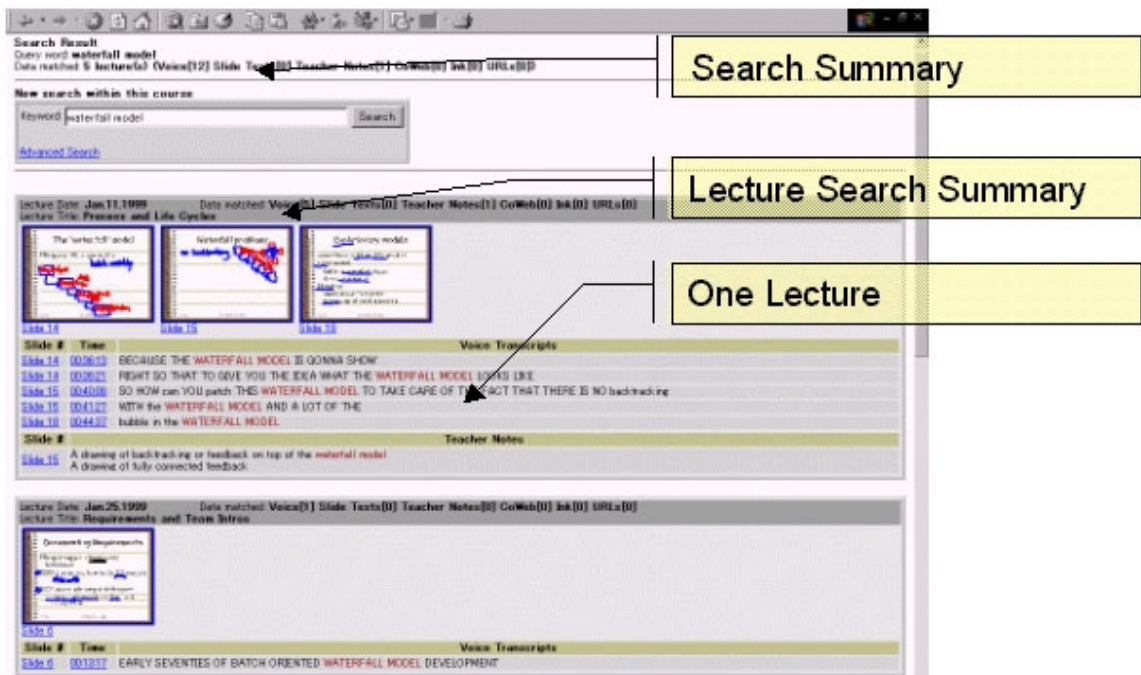
Figure 3-10: Advanced search interface showing search results over an entire course. Each lecture is summarized and all results are shown at once.

In addition to searching a particular lecture, students could also search over an entire course. This interface, shown in Figure 3-10, highlights matched results for each lecture in a condensed summary format.

Moving to a database and dynamically generated notes allowed us to do more than just provide searchable notes, it provided us with the opportunity to create student-

editable notes. Our first attempt at creating editable notes was with the ClassPad interface using JavaScript and Perl scripts. This interface, shown in Figure 3-11 enabled students to annotate the captured slides with private notes. These notes were typed in as plain text, and could contain hyperlinks to slides and audio segments.
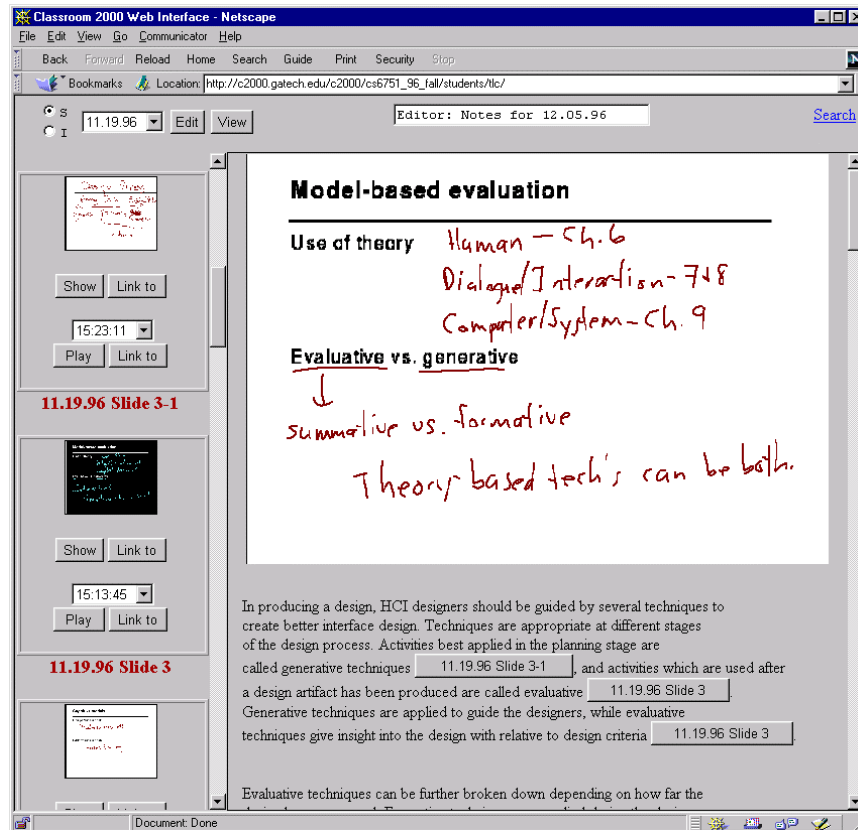
Figure 3-11: ClassPad's editable notes interface. Notes could be annotated and saved (the input area is just out of sight in the figure) along with links to specific points in the audio or to specific slides.

Unfortunately, the scripting technology utilized was once again highly browser-dependant and we found that a large majority of the students could not use this interface, so it was abandoned. Our second attempt at integrating student notes (shown in Figure 3-12) with the captured slides occurred after we implemented the database interface.

This time, we decided to leverage off of an existing student annotation system developed by Mark Guzdial [36]. Collaborative Websites, or CoWebs., are basically a set of world-editable Web pages. Users do not have to be familiar with HTML to create and edit CoWeb pages, although copy and pasting skills are helpful for generating links between the two interfaces.
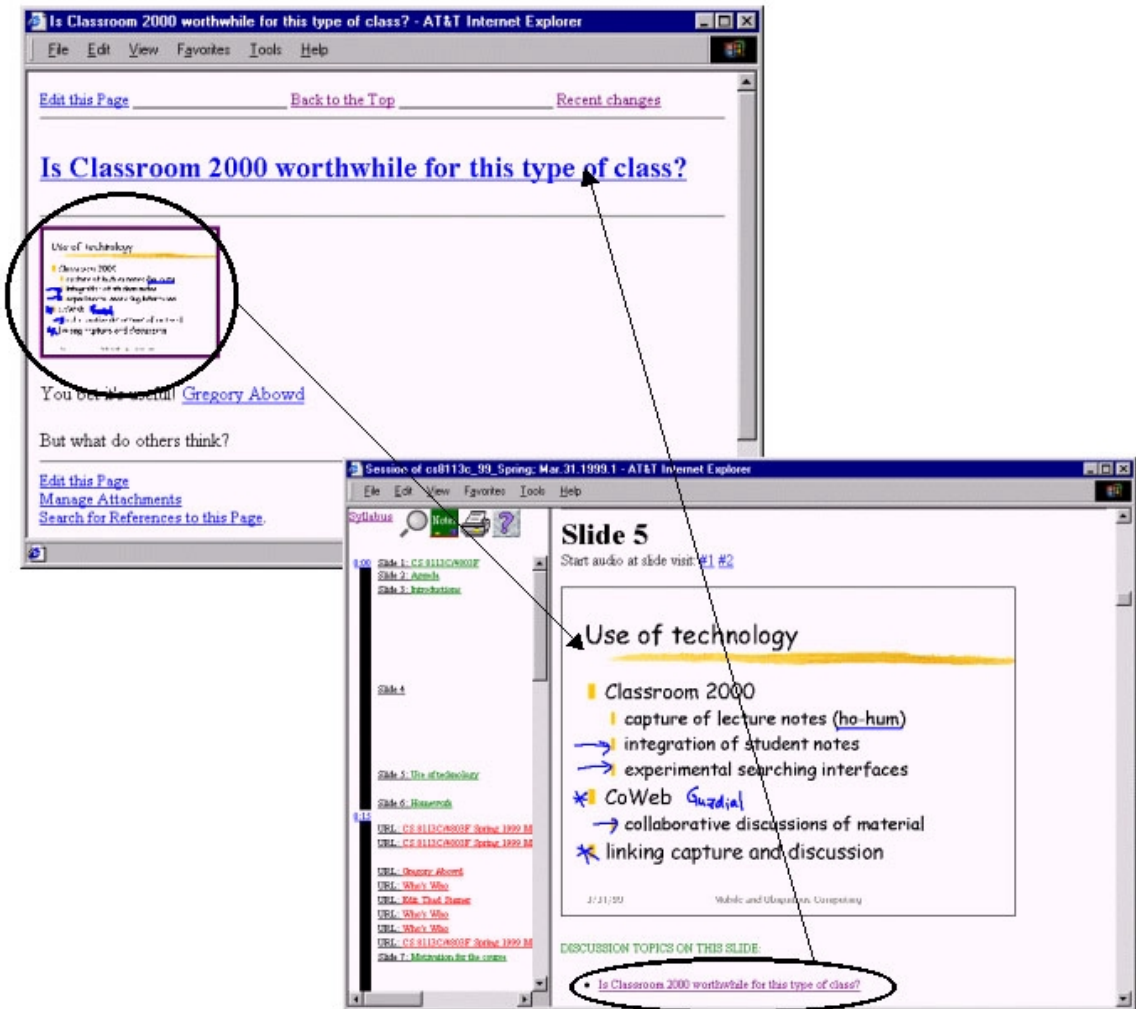
Figure 3-12: Linking of eClass notes and CoWeb pages. The bottom frame contains a hyperlink which takes the user to a CoWeb page. The CoWeb page in turn can contain thumbnail links to every slide captured with eClass.

3.2.2.8 Behind the Scenes – The Servers

All of the programs described above only tell half of the story. Behind the scenes, we have several servers running to enable all the eClass components to work together. The servers, together with the client software comprise the Zen* system diagram shown in Figure 3-13.
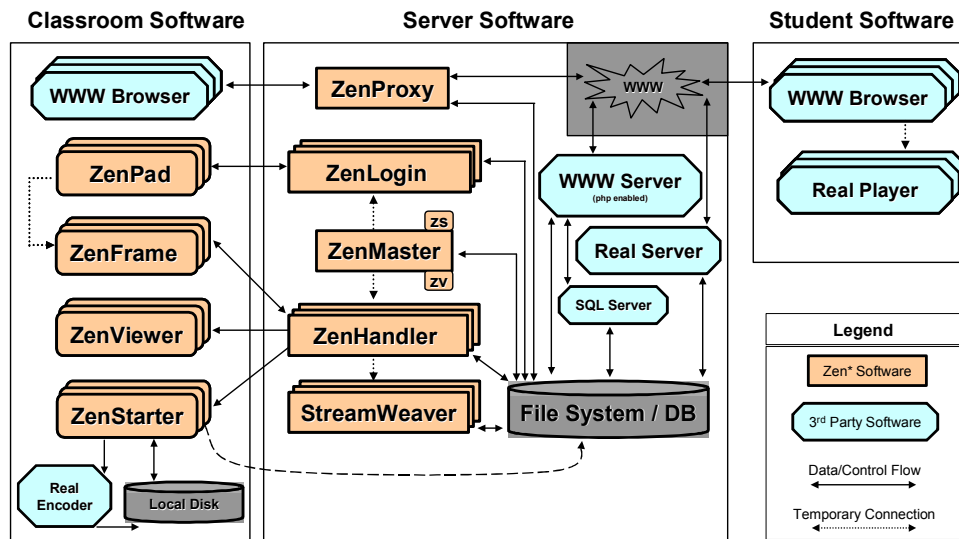
Figure 3-13: The complete Zen* system that comprises eClass.

eClass relies on the use of several third party servers to help store and retrieve information. We use an Apache Server (Apache Software Foundation) as our Web server, a Real Server (Real Networks) to stream video and audio, and a MySQL Server (Open Source) as our database server. Once these three commercial servers are running, we then run our two servers, ZenMaster and ZenProxy.

The heart of our system is the ZenMaster server, a multi-threaded Java program that runs on the system server machine. Classroom sessions are initiated through

ZenPad, invoked either as a stand-alone program or through a Web browser in the classroom. Multiple classrooms can run ZenPad clients simultaneously.

Each ZenPad client goes through the ZenMaster server and establishes a connection with a ZenLogin server module. This module handles all of the pre-production tasks such as user authentication, lecture creation, and slide imports.

Recall that the classroom uses ZenViewers to display previous slides and ZenStarters to automatically record audio and video. These programs connect to ZenMaster and essentially announce their presence by specifying the IP address of any ZenPad machines they want to monitor. ZenMaster stores these requests in a global address space.

Once a lecture is ready to begin, ZenPad launches ZenFrame (shown in Figure 3-3) that again connects to the ZenMaster server and then instantiates a connection to a ZenHandler server module. ZenFrame sends to this module all of the ink and slide navigation events from the instructor. Meanwhile ZenHandler also establishes connections to any ZenViewers and ZenStarters that have been started for the room in which ZenFrame is running. ZenViewers receive all of the ink and navigation events of ZenFrame through ZenHandler and therefore acts as an extended display showing the current ZenFrame screen, the previous screen, or an overview of screens, updated in real time. ZenHandler tells ZenStarter that a class has started and ZenStarter runs the RealEncoder program that begins encoding audio and video for the class. As the class is proceeding, ZenHandler is saving all of the captured lecture material to the server disk.

The other server, ZenProxy, is a simple Web proxy that records all Web pages visited by browsers configured to go through the proxy. When the class is over,

ZenStarter sends the encoded audio and video files to the server disk while ZenProxy sends all of the URLs visited to the server disk. ZenHandler then invokes StreamWeaver, which takes the time-stamped streams of information and creates Web-accessible artifacts by generating GIF and JPEG images of the slides with ink transposed on them and placing all of the data into the system database.

The entire post-production process takes about one minute to complete. After the class, students can access the captured lecture materials by using their Web browsers with streaming audio capabilities to access PHP scripts that in turn query the database for classroom information and data.

The storage requirements for our capture are relatively modest. Media dominates our per-lecture storage costs since we capture two media files per lecture, one audio-only file and one audio and video file. Depending on the lecture, storage of Zen* files typically amount from 20KB to 200KB per lecture. The media files are usually 3-5MB for audio and 5-7MB for audio and video.

3.2.2.9 Summary

All in all, there is nothing remarkable about the tools that eClass uses, but the way that we integrate them enables us to build a complex note-taking system. Table 3-1 highlights all of the eClass components and the phases in which they are used.

Table 3-1: Summary of eClass components and the phases they support. Software we created is listed in a bold font and third party software is listed in italics.

		Pre-Production	Live Capture	Integration	Access
Client		**Transfermation**	**ZenPad** **ZenViewer** **ZenStarter** *WWW Browser* *RealEncoder*		*WWW Browser*
Server		**ZenMaster**	**ZenMaster** **ZenProxy**	**StreamWeaver** *MySQL Server*	**PHP Scripts** *WWW Server* *Real Server* *MySQL Server*

From a hardware point of view, there is no "standard" eClass setup. We have had several installations at Georgia Tech, Georgia State, Kennesaw State University, McGill University, and Brown University, and no two installations utilize the same equipment. We view a typical installation instead as the minimal services that the room can provide and the hardware needed to provide them. How this is actually accomplished may be through several different hardware configurations using different products and infrastructures. For example, one computer could control all the services for an entire classroom, or there could be multiple computers for each service. We are not investigating the impact of the choice of technology used in providing these services (configuration-wise or by determining the impact of using alternative electronic whiteboards such as a SmartBoard instead of a Liveboard), although it may considered for future work. The important thing is that the captured notes are independent of the physical equipment used in the classroom.

3.3   Applying the System in an Educational Setting for Authentic Use

The eClass project has been a living research project, supporting classes since September 1996. The demands of supporting real live classes over the past few years

have been great, but in doing so, we have been able to collect data on a scale not previously attained. We have recorded 97 courses with 2,351 lectures and 20 meeting groups with 411 meetings. It has been in use continuously, supporting undergraduate and graduate classes in the College of Computing. Because of the age of the project, we have minimized the "wow" effect that one might expect from the introduction of the technology in the classroom. Because of the age of the project and our live lecture environment, we have achieved authentic use of the system. Students have begun to rely on eClass and often demand that their professors use it. Teachers have also expressed the desire to have more eClass-equipped rooms. In short, we have a living, working, established system in place on which we are able to do authentic evaluation.

3.3.1 How Installations at Other Institutions Vary

Other eClass installations have varied in the type of equipment and the number of computers and platforms used. In all installations, the Zen* software infrastructure remains the same, aside from a few configuration files. eClass installations can vary based on a number of equipment choices. These installations are summarized in Table 3-2.

The Type and Operating System of the Server Machine

At Georgia Tech, the server for the College of Computing (CoC) operates on a Sun Systems machine running Solaris. Kennesaw State University (KSU) and Brown University (Brown) have similar setups, but McGill Univeristy (McGill) is running their server on a PC running Microsoft NT.

The Type of Electronic Whiteboard Used

The type of electronic whiteboard used varies by university and by rooms within a university. Typically, an electronic whiteboard requires a PC running Windows for it to function. Rooms in the CoC use Liveboards, rear- and front-projected SmartBoards, and a Mimio extended whiteboard. KSU uses a non-project SmartBoard. McGill and Brown have very large rooms making any electronic whiteboard too small to be useful. Our solution is to have the instructor write on a small pen tablet computer that is then projected on a very large screen.

The Type and Number, and Mode of Extended Whiteboards

The kind of extended whiteboards and the number of them can vary by room. Typically, an extended whiteboard consists of a computer and a projector. The computer runs a Web browser and through the ZenViewer applet, shows based on the mode, either the current or previously visited slides. In the CoC, there are two computers with two projectors. If both viewers are used, then one viewer shows the previous slide, and the second typically shows a grid of the last four slides visited. If only one viewer is used, it typically shows the previous four slides. McGill and ECE do not use an extended whiteboard. KSU uses a laptop computer to show the previous slides. Brown uses a PC to show the previous four slides.

The Encoding Machine

Whether or not audio and video is captured depends on the room. The CoC has a room with a dedicated computer encoding video while the primary ZenViewer machine simultaneously encodes the audio. Both machine encode in Real Audio format. KSU, McGill, and Brown use the computer that is driving the electronic whiteboard as the

encoding machine and they all encode audio using Real Audio, except McGill, which instead encodes to a Microsoft streaming format.

Web Page Capture

Currently, only machines in the CoC capture Web page URLs. All Web browsers in the classroom are configured to go through a Web proxy we've built which saves the URLs visited. The secondary ZenViewer machine is used as the primary Web surfing machine, although occasionally the electronic whiteboard will be utilized instead.

Database Access

Currently, only CoC is using the database version of eClass. This is the only software difference between the eClass installations.

Table 3-2: Summary of differences in installation of eClass systems.

Installation	Server Machine	Electronic Whiteboard	Extended Whiteboards	Encoding Machine	Web?	DB?
CoC (102)		Liveboard	PC (x2)	PC / Real (x2)		
CoC (101)	Sun/Solaris	Liveboard	PC	PC / Real	Yes	Yes
CoC (381)		Smartboard, Mimio (both front projected)	None	PC / Real		
KSU	Sun/Solaris	Non-projected SmartBoard	Laptop	WB PC / Real	No	No
Brown	Sun/Solaris	Pen Tablet w/PC	PC	WB PC / Real	No	No
McGill	PC/NT	Pen Tablet w/PC	None	? / MS	No	No

3.4   Meeting the Requirements

We begin this chapter with a listing of requirements for building capture and access applications in the classroom. We now revisit these requirements to show that eClass has met them.

It is important that all students have access to the captured materials. For the first prototype of eClass, manual effort was needed to create Web pages for students to access.

When eClass was first built, we tried to make the access more powerful by having them accessed through a Java applet instead of HTML. The access was more powerful, but the requirement of running Java was too great at the time (1997). Our system only ran on the Netscape browser, and the most current version needed to be installed. Getting Java to run on this early version of Netscape was also a non-trivial task, and as a result most students failed at accessing the notes.

We then came to realize that the HTML access interface, although less powerful, was more useful, and much more accessible. This lesson learned also applied to our choice of recording medium. Initially, we were using our own stream media format, but it only ran on Sun machines, and was difficult to install. With the creation of third-party streaming media players, such as Real Audio, we were able to once again reach more students with less effort. Finally, we chose to encode the video at a much lower fidelity than we could have so that student accessing the notes through a modem would still be able to view it.

Catering to the lowest common denominator has been a significant challenge, but one that we feel has enabled our system to be used by many people. By using less sophisticated but more reliable technology, we've had to struggle to build in the functionality we wanted. In some cases, it would have been easier to go with a more sophisticated technology, but we have resisted the temptation out of concern that all students have equal access to the captured lecture notes.

Through much manual effort, we feel that we have achieved everyday use of the system. It has been running for four years and student questionnaires reveal that they do use and depend on it. We have tried to automate as much as possible the process—

motivated solely by the fact that we were the ones doing all of the manual effort. Once we achieve a certain level of automation, and a certain level of expertise among our instructors, we were able to essentially sit back and let the system run itself.

One way we were able to increase use was by making the system as "walk up and use" as possible, while still retaining some level of security. (We didn't want non-instructors using the system.) Figure 3-14 shows the initial ZenPad login screen. All an instructor has to do before starting a class is type in their username and password and click on the 'Begin Lecture' button. Previously, users had to explicitly log in and create a class for their course before they could start recording the lecture. Figure 3-15 shows this complicated, but powerful interface. From this screen users could create courses, lectures, upload materials, and start recording a class, which would then launch the ZenPad whiteboard interface. The extra functionality proved to be to complicated for most of our users who wanted to simply walk in and start writing on the board.

Figure 3-14: Initial ZenPad screen showing the automated course prediction. If the instructor had previously uploaded slide using Transfermation, then the *title* field would already be filled.

Figure 3-15: ZenPad's expert interface, not for the first-time user.

We feel that we have built a fairly unobtrusive classroom. eClass looks like regular classroom, not a studio production environment. The use of small microphones embedded in the ceiling combined with small static cameras in the back of the room does not create a video production presence. Through the use of automation, the instructor doesn't have to do much to teach in the classroom—just specify who he is and a title for the lecture. We could have done better, though. There are occasional failures in the technology, and sometimes these failures result in a significant degradation of the lecture.

By separating capture from access, and by further separating the three phases of capture (pre-production, post-production) we have been able to significantly evolve the system over time. As discussed above, we have been able to build in automation into the system where previously there was none. We have also been able to add new features as students requested them, and then we have even re-designed and re-implemented these features once we had a better understanding of how to use them. For example, Web logging was a desired feature and we first implemented it by running a modified Web browser that only ran on a Macintosh. Once we realized the need to capture browsing activity from many different locations, we then modified this system so that any Web browser on any platform could have its browsing activity captured.

We initially stored all of our data in an inflexible and constrained file system. When we realized we needed more flexibility with our data, we were able to convert to a database storage system with minimal effort. This allowed us to create dynamic HTML interfaces on the fly whereas before we only could create static HTML pages. The system as it stands today is radically different from our first prototype, but we were able to evolve it over time while using it.

Finally, we have been able to do deep amounts of evaluation on eClass. By using student questionnaires we were able to get anonymous, frank feedback about the system. Instrumenting our interface to query students and to provide an access record has allowed us to understand how our system is used, and how we can provide a better service. The modular nature of the system has allowed us to install it at several institutions, providing us with more evaluation data with minimal effort on our part.

In conclusion, eClass is a system that allows universal access to materials and has become everyday. It is fairly unobtrusive system, and we have shown how we have been able to evolve it over time in a living environment. It has also allowed us to evaluate the impact of technology in the classroom on a level that has not yet been possible. In the next chapter, we discuss how we did this evaluation and the questions we want to answer.

CHAPTER IV

EVALUATION GOALS AND METHOD

As stated earlier, by building and using eClass we wanted to understand capture and access in the classroom domain so that we could generalize our findings to other domains. We had two main objectives for our evaluation:

- understanding the generalizations of capture and access

- understanding the impact of eClass on the classroom experience, students, and instructors

We could meet some of these goals by experience, and others by evaluation. In this chapter, we first examine some of our evaluation goals that could be answered by using our system over a longitudinal study, and then detail the specifics of the goals that we could only achieve through more empirical evaluation techniques. We conclude this chapter with a listing of the actual data collected and the methods used to collect it over the course of our research. In the next chapter, we detail the results of our evaluations and our lessons learned from experience using the system.

To understand the generalizations of capture and access, we first need to understand how eClass was used and evolved over time. These lessons learned benefit future ubicomp researchers by helping them to avoid the pitfalls we've encountered. We also need to determine the requirements for capture and access, both in the classroom and other domains, and to determine what infrastructure and devices are needed to support varying levels of capture and access. Additionally, an understanding of the equipment and roles people needed to fulfill enables us to provide a complete picture on what is

required to build a capture and access system. We wanted to identify the challenges the ubicomp model brings not related to research and look at different techniques for viewing large repositories of captured materials.

In understanding the impact of eClass on the classroom, we had many questions to answer. First, we wanted to determine for which classes is the technology appropriate and for which classes the technology fails. Next we needed to determine if the online notes of eClass were useful and how they were actually used, including why and when they were accessed and from where, and for what reasons.   This involves understanding which note augmentations were perceived as useful and which were not.

To understand the impact of eClass on the students, we wanted to be able to determine if the students like the technology and if they find it useful. We need to determine if eClass provides students with advantages that traditional classrooms do not as well as understand what disadvantages eClass brings.   Since eClass takes notes for students, understanding how the system effects their note taking style is important because we want to encourage better note taking.   We are also interested in how eClass impacts the in-class experience for the students. For example, does eClass encourage students to skip class? Do students worry about their voices being recorded, and hence, ask fewer questions? Does it help them learn or achieve better grades? And finally, we wanted to determine how the students actually use the online notes in their study practices.

To understand the impact on the instructors, we wanted to look at which lecturing styles were best supported by the technology. This includes looking at the lecture materials presented in class and how they are presented. We wanted to see if instructors

liked the technology, determine if they felt that they could teach more effectively, and see how intrusive the technology was to the instructors.

Through building, using, and evolving eClass over a long period of time, we have come to understand how the system has evolved and general capture and access issues. These contributions are detailed in chapters 3 and 6. However, to understand the impact of eClass on the students, the instructors, and in general, the classroom experience, we needed to do more than simply use the system, we needed an evaluation plan.

Our methods for understanding the impact of eClass on the classroom, students, and instructors include distributing and then analyzing student and instructor questionnaires, studying online note access logs and doing classroom observations. Additionally, we performed two laboratory-like experiments to help answers to questions we couldn't answer from the evaluation data we had already collected.

4.1 Summary of Use

We started authentically using ClassPad to capture classes at Georgia Tech in January 1996. During the next year, driven by feedback from users, we rebuilt the system into a much more automated capture system. One year later, in the Spring 1997 term, we started using the new system, Zen*, which has been in use since. Our observation period officially ended after the completion of the Spring 2000 term, for a total of 13 semesters. During that time, we captured all or partial lectures from 98 academic courses (75 unique courses) consisting of 2,335 lectures, taught by 35 different instructors in two different classrooms. The system was also occasionally used to capture both our meetings and other research groups' meetings (at Tech) during several terms. In

total, we have captured 20 of these 'meeting courses' from 12 different research groups for a total of 738 meetings.

In addition to Georgia Tech, other researchers and instructors have installed and used eClass at other universities. At Kennesaw State University, it was used for four semesters (Winter 1998, Spring 1998, Fall 1998, and Spring 1999) to teach eight courses. At Brown University, it was used to teach one course in the Fall 1999 semester and was slated to be used again to teach two more courses in the Fall 2000 semester. McGill University used the system in the Spring 1999 semester to teach four courses and is currently integrating the system with their own research efforts. Additional universities (Georgia State University, Georgia Perimeter College, Sao Paolo at Sao Carlos) are currently using or installing eClass, but we do not have any plans for collecting data from these sites.

From the Spring 1997 semester through Spring 2000, we have identified 59,796 anonymous accesses to the lectures captured by the system (including other universities). This is a conservative estimate of the number of actual study sessions because we only are only counting accesses for which we were able to determine a complete study session. The actual count of "Web hits" is much larger with over 200,000 accesses.

4.2   Summary of Data Collected

Since its initial incarnation, we have collected many different data sources on the use and impact of eClass. Although the bulk of our evaluation comes from observing how students access and use the captured lecture material, it is not our only source of information. We employed four different methods for obtaining information about what material students were accessing, how they were accessing it, when they were accessing

it, and why and where they were accessing it. These methods included Web-log analysis with session tracking, questionnaires, controlled experiments, and classroom observations.

4.2.1 Web-Logging with Session Tracking

Our initial analysis plan for eClass use was to examine Web server logs. Because the on-line notes are Web-based, we were able to look at the logs and perform coarse usage studies. We have collected the Web logs from courses taught at Georgia Tech, Kennesaw State University, Brown University, and McGill University. Although useful, it quickly became apparent that the Web server logs alone were not enough to provide a useful detailed analysis of how the system was being used. It was tedious and sometimes impossible to determine individual student access session; the pages they visited, the amount of time spent studying, and the number of audio/video links they clicked. Additionally, the Web logs alone did not provide any reliable data on audio and video usage. For example, just because the Web logs indicated a user tried to play a video clip, it does not mean that the user was successful in playing it. To obtain that information, we needed to merge the Web logs with the logs of the server responsible for delivering the audio and video (in our system, Real Server).

To compensate for these difficulties, we attempted to isolate different users of the system and analyze their on-line note accessing patterns. For only one course (a class on Software Engineering taught in Spring '98), we used simple Web user-authentication to uniquely identify by person each page hit in the Web server logs. This gave us a complete record of user accesses and study patterns, but it came at the expense of student privacy. Although there was no significant dissent from the students after a quarter of

use, we felt the lack of anonymity was counter to the spirit of education and was neither feasible nor ethical to implement on a college- or university-wide scale.

When we tried to examine the Web server logs to determine student study sessions, we found that the sheer volume of data recorded was prohibitive in doing any kind of useful analysis by hand. Also, we weren't able to mechanically extract the information because of the non-uniqueness of the URLs visited in our HTML notes interface. For example, finding when a student began a study session is non-trivial because of the many ways a study session can be initiated, and the many non-unique URLs associated with starting a session. Finally, the Web server logs weren't sufficient because although they log when a user *visits* a page, they don't log when the user *exits* a page. In order to determine events such as when a user stopped playing a media file or when they finished their study session we needed to find a way to explicitly log that information.

To collect detailed logs about the study sessions for students and how they were using the system, the HTML captured notes interface needed to be modified. Using JavaScript and frames, a hidden "status window" was created. Wherever a significant event occurred, such as a user clicking on some ink to play an associated media clip, the interface was modified. It was changed so that in addition to doing what the interface normally did (in this case, playing the video at the time the ink was written), the interface would also load a document into a hidden status window. The document URL was named such that by looking at the logs from the Web server, we could tell what the user just did (in our example, a document named inkClick.html was loaded into the status window). In this way, we could create a "cookie crumb" trail of user-initiated events and

actions. Table 4-1 shows the complete listing of events that we captured along with their corresponding HTML file.

To aid in the logging, we embedded (via parameters) the URLs listed in Table 4-1 with the course and lecture that the student was viewing. We also know because of the Web server logs what time the access was made and from what IP address. Finally, to play back Real media files, we created two CGI-scripts (Ramgen for audio, Rmgen for video) that generate an appropriate call to the Real server. Also embedded into the URL for the CGI call is the media file and the time offset into the file.

Table 4-1: Logging files used and the corresponding event that a Web log entry indicates occurred.

HTML File (URL)	Event Description
StartLecture.html	User begins viewing captured notes for a specific lecture.
EndLecture.html	User exits the notes and goes to another non-lecture specific URL.
Help.html	User clicks on the help icon.
InkClick.html	User clicks on the instructor's handwritten ink to play audio/video at that time.
SlideClick.html	User jumps to a slide by clicking on the slide link on the timeline.
SlideMediaClick.html	User plays audio/video at the time the slide was visited.
TimeLineClick.html	User plays audio/video by clicking on a continuous timeline.
StopMedia.html	Users stops playing audio/video.
WebClick.html	User visits a web page visited during class.
Rmgen / Ramgen	Called indirectly whenever a user wishes to play audio/video.

In addition to these logs, we also have available for examination the system logs from our main server, ZenMaster. The ZenMaster logs can be used to determine how often the system failed and what caused the failure. All other information in the ZenMaster logs is redundant. Table 4-2 shows a summary of all the server logs collected.

Table 4-2: Summary of logs collected. A "-" indicated we have no logs for that type. An "*" indicates that we don't have Real Server logs, but we have custom logs which contain similar data.

School – Term	Log Type		
	Web Server	Real Server	ZenMaster
GA Tech – Fall 1997	-	*	-
GA Tech – Spring 1998	Yes	*	-
GA Tech – Fall 1998	Yes	Yes	Yes
GA Tech – Winter 1999	Yes	Yes	Yes
GA Tech – Spring 1999	Yes	Yes	Yes
GA Tech – Fall 1999	Yes	Yes	
GA Tech – Spring 2000	Yes	Yes	Yes
KSU – Fall 1998	Yes	-	-
KSU – Spring 1998	Yes	-	-
KSU – Spring 1999	Yes	Yes	Yes
Brown – Fall 1999	Yes	Yes	Yes
McGill – Fall 1999	Yes	Yes	Yes

4.2.2 Questionnaires

The server logs gave us plenty of quantitative measurements, but we also wanted to obtain input from the students and teachers using the system. To help obtain perspective, we collected answers from six different questionnaires distributed at various times through the lifetime of the project. The questionnaires, explained bellow, consisted of five different student questionnaires and one questionnaire for the teachers.

Usage surveys. During the first two years of use, whenever a student tried to view the on-line captured notes, they would be asked (only once per study session) to fill out a small survey asking why they were viewing the notes. Default options included reviewing a class that was attended, reviewing a class that was missed, studying for a test, and getting help with a project or homework and curiosity. The students could supply their own reason as well.

We have collected data from these surveys for classes at Georgia Tech during Fall '97, Spring '98, and Fall '98 quarters. During these quarters, answering the survey was mandatory before the captured notes could be viewed. We also have data from this

survey for Winter '99 and Spring '99 quarters at Georgia Tech, but students were not required to answer these surveys before viewing the notes. A total of 12,924 responses were logged, but because students were never required to answer any questions and instead given the option of merely skipping the survey, 4,866 of the entries do not indicate a reason for visiting the notes – leaving us with 8,058 valid responses.

End of semester survey. At the end of each quarter, all students were asked to fill out (anonymously if desired) a questionnaire on their use of the system. Comments were solicited on what features of eClass they found particularly useful or distracting. We have data from this questionnaire for classes from Georgia Tech for Fall '97, Spring '98, Fall '98, Winter '99, Spring '99, and Fall '99 quarters. We also have data from Kennesaw State University classes for the Winter '98, Spring '99, and Fall '99 semesters and from the Fall '99 semester at Brown University giving a total of 965 student questionnaires with more than 22,010 responses.

Our goal in administrating these student questionnaires was to obtain from a large user population the general qualitative reaction to eClass as well as self-reports on how students used (or didn't use) the technology. During the past four years, we have modified the questionnaire to remove questions with predictable answers with new questions that were not previously addressed. The responses are from undergraduate and graduate students enrolled in 45 courses (28 unique courses taught during a period of three years), taught by 24 different instructors. The courses cover undergraduate and graduate level material and topics taught in Math, Computer Science, and Electrical Engineering.

End of semester teacher survey.   At the end of the Winter '99 quarter, we asked all current and previous Georgia Tech teachers who have used eClass in the past to fill out a questionnaire on their use of the system. We collected a total of 18 responses from instructors, representing 51% of all instructors who have taught using eClass.

Privacy survey. In response to questions on how students felt about privacy and eClass, we created a special questionnaire target just toward how students felt about eClass with respect to privacy. This questionnaire was administered mid-semester to an introductory class on human-computer interaction taught during the Fall '99 semester by an instructor who was an expert in teaching with eClass. We collected a total of 19 anonymous responses from this survey.

Ubicomp workshop survey. During summer, 1999 we hosted a workshop on ubiquitous computing using a version of eClass specially modified for a workshop environment. At the end of the workshop, we administered a special survey on the participants' view of the system. A total of 27 responses were collected.

McGill survey. After our system was used at McGill, we gave them our standard questionnaire to administer. They in turn modified our questionnaire making it much shorter and more open-ended and sent us the results. Forty-nine responses from students in two courses were collected.

KSU substitution survey. A professor at KSU was teaching a course that she had previously taught using eClass. Due to a pregnancy, she was unable to be present for the final three weeks of class, so in lieu of teaching class, she made available the eClass notes from the last time she taught the course. Since this was a new use of the system,

we prepared a special questionnaire for those students to answer after the final exam on their opinions of the system. We collected 100 responses from this survey.

All of the questionnaires described above can be found in the appendices and are summarized in Table 4-3.

Table 4-3: Summary of questionnaire data collected. An "*" indicates that we don't have answers to the full questionnaire.

School – Term	Questionnaire Type	# Courses	# Responses
GA Tech – Fall 1997	Standard	4	60
GA Tech – Fall 1997	Survey	4	498
GA Tech – Spring 1998	Standard	9	177
GA Tech – Spring 1998	Survey	11	1091
GA Tech – Fall 1998	Standard	3	116
GA Tech – Fall 1998	Survey	20	1445
GA Tech – Winter 1999	Standard	9	31
GA Tech – Winter 1999	Survey	25	2845
GA Tech – Spring 1999	Standard	12	226
GA Tech – Spring 1999	Survey	15	2178
GA Tech – Summer 1999	Ubicomp	1 (workshop)	27
GA Tech – Fall 1999	Modified Standard	6	124
GA Tech – Fall 1999	Privacy	1	19
GA Tech – Fall 1999	Instructor	18 (instructors)	18
KSU – Spring 1999	Standard	3	91
KSU – Winter 1998	Standard	1	60
KSU – Fall 1999	Standard	1	27
KSU – Spring 2000	Substitution	1	100
Brown – Fall 1999	Standard *	1	100
McGill – Fall 1999	Special	2	49

4.2.3 Controlled Experiments

To help answer some of the questions of the impact of eClass we conducted two similar experiments, each on real courses and lasting for the duration of the course. The main idea behind the experiments was to teach the same course in two different sections – one with eClass support and one without – and look for any effects related to student note taking and performance between the two sections. Specifically, we were looking to quantitatively measure the impact, if any, of eClass on individual note taking styles and

to see if use of the system was positively correlated to performance in the classroom. Additionally, we wanted to see if we could support the positive reactions from the questionnaire and determine if there were any trends to be found between classes having captured notes and those without this support.

The first experiment was performed on two sections of an undergraduate software engineering course at Georgia Tech. Students determined the course sections based on the meeting times for the sections. The course met three times a week with section A in the morning and section B in the afternoon. Both sections were taught with the same instructor and both sections used the same eClass technology even though the two sections met in different rooms. The only significant difference between the two sections was that section A was allowed access to the eClass notes whereas section B was not. In other words, section B was a normal class taught in a multimedia-enhanced classroom. The on-line notes were not processed for Section B and the notes for Section A were password protected. Section A was instructed not to give their access passwords to section B or otherwise divulge any information about the class. Section B knew about eClass and was made aware that they were not going to have access to the automatically generated notes.

The instructor was an expert user and researcher of eClass technology. The majority of his lectures consisted of annotating on top of already prepared PowerPoint slides that had been imported into the system. The instructor made these slides available at least 24 hours in advance of class so that the students had the option of printing them out before class and annotating on top of them. A few lectures consisted of the instructor writing on blank slides, much like a traditional class taught using a whiteboard. These

lectures were discussion driven and therefore, there were no notes prepared for the students in advance.

The course had project assignments as homework as well as three exams and four quizzes. The quizzes were unannounced. Two of the quizzes were held at the end of a lecture and were based solely on that lecture. Two of the quizzes were held at the start of class and were based solely on the previous lecture. Exams for both sections were always held on the same day, with section A being first in the morning and then section B in the afternoon. The third and final exam was a take-home exam. We were allowed access to these grades.

To minimize cross-section interference, the lecture order was reversed in the last half of the course. In the first half of the course, section B had the same lecture as the one provided for section A earlier that day. In the latter half, section B would have the first lecture on a topic and section A would have the same lecture at the next class meeting.

At the end of the course, students from both sections were provided the opportunity to turn in their entire set of notes for the course for extra credit. If a student did not take notes for a lecture, the student was to indicate this by providing a blank sheet of paper saying that they took no notes for that day. Of the 35 students in section A, 13 complete sets of notes were received, and of the 45 students in section B, 15 complete sets of notes were collected. In addition to collecting notes from students, they were also required to complete a survey (anonymously if desired) about the instructor's use and their own use of eClass.

Finally, students in section A were given a username and password to access the on-line notes. Once logged in, a student could view the notes and we could keep a record of their browsing activity through the lectures. This allowed us to track individual student study sessions to determine how a student used the system over the course of a semester.

One year later, in the Spring 1999 semester, a similar experiment was performed at KSU on an undergraduate calculus course. This time, however, the technology in the two sections was not equal. One section was taught in a eClass enhanced room; the other section was taught in a traditional room with chalkboards. The eClass enhanced room consisted of one 60-inch diagonal electronic whiteboard and one projected overview screen. The room for the other section contained one full wall of chalkboard, approximately 20 feet, and another, 8-foot chalkboard on the left wall of the room, next to the front wall.

We collected attendance records for the 85 enrolled students in both sections for the duration of the term. In addition, we collected grades for homework, quizzes, and exams for both sections of the course, but did not collect any notes from students or uniquely identify their study sessions. The on-line notes for the captured section were not password protected, but the students in the other section were not made aware of their presence[1]. Lecture order was not reversed halfway through the course as it was for the Georgia Tech experiment.

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[1] eClass was relatively new and unused at KSU at the time of the experiment.

The instructor was again an expert user of eClass technology. Her lectures consisted of writing the lecture notes on the whiteboard from her own personal copy of notes. The course had 11 quizzes, two projects, and three exams. The quizzes were unannounced and were always some problem assigned in the homework.

4.2.4 Observations

We have had the fortune of attending and observing many of the lectures taught using eClass. Although there were not many observations planned, we were able to take advantage of several observational opportunities.

4.2.4.1 Comparison of Instructor Behavior

After the experiment at KSU, we again had the opportunity to observe how the technology affected one section of a course compared to different section taught in a non-eClass enhanced room with the same instructor.

We collected video of two lectures taught for each section, four lectures in all. The goal was of collecting this data was to analyze how the technology affected the instructor's ability to teach the material, and how the instructor adapted to the technology. To do this, we noted how the instructor taught the same material by using eClass technology versus using the chalkboards.

4.2.4.2 Attendance Comparisons

To help determine the impact of eClass on attendance (in addition to the attendance records from the KSU experiment), we performed a small attendance observation in the Fall 1999 semester. During a 28-day period, in the middle of the semester from October 15 to November 12, we manually took attendance from 12

courses taught in eClass equipped rooms. We did this by standing in the hallway and peeking in the classrooms to count the number of heads in a lecture. The counts were taken approximately 15 minutes after the lecture had begun. The lecture counts were taken from random days primarily in the morning and early afternoon hours. We collected attendance records from seven courses that did not use eClass to capture lectures and from five courses that did. In sum, we had 23 attendance samples from the non-captured classes and 33 from the captured classes. The goal was to determine if the eClass technology had a negative impact on attendance.

4.2.5 Summary

Our initial emphasis for eClass was simply to get it in everyday use. After we achieved that goal, we then proceeded with the evaluation tasks. Due to strict humans-as-subjects rules, we were limited in the amount of logging and personal information acquisition we could have otherwise done. Although better experiments and observations might have been possible, we feel that we have collected as much data as is possible about the use of our system while allowing for maximum anonymity. In the next chapter, we reveal our evaluation results based on the data we have collected.

CHAPTER V

EVALUATION RESULTS

In this chapter, we explore our evaluation results from using the system over a period of four years. First, we look at the overall impressions and conclusions we can make about eClass. Next, we look at how the system impacted students, and then how they used the captured lecture materials. Finally, we look at the impact on instructors and give our general conclusions.

5.1 A Brief Overview

Throughout this chapter, we will be giving many statistical results based on the questionnaires. To aid the reader, before we begin, we would like to explain how we analyzed our questionnaire responses.

For each question asked and answered, we wanted to see how the responses varied based on eight different factors. These factors are summarized in Table 5-1

Table 5-1: Factors and their variables used in questionnaire analysis.

Factor	Variables
The school attended	GATech, KSU
The grade level of the student	Undergraduate, Graduate
The student's experience with eClass	Previous experience, No previous experience
The instructor's experience with eClass	Previous experience, No previous experience
Ink density of course taken	Top 1/3, Middle 1/3, Bottom 1/3 of all courses (measured by the sum of ink pixels per course)
Access ranking of course	Top 1/3, Middle 1/3, Bottom 1/3 of all courses (measured by the sum of all sessions per course)
PowerPoint usage in course	Mostly PowerPoint slides, Mostly handwritten slides (which there is more of; handwritten or PointPoint slides)
Slide count for the couse	Top 1/2 Bottom 1/2 of all courses (measured by the count of all slides per course)

We conducted eight chi-square tests (one for each factor) on each set of responses for every question to determine if there were any relationships between a factor and the response to a question. These responses are summarized in Appendix D. The interested reader is also referred to Appendix C, where we list all of the questions asked and for each question, the number of student responses.

Many of the questions we asked were answered by indicating a response on a Likert scale containing the following choices: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree. Occasionally, when we are only interested in general responses, we will aggregate these five choices into three (Agree, Neutral, and Disagree) by combining Strongly Agree with Agree and Strongly Disagree with Disagree.

5.2 *Overall Impressions of eClass*

Here, we look at student opinions of eClass based on end-of-semester questionnaires. Overall, we find that students found eClass useful to them, and that they prefer using eClass to courses that do not. We show that eClass was used authentically and further our claim that eClass was built and used for a real need, and that eClass is perceived as a bona fide learning tool.

5.2.1 eClass Has Authentic Use

Before we can consider our evaluation results, we need to show that our system was indeed put into everyday use. In this section, we go beyond reporting on the sheer volume of users and concentrate on showing that eClass was built for a need that existed, was used mostly for the need it was built, and that it was a reliable, dependable service.

eClass was built to provide the service of automatically capturing college lectures and making available that material for later access by students. We have shown why we believe this is a beneficial service to students, but now we look at what the students say.

Figure 5-1 shows what students view as the most important factors to succeeding in a class. It verifies that we should center the bulk of our capture and access research in the classroom on supporting the capture and access of lectures because attending the lectures is generally regarded as the most important part of succeeding in class.
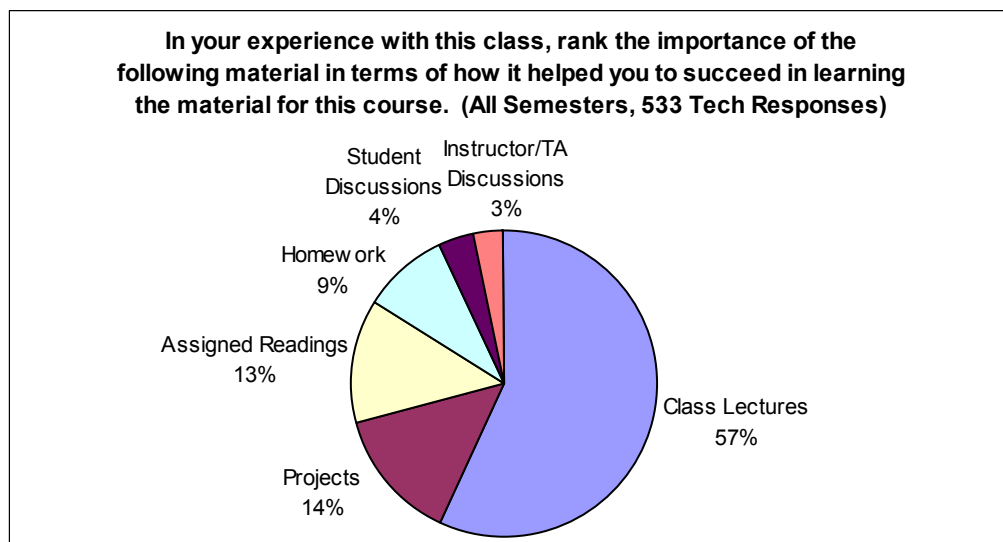
Figure 5-1: Relative importance of factors relating to classroom success.

Next, we look at if our system was actually used as we had intended it to be used; as a tool for the review of lectures that were previously attended. Figure 5-2 shows the main reasons students access the notes (when they gave a reason) at access time.

The main reason the students access the notes is to review a lecture that they had already attended, but we see that a combined 54% of students are using eClass to review lectures, indicating that our system is mostly being used for the purpose for which it was built. Later, in section 5.4.5, we will strengthen this claim by showing that use of eClass is strongly correlated to the nearness of lectures and exams.

Authentic use also requires that our system be perceived as dependable and reliable service. This was a concern for us because we could not anticipate the many failures we had in supporting live classes, such as unannounced network failures, machine failures, and user error due to lack of training (typically because we could not readily give advice to untrained users).

**Reasons Given at Access Time for Viewing Online Captured Notes.
(All Semesters, 8700 Non-Blank (of 12,343) Responses)**

Follow up an interesting point / curiosity 17%

Get help with homework / project assignment 13%

Study for an exam 16%

Review a lecture after attending it 38%

Review a lecture that was missed 16%
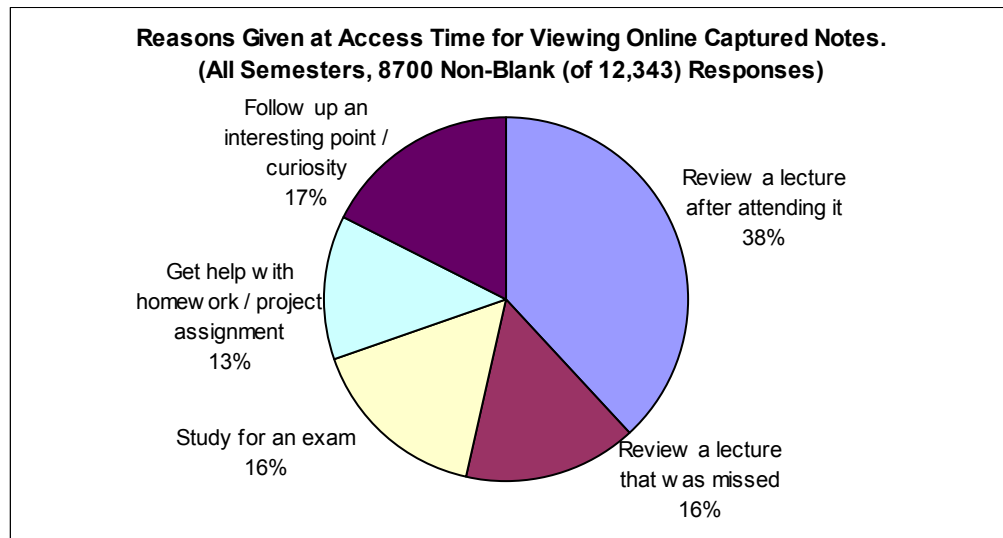
Figure 5-2: Reasons given at access time for viewing the notes.

As it turned out, students were remarkably tolerant of the occasional failure and showed their trust in the system (see Figure 5-3). 76% of the students replied that they trusted the captured lecture notes would always be available with only 6% disagreeing.

I trust the captured lecture notes will be available after every class.
(All Semesters, 386 GATech Responses, 196 KSU Responses)
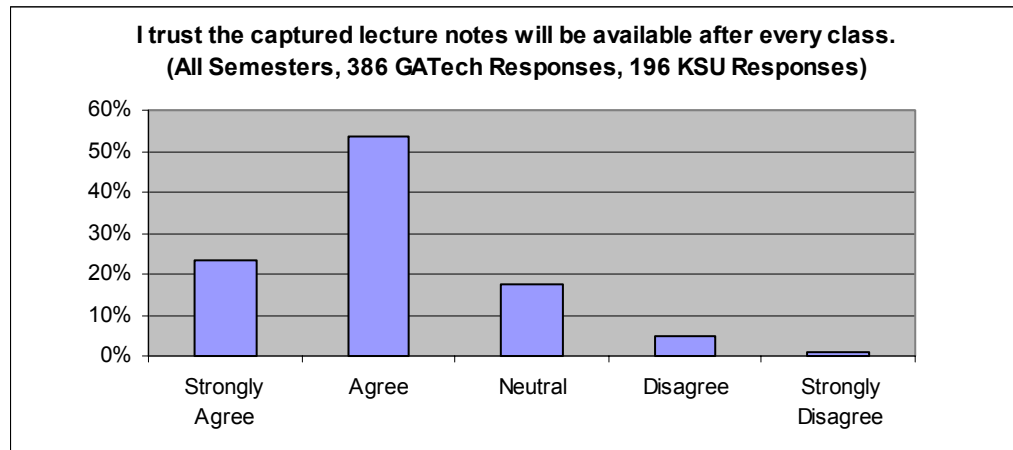
Figure 5-3: Student trust in eClass.

All of these factors combined help to show that eClass was used authentically in a live setting. Volume of use indicates that we achieved everyday status, and student surveys indicate that our system was built to support a need, was used to fulfill that need, and was a trusted tool.

5.2.2 eClass Is Perceived as a Legitimate Learning Tool

In this section, we show that qualitatively, students see eClass as an asset to their learning experience. They report that they like the technology and find it desirable, that eClass helps them pay better attention to the lecture, that the technology is appropriate for many different types of classes, and that they would prefer eClass to other technological solutions.

In order for us to build capture and access capabilities into a classroom, we needed to move traditional classroom objects such as a whiteboard to a digital domain and equip the classroom with recording devices. One possible drawback with this

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approach is that the students might resent the introduction of all the technology into the classroom as complicating the lecture experience.

The classroom lecture was more engaging or interesting to me as result of the use of technology in class and the availability of notes afterwards. (All Semesters, 386 GATech, 196 KSU Responses)
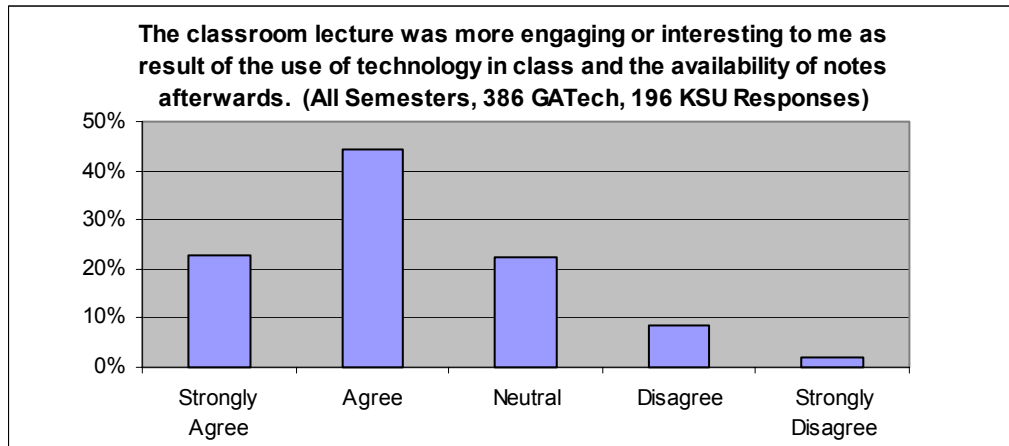
Figure 5-4: Students found eClass makes the class more engaging.

Figure 5-4 shows overall, 67% of the students felt that eClass made the lecture more engaging, as opposed to 10% who felt otherwise. We would probably notice this type of positive reaction based on the introduction of any new technology into the classroom. However, there is no statistical significance in the responses (shown in Table 5-2) based on whether or not students have taken a class using eClass before (χ^2 (4) = 2.95, $p = 0.566$). This inclines us to believe that our positive results are not due simply from a change from the status quo, but rather that the students genuinely appreciate the enhanced classroom over continued use.

Table 5-2: χ^2 breakdown of significance for technology making the course more interesting.

		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The classroom lecture was more engaging or interesting to me as a result of the use of technology in class and the availability of notes afterwards.						
Factors	*Values*	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
Student Experience	Previous Exp.	33	58	25	8	3
	No Previous Exp.	59	122	53	20	5

One working hypothesis for eClass was that the automatic capture of notes would allow students to stop being scribes and start *paying better attention* to the material being taught. We asked the students directly if our hypothesis was sound (Figure 5-5). 59% of the students surveyed believe that they can pay better attention in class because eClass is capturing all of the written and spoken details for them while 14% disagree.[2]

Student responses to this question varied based on the level of the student, the experience of the student with eClass, and whether or not the course taken by the student utilized PowerPoint slides (summarized in Table 5-3). Graduate students were more likely to strongly agree while their undergraduate counterparts were more likely to be neutral (χ^2 (4) = 14.76, p = 0.005) indicating that graduate students might be more comfortable with the technology. Also, students with prior eClass experience were more inclined to strongly agree (χ^2 (4) = 14.86, p = 0.005). Finally, students in classes that use PowerPoint slides were more likely to Agree and those in courses without PowerPoint were more likely to answer neutral (χ^2 (4) = 10.28, p = 0.036).

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[2] We believe factors relating to students disagreeing are related to the few instances when the technology does fail, and students are left with the impression of the technology holding up the classroom.

Table 5-3: χ^2 breakdown of significance for paying better attention.

		Because captured lecture notes are available after class, I was able to better pay attention to the lecture.				
Factors	*Values*	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
Grade Level	Graduate	84	133	64	30	10
	Undergraduate	71	129	109	48	12
Student Experience	Previous Exp.	69	94	61	19	15
	No Previous Exp.	86	168	112	59	7
Dominant Slide Type	PowerPoint	79	138	69	37	14
	Handwritten	76	124	104	41	8

Surprisingly, if we select the people who felt like eClass did not help them pay attention (those who answered neutral or disagree) and look at whether they found eClass to be more engaging, we find that 49% agreed, 32% were neutral, and 19% disagreed (out of 163 total responses). So while some students feel that the technology doesn't help them pay better attention, at the same time they generally agree that the technology still makes the class more engaging.

Despite the design of eClass to support presentation-style lectures, other instructors who employed more discussion-style lectures used it as well. To make matters worse, many of the instructors who used the system received very little training on how to it as we typically did not know in advance which professors wanted to use the capture technology, and for which classes they wanted to use it.
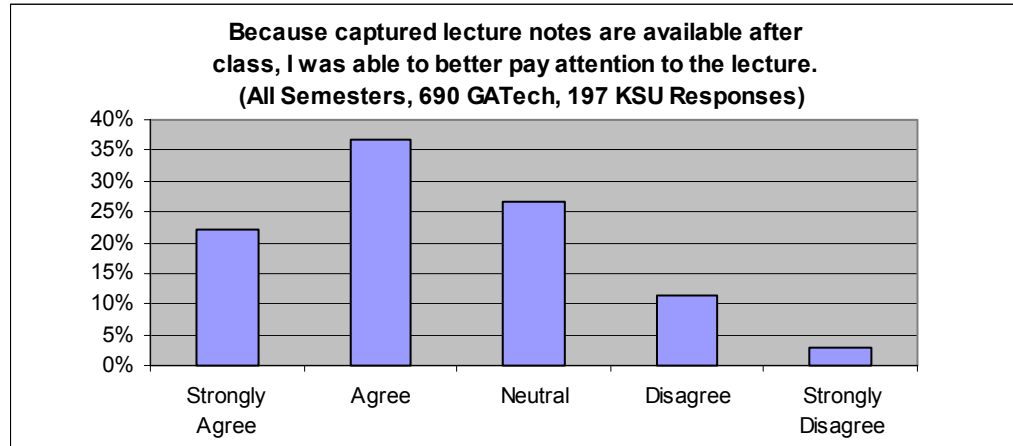
Figure 5-5: eClass promotes paying better attention in class.

Much to our surprise, Figure 5-6 shows that even with a lack of formal training, an overwhelming 89% of students felt that the instructor used eClass effectively in class. This is a surprising result! Recall that Classroom 2000 is a research prototype, and that it is not a product. We have not formally trained many users of the system, or instructed them in what we feel is the best way to use the system. In fact, we think many users of the system are not using it to full potential. Over a short period of time, professors have discovered how to use the technology in a way that is comfortable for them, and the conclusion is that the students feel they are doing a good job.

The lecturer used the Classroom 2000 technology effectively in class.
(All Semesters, 384 GATech, 197 KSU Responses)
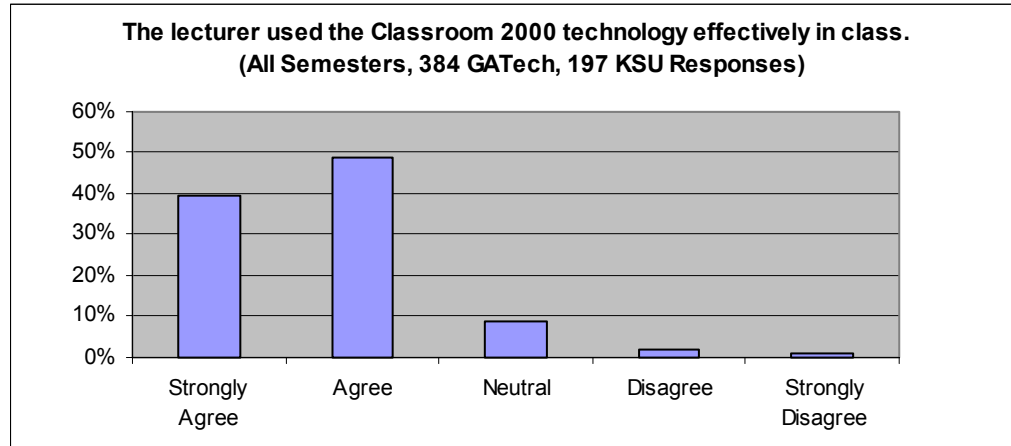
Figure 5-6: Assessing if the lecturer used eClass effectively.[3]

We felt that eClass would be particularly well suited to certain types of classes such as Math and Physics classes where a great detail of information is written on the board by the professor. It was unclear, however, how well eClass would fare in more discussion-oriented classes.

Figure 5-7 shows that surprisingly, 83% of students thought that eClass was well suited for the courses they took regardless of the course! Again, this includes a wide variety of classes from introductory, to survey, to didactic, to discussion-oriented classes. The technology was obviously designed for a transmission-driven style lecture, but the system seems well adaptable to other teaching styles. This is further supported by the fact that more and more instructors continue to teach their classes using eClass.

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[3] Most questionnaires were administered before we changed the name to eClass; we present the questions exactly as they were worded.

This type of course is well-suited to Classroom 2000 technology.
(All Semesters, 386 GATech, 196 KSU Responses)
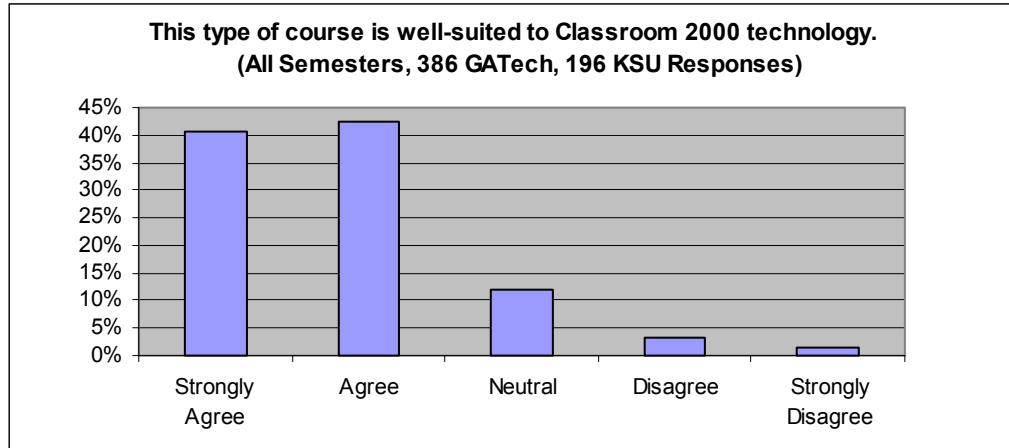
Figure 5-7: Appropriateness of eClass in various courses.

In fact, the only contributor to making students answer disagree is based on the amount of ink written on the slides for the entire course. As shown in Table 5-4, students who attended a course that ranked in the bottom third of ink density (measured in pixels/slide) tended to disagree while their counterparts in more ink-dense courses agreed (χ^2 (8) = 22.54, p < 0.005). We concluded then that eClass is appropriate for various instructor styles and course topics, recognizing that in the ink degenerate case, eClass was providing minimal indexing into the media. As we will see in section 5.4.3, this minimal level of indexing is enough.

Table 5-4: χ^2 breakdown of significance for appropriateness of the technology.

This type of course is well-suited to Classroom 2000 technology.						
Factors	*Values*	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
	Top 1/3	52	54	14	2	3
Ink Density	Middle 1/3	80	94	31	3	1
	Bottom 1/3	20	15	8	7	2

Perhaps the best way to find out whether students find value in eClass is to ask them if they would prefer to take a course with eClass or one taught in the traditional way. We found (see Figure 5-8) that students prefer eClass with 78% of students agreeing and only 5% preferring the old way.
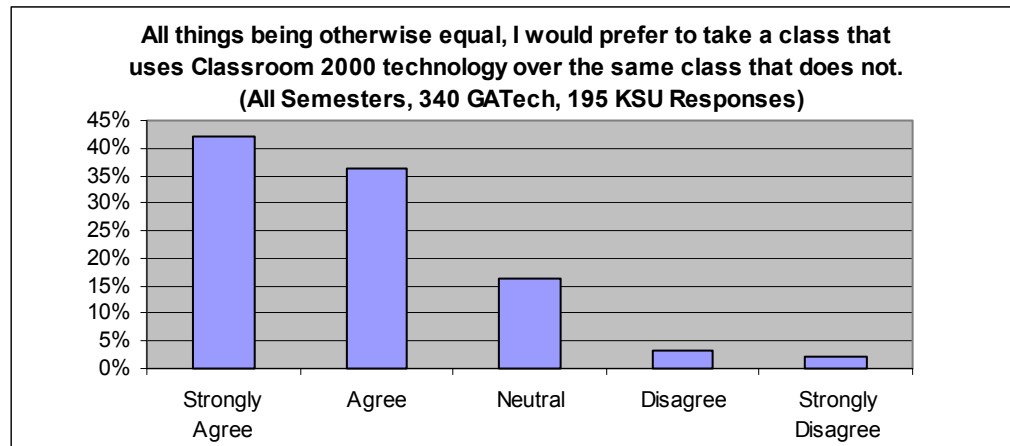
Figure 5-8: Preference of eClass to traditional methods.

An interesting phenomenon is that students will indicate a strong feeling that eClass is a valuable resource and helps them pay more attention in class *even if they never accessed the captured notes* (67% Agree, 10% Disagree)!

We also asked students if they would prefer taking a course equipped with eClass or one that gave out printed slides of the lecture before class. 14% of students would prefer just having handouts with 73% choosing eClass. Finally, we asked students is they would prefer taking a course equipped with eClass or one that was broadcast over cable television as many colleges do. Only 6% of students would prefer taking the course broadcast over cable with 69% preferring eClass.

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5.2.3 Overall Impression Conclusions

As an educational technology program, eClass is not perfect. It has many flaws, and some researchers would argue that we are supporting the wrong learning models. Be that as it may, eClass was built to support students taking traditional college lectures. Students have responded that what we have built is preferred to traditional classes and helps them succeed in the class (59% Agree, 13% Disagree). They report that it is useful in courses for which we did not think it would succeed, and used well by instructors with differing teaching styles.

5.3 Impact on Students

In this section, we examine some of the effects eClass has on the students. We will look at how eClass effects attendance, student notes, and exam and class performance. We will also highlight some viewpoints students have on privacy with respect to eClass.

5.3.1 eClass Does Not Encourage Skipping

One of the biggest concerns that we are often asked about eClass is whether its use encourages students to skip classes. The reasoning is that if the lecture experience is available on-line, then students will not be motivated to join in the live class and instead just watch it from home at their leisure. On the surface, this seems like a reasonable concern, but we have always maintained that the service provided by eClass was designed to be a supplement for a lecture – not a replacement for it. We believe there are some key aspects of the lecture experience that eClass does not preserve or enable, such

as remote interactivity, and that without the benefit of actually being there, the on-line notes are not valuable enough to serve as a substitute for attending lectures.

For example, we designed the on-line notes interface to be used more as a 'table of contents' to facilitate easy indexing into particular portion of the lecture rather than as a general replay tool. The lack of a mechanism for the automated replay of a lecture means the task of replaying a lecture is more complicated than just watching a video. Perhaps if the on-line notes interface was more sophisticated and allowed this type of use (along with higher quality video), we might anticipate some decline in attendance. However, as the current system stands, we do not think students would use eClass as their sole information source for a lecture, nor did we intend it to be used as such when we first envisioned it.

But still, it is a valid question, and who better to answer it than the students? Since Fall 1997, on the end of the term surveys, we have asked students if they feel (after having just completed a course using eClass technology) whether or not eClass encourages students to skip class.

Figure 5-9 shows the summary from student responses at Georgia Tech and Kennesaw State. These figures include 757 responses, (563 from Tech, 194 from KSU) and cover all terms of use at both institutions. It turns out that, as a whole, students are evenly divided as to whether or not they think it encourages students to skip classes with 30% agreeing, 35% disagreeing, and 35% having no strong feelings either way.
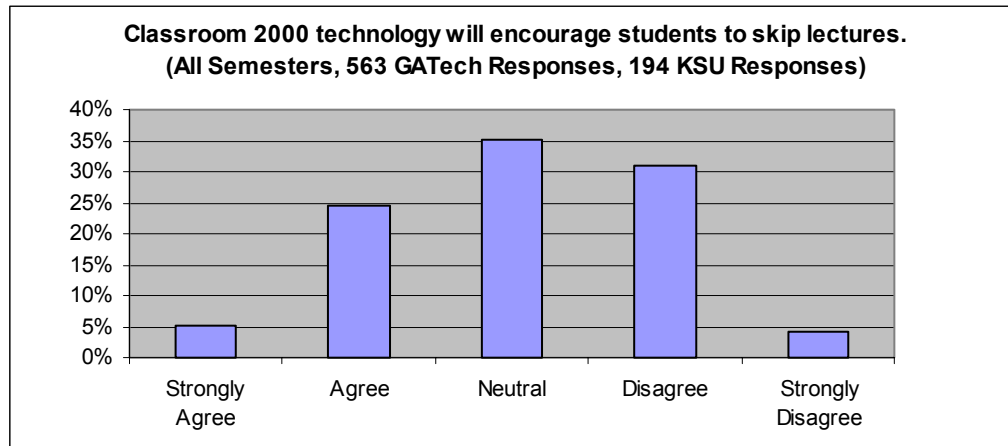
Figure 5-9: Student opinions on whether eClass encourages skipping class.

As shown in Table 5-5, if we segregate the responses from students by term for each school, we see that these figures represent a stable response since student responses to this question have not changed significantly over the years (χ^2 (16) = 19.17, p = 0.263 for GT, and χ^2 (12) = 10.87, p = 0.542 for KSU). Additionally, students from both Georgia Tech and Kennesaw State do not answer the question differently (χ^2 (4) = 1.42, p = 0.843) indicating that both technical and liberal arts students answer similarly.

Interestingly enough, graduate and undergraduate students answered this question differently. Graduate students were more likely to disagree while undergraduate students were more likely to agree that eClass encourages skipping (χ^2 (4) = 12.67, p = 0.013). This might be because undergraduate classes are more structured and tend to more closely follow the reading, slightly diminishing the importance of attending lectures. Graduate classes, on the other hand, may tend to be more discussion based and cover material not present in the readings. Alternatively, graduate students may simply be more mature students and as such, would be less likely to miss a lecture under any circumstance.

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Table 5-5: χ² breakdown of significance for technology encouraging skipping.

Classroom 2000 technology will encourage students to skip lectures.						
School	Term	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
GATech	Fall 1997	2	11	23	23	2
	Spring 1998	12	39	43	29	4
	Fall 1998	5	28	35	42	6
	Winter 1999	1	12	11	8	1
	Spring 1999	11	49	88	70	8
KSU	Winter 1998	2	10	9	9	2
	Spring 1998	3	15	12	14	3
	Spring 1999	2	17	35	33	3
	Fall 1999	1	5	11	6	2
Factor	Values	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Grade Level	Graduate	10	37	63	76	9
	Undergraduate	21	102	137	96	8

A related question is whether or not students feel that eClass makes them personally feel less worried about missing a class if they need to. Figure 5-10 shows the results from 760 student responses (565 from Tech, 195 from KSU). Overall, students feel somewhat more strongly that it does make them less worried about missing with 49% agreeing, 30% disagreeing, and 21% having no opinion.
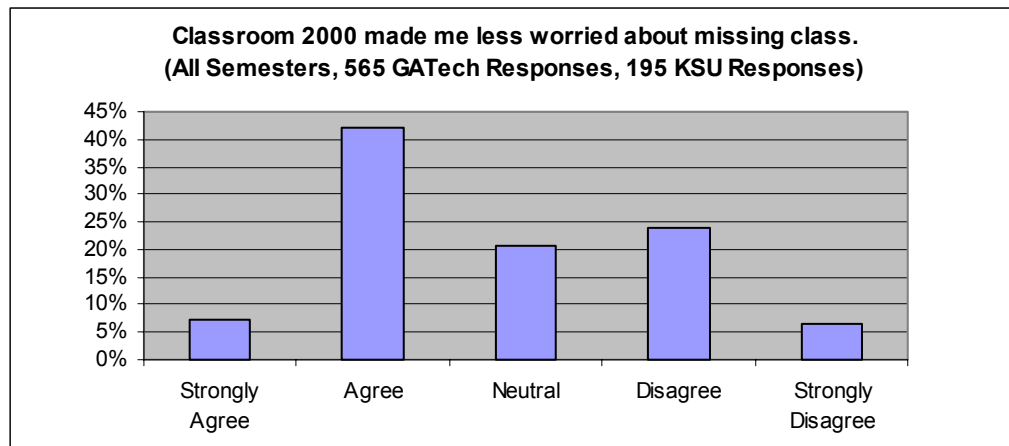
Figure 5-10: Student opinions on whether Classroom lessened the worry of missing a class.

The questionnaire data seems to indicate that while eClass does not encourage skipping, it does relieve students of some of the worry of missing a class when they must, but these answers are not as consistent as asking whether eClass encourages skipping. In general, compared to asking is eClass encourages skipping, students answering this question were more likely to have an opinion rather than be neutral.

We found several factors in determining how students answered this question (summarized in Table 5-6). Overall, KSU students were more likely to strongly disagree instead of agree (χ^2 (4) = 20.00, $p < 0.005$) compared to their GT counterparts. Again, this is probably reflective of Tech students being more comfortable (and more trusting) with technology in general than their KSU counterparts.

Table 5-6: χ^2 breakdown of significance for eClass relieving worry of missing class.

Classroom 2000 made me less worried about missing class.						
Factors	Values	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Grade Level	Graduate	22	97	34	38	4
	Undergraduate	20	160	79	89	22
School	GATech	42	257	113	127	26
	KSU	13	62	43	54	23
Dominant Slide Type	PowerPoint	23	117	40	48	6
	Handwritten	19	140	73	79	20

Once again, graduate and undergraduate students answered this question differently. Graduate students were more likely to strongly agree and agree while undergraduates were more likely to be neutral or disagree (χ^2 (4) = 17.57, $p < 0.005$). Additionally, students in courses that utilized PowerPoint slides were more likely to strongly agree and agree while students in courses without PowerPoint slides were more likely to be neutral. Because eClass does a better job of capturing prepared slides than it

does handwritten slides[4], this might cause student in courses with prepared slides to feel more strongly that the system will capture the presented information if they have to miss class.

Looking at the reasons from students accessing the online notes gives us more of an indication that eClass does not encourage skipping. If it did, we would expect the majority of students to answer that they were viewing the notes because they missed class, but the majority of students responded that they were accessing the notes to review a lecture after attending it. Recall Figure 5-2, wherein we show the responses students gave for viewing the notes. If we assume that students wanting to follow up on an interesting point, and those who were getting help with homework attended class, then we have 68% of students accessing the notes after attending a lecture, not something we would expect if eClass encouraged skipping.

Of course, questionnaires and surveys do not tell the whole story. To get a more quantitative answer, we examined two sets of actual attendance records: one set from the Kennesaw State University controlled experiment, and one set from observations at Georgia Tech (both of these experiments are detailed in chapter 4).

Figure 5-11 shows a summary of the random mid-semester attendance samples for captured and non-captured classes taught at Georgia Tech along with a linear regression analysis trend for both types of classes.

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[4] Often, an instructor's handwriting is sloppy and hard to read compared to PowerPoint slides.
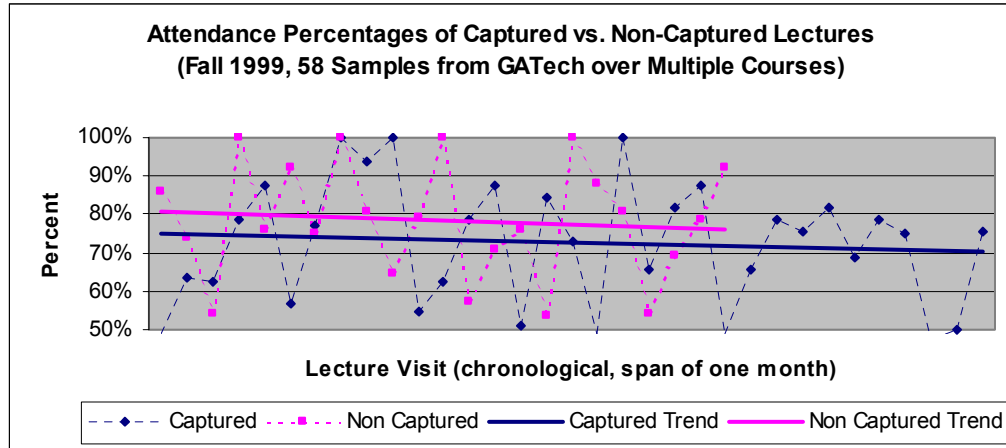
Figure 5-11: Graph of GATech attendance percentages for captured and non-captured courses.

Figure 5-11 reveals two interesting points. First, the trend lines indicate that the attendance in captured classes is around 5% lower than in non-captured classes. Second, the trend lines suggest that attendance dropped off slightly for both captured and non-captured classes at the semester continued.

To determine whether use of eClass indeed had a negative impact on attendance we first checked to see if the decline in attendance for either captured or non-captured classes was statistically significant. For this data, a linear regression analysis on the trends turned out not to be significant (F $(1/32) = 0.25$, $p = 0.62$ and F$(1/22) = 0.16$, 0.68 respectively).

We then examined the average attendance values for each type of class: 78% for non-captured courses and 72% for captured courses, indicating that eClass might again have a slight effect on attendance. However t-tests reveal that the difference in attendance means is not statistically significant (F$(54) = 1.40$, $p = 0.168$) so we can conclude that the attendance data collected from Georgia Tech does not support the notion that use of eClass results in lower attendance.
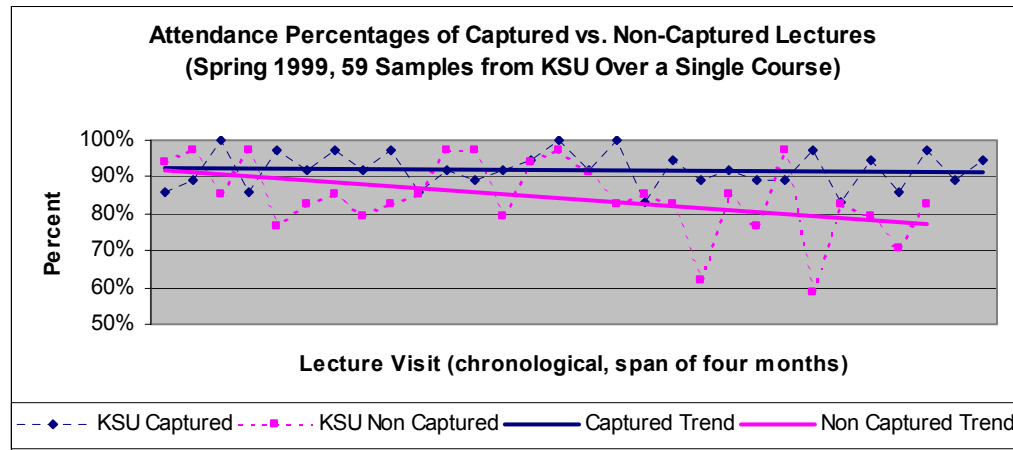
Figure 5-12: Graph of KSU attendance percentages for two sections of a course, one captured and one non-captured.

Next, we examined the attendance logs from KSU. Figure 5-12 shows a summary of the attendances for captured and non-captured classes along with a linear regression analysis trend for both types of classes. As the graph shows, the attendance data from KSU is even more encouraging and t-tests indicate that students in the captured class are more likely to attend class than their counterparts in the non-captured class ($F(56) = -3.61$, $p < 0.005$). Further, regression analysis on the data from KSU indicates that students in the non-captured classes had an attendance decline as the semester progressed ($F(1/27) = 0.10$, $p = 0.02$) while those in the captured class did not ($F(1/29) = 5.86$, $p = 0.75$).

It seems then, that use of eClass actually improved attendance at KSU. Again, these results are from the same instructor teaching the same material at the same time of day (9 a.m., Monday and Wednesday for section 1, the non-captured class, Tuesday and Thursday for section 2, the captured class).

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Thus, using data from our two experiments, we failed to find any proof that eClass has a negative impact on attendance either at Tech or KSU. Therefore, we conclude that overall, through student questionnaires, surveys, and attendance logs, use of eClass does not negatively affect attendance. We imagine that other attendance factors – such as the time of day of the class, the lecture topic, or the engagement level of the professor –might dominate.

As we stated at the beginning of this section, we did not think eClass was a substitute for attending lectures. However, we feel that with the addition of remote interactivity tools, eClass might start to encourage students to view the lectures wherever it is more convenient. The level that this would cause disruption in the classroom would need to be outweighed by the benefits of having remote participants. We leave this question to future researchers.

5.3.2 Students Take Fewer, More Summary Style Notes

One of our main motivations of eClass was to reduce the need for mundane note copying for the students. It is not surprising then, that students report taking fewer notes than they would in a traditional classroom. It was not our intention however that students should stop taking notes altogether, but rather that they would take more personalized notes of items not explicitly written down in the classroom.

One of the ways we attempted to measure the impact of the technology on the students' notes was to have the students reflect on their note taking practices after completion of a eClass course and noting any deviations from their normal note-taking routine. We begin by looking at student responses to our end of the course questionnaire. In an open-ended question, we asked students to

Briefly describe your note-taking practices in classes similar to this class but not using eClass *technology.*

The response was open-ended, but we found that many students answered in similar ways, making it easy to categorize their answers. In instances where the categorization was not obvious, we labeled the answer, 'other.' Table 5-7 shows the responses from Fall '97, Spring '98, and Fall '98 (323 total answers). It shows that 70% of students report that they write down at least as much as the professor writes on the board with 42% writing down what the professors says as well. We obviously expected some change in note taking behavior because eClass records everything the professor writes and says.

Table 5-7: Note taking style in classes without eClass technology.

Note Taking Style	Percent
I write down what professor writes and important points he says.	41.8%
I write down everything the professor writes.	28.5%
I take few notes – just important points.	17.0%
I take no notes.	6.2%
Other	6.5%

We then asked students,

Have your note-taking practices in this class changed as a result of eClass*? If yes, briefly describe the change.*

A surprising 40% (shown in Table 5-8) said that the technology did not affect them at all, whereas 55% said that they took fewer or no notes. Although this indicates that students are affected, it does not indicate if a student with a particular note taking style is more likely to be affected than would be another style.

Table 5-8: The effect of eClass on note taking.

Effect of eClass	Percent
Did not affect me at all.	39.7%
I took less notes, outlined, pay attention more to lecture.	31.3%
I took no notes.	23.8%
Other.	5.3%

Students report that they take fewer notes because of eClass —but can we show empirically that this is the case? In Spring 1998 we collected notes from two sections of a Software Engineering course. Recall that both classes had the same instructor and were taught using eClass technology, but only students in section A were allowed to view the captured notes. At the end of the semester, we collected notes on a volunteer basis and then rated each page of notes based on their content and compared them to the slides presented in class. Our rating system was based roughly on student responses to their note taking practices. A rating of '0' indicates that the student did not write anything for a presented slide (took no notes). A rating of '1' means the student wrote some summary details, or processed some information in their own words. A rating of '2' indicates the student wrote what was presented on the slide. A rating of '3' means the student wrote what was already prepared on the slide and everything the instructor wrote.
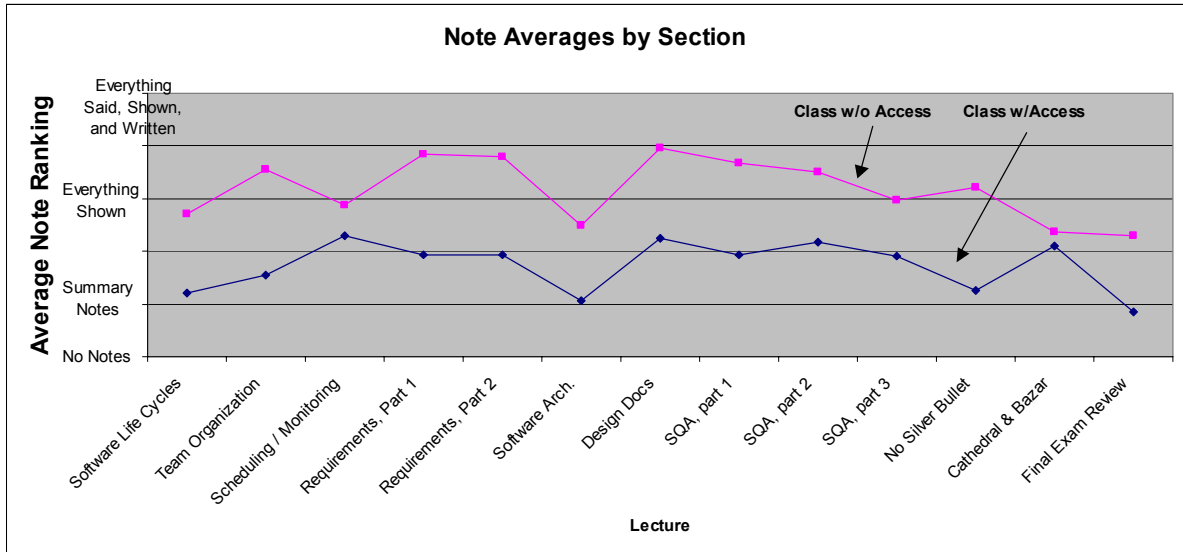
Figure 5-13: Comparison of notes between students in the same course.

Figure 5-13 shows that the students with access to the captured notes indeed took consistently fewer notes throughout the semester. T-tests show that students in section A took fewer notes than their section B counterparts (F(1/24) = 14.02, $p < 0.005$, yet both sections performed equally well on the midterm and final exams (Midterm exam scores were 81.5 (stdev = 7.5) and 79.5 (stdev = 13.1) and Final Exam was 80.3 (stdev = 15.3) and 79.5 (stdev = 13.1) captured, non-captured classes). So it seems, on first glance, that taking fewer notes is not necessarily a bad thing.

To better understand the effect eClass has on note taking, Table 5-9 shows the effect of eClass (as reported by the students) based on whether or not students had access to the captured materials. In it, we see that the instructor's use of eClass technology does not encourage fewer notes, but that the access to captured materials is what causes students to take fewer notes. This may seem obvious, but it is important to note that it is

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not the technology *in the room* that affects the note taking style, but the access to captured materials that alters the note taking behavior.

Table 5-9: The effect of eClass on note taking as reported by students from a Spring '98 software engineering course taught in two sections, one with access to captured materials, one without access.

	No Effect	Took Less Notes	Took No Notes	Other
Access	24%	30%	42%	3%
Non-access	73%	22%	0%	5%

As stated earlier, we are hoping to encourage better note taking practices. To determine if we are having a positive effect, we need to look at how specific note taking types were affected by the technology. Table 5-10 shows the breakdown of the effect of eClass on specific note taking types. For each effect (no effect, less notes, no notes) we have highlighted the note taking style with the largest percentage of people. These highlights bring out a few interesting points. First, students who took few notes or who outlined were most likely to not change their note taking style. The students in this category often said that they take 'summary' notes.

Table 5-10: The effect of eClass on specific note taking styles.

		Effect On Students			
		Did Not affect me at all.	*I took less notes, outlined, paid more attention to lecture.*	*I took no notes.*	*Other*
Note Taking Style	*All Students*	40%	31%	24%	5%
	I write down everything the professor writes and says.	28%	40%	21%	11%
	I write down everything the professor writes.	32%	34%	27%	7%
	I take few notes – just the important points.	45%	27%	10.2%	10%

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On the other hand, if we look at students who were trying to write down everything that happened in the classroom, we find they tend to say that they ended up taking more summary-style notes. Finally we note that among students who are basically capturing what eClass captures, they tended to be evenly distributed with regard to the effect on note taking style but that they were more likely than others to take no notes. We find it promising that eClass allows verbose note takers the ability to relax a little bit and take fewer notes and pay more attention, without disrupting students who feel that their note taking style is fine for them.

In conclusion, we have shown that although use of eClass does result in students taking fewer notes, our surveys and actual note analysis indicates that students are taking more personal, more summary style notes. Student interviews and conversations point to the same conclusion as well. Before taking a course equipped with eClass, a common student sentiment was:

> *I attempt to write down everthing the professor does. This is sometimes distracting.*

And after taking a course with eClass they report:

> *I did not try to write down everything that was said, just parts I found interesting or important.*

We believe that students will adapt to the study and note taking style that best suits them. That over 50% of students enrolled in eClass classes change their note taking style indicates that we are providing a service of which they are taking advantage. However, in our controlled study, we found it alarming that 42% of students said they took no notes. This indicates that the system is capturing approximately what the

students would capture anyway (a good thing), but that they are not supplementing this information with personal annotations. We examine this observation further in the next section.

5.3.3 Students Want Personalized Notes

Since a significant percentage of student stopped taking notes altogether with the use eClass, this implies that the captured notes are 'good enough' to preserve the lecture experience. To test this hypothesis, we asked the students at KSU if their own notes taken in class were more useful to them than the captured lecture notes. As Figure 5-14 shows, we found that only 17% of them thought eClass notes were more useful.
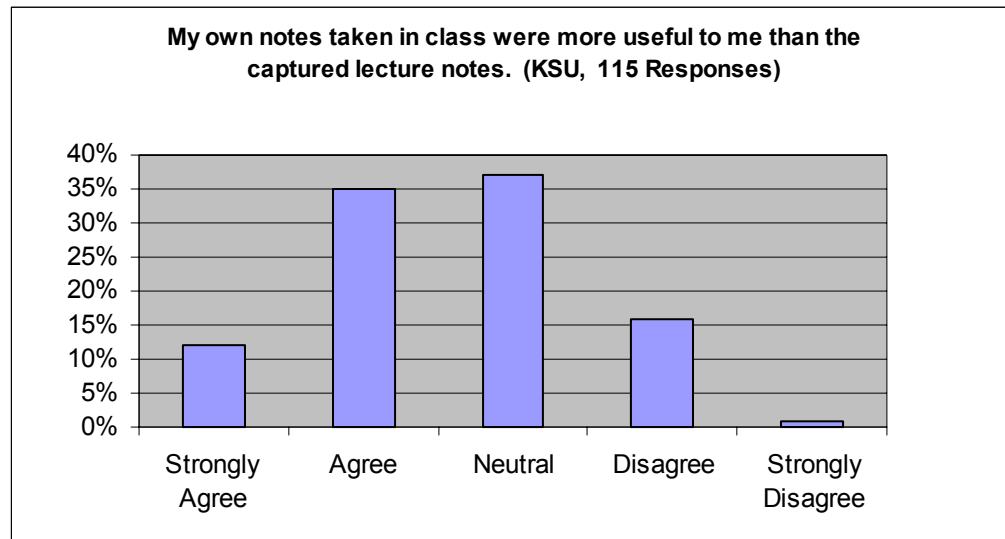
Figure 5-14: KSU results on preference of personal notes to eClass notes.

Tech students answered a similar question (with a reversed scale) in the same fashion. Figure 5-15 shows the results of asking them if they would rather have only the

eClass notes or only their own notes. Again, only 23% of the students seem to prefer having only eClass notes.

I would rather have ONLY the eClass notes over just having ONLY my notes. (GATech, 124 Responses)
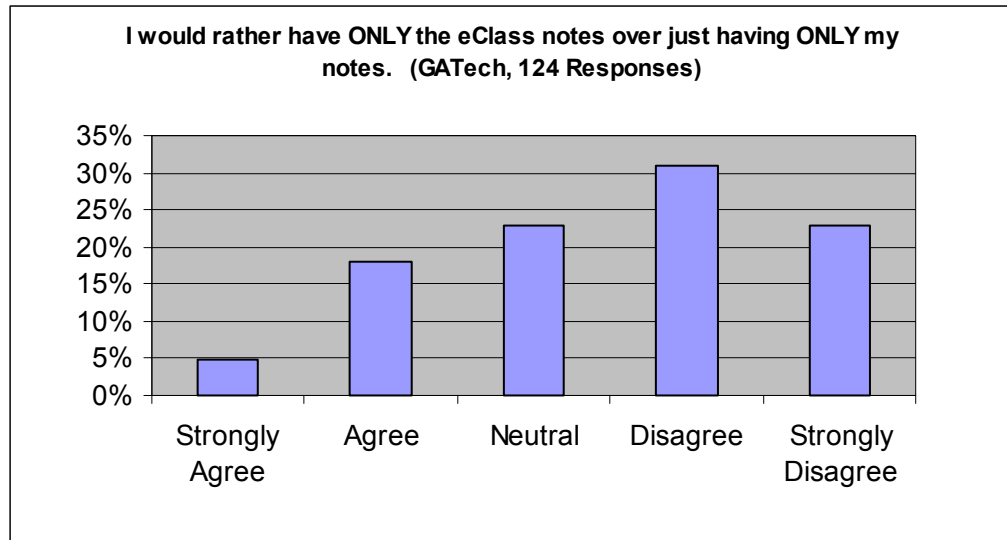
Figure 5-15: GATech results on preference of personal notes to eClass notes.

Given this, we wondered if eClass was really any more useful than just providing handouts before class. Handouts would alleviate students from copying down prepared material and they would only be required to write what the professor writes and says. Yet, when we asked the students if they would prefer taking a course where the lecture material was handed out before class or one that uses eClass, 73% of students preferred taking an eClass course, with only 14% preferring handouts.

We deduce from this that students enjoy the services of eClass, but they feel that their own personal annotations are most important to them (even if they choose not to write any). In other words, students would rather copy down everything if that allowed them to make their own personal annotations. To back up this idea, we asked Tech students if the value of the captured lecture notes would be enhanced if their own notes

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were included. Over half of the students felt that it would with only 12% indicating that it would not.

We have shown that the captured notes alone are not enough and that there is a strong desire for the integration of personal annotations along with the captured material[5]. We have also shown that the services of eClass are better than simply giving printouts of the prepared slides. Basically, this is because of the Web/Audio/Video augmentation of the notes, but we will explore this later when we look at how eClass was used.

5.3.4 Privacy Is Not A Worry, But Needs To Be Addressed

Privacy did not start out as an issue in our research. In retrospect, we were probably naïve not to consider privacy issues since we are using cameras and microphones in a public setting, but we assumed it was not a concern since we were never approached by any students or instructors about it.

As our research matured, an instructor approached us with her concerns that students were not asking questions because they were being recorded, and further suggested that if they were concerned with asking questions, they would probably not say so because that might brand them as a Luddite.

By this time, we were aware that students might not want to appear on a video recording, or that they might be less inclined to ask questions for fear of asking a 'dumb' question and having that experience recorded. But by this time, our everyday system had

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[5] Colleagues have instrumented StuPad, a student note taking device that runs on top of the services that eClass provides. We discuss this more in chapter 6.

evolved to where only the instructor was videotaped[6] and the student voices were almost imperceptible on the audio. We believed that these issues were not really student concerns, but to verify this, we inserted a few questions on privacy in our questionnaire to students in the Fall 1999 semester.

To begin, we asked students point-blank if they felt less inclined to ask questions because they knew that their voice was being recorded. Figure 5-16 shows that only 6% of students felt less inclined to asked questions in class. This comes to about one or two students per class. Student opinions did not vary among students with or without prior experience, or based on instructor experience, or by any other factors we could measure.
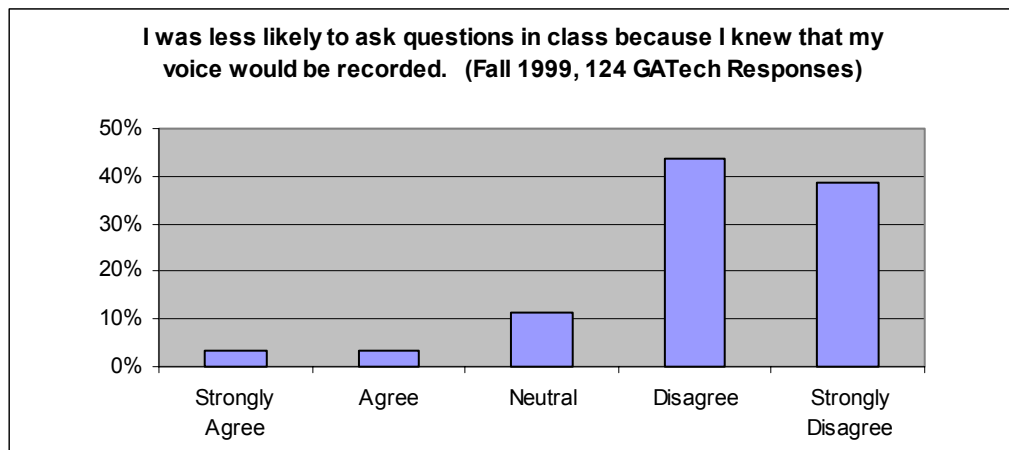
Figure 5-16: Responses on privacy involving recording student voices.

Now, it is a valid (and respected) argument to say that if not everyone is comfortable with being recorded than no one should be recorded, especially so in an

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[6] The back (top) of the heads of students in the first row were visible at the bottom of the camera image.

educational domain. We believe that cameras and recorders in public places make people uncomfortable at first, but then gradually they get used to them, and eventually, ignore them. We are on camera a surprising amount of the time anyway, in retail stores, on the highway, in casinos, banks, etc. Should these places stop recording because a few people object? Do the wants of the one (or two) outweigh the wants of the many? Probably not, but that does not mean that we should ignore them. One way to get around this problem is by ensuring that students are not videotaped, and for the most part, we have done this. We can also turn off the microphones so that only the instructor's voice is recorded. We asked the students how they would feel if this were the case.

I would be more comfortable with Classroom 2000 if only the instructor's comments were recorded instead of everyone's comments being captured. (Fall 1999, 124 GATech Responses)
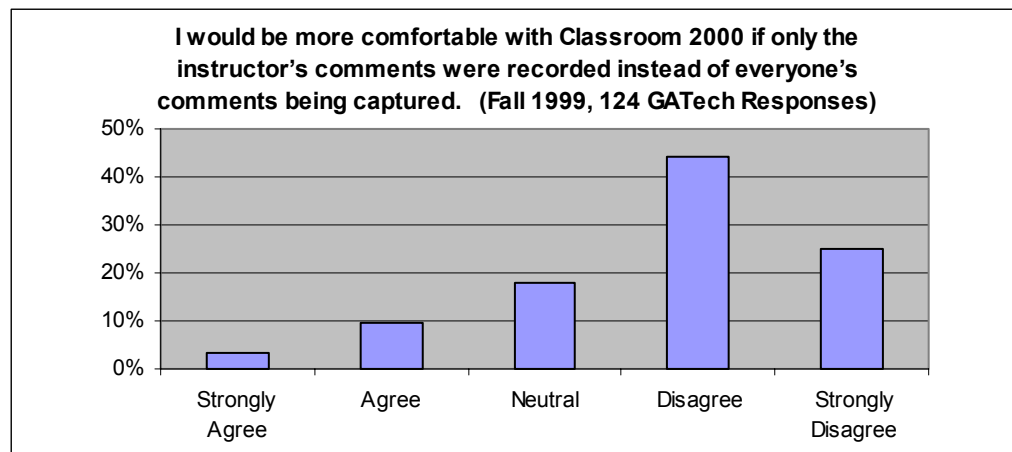
Figure 5-17: Responses to having only the instructor's voice recorded.

Figure 5-17 shows that 13% of students would prefer this situation, but that 70% of them disapprove. We conclude from this that students recognize the importance of class participation and that they do value the questions of their fellow students. So, despite concerns over recording student voices, there is a perceived value in having student voices recorded.

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One way that we could make the recorded voices more private would be to only allow access of the captured notes to the students of the recorded class. When we asked students if they were concerned that outsiders (anyone on the Web) could listen to the captured lectures, we found that only 10% of students felt this was a concern with 76% not really regarding it as an issue (Figure 5-18).

I was concerned that people outside of class could listen to the lectures on the Web. (Fall 1999, 123 GATech Responses)
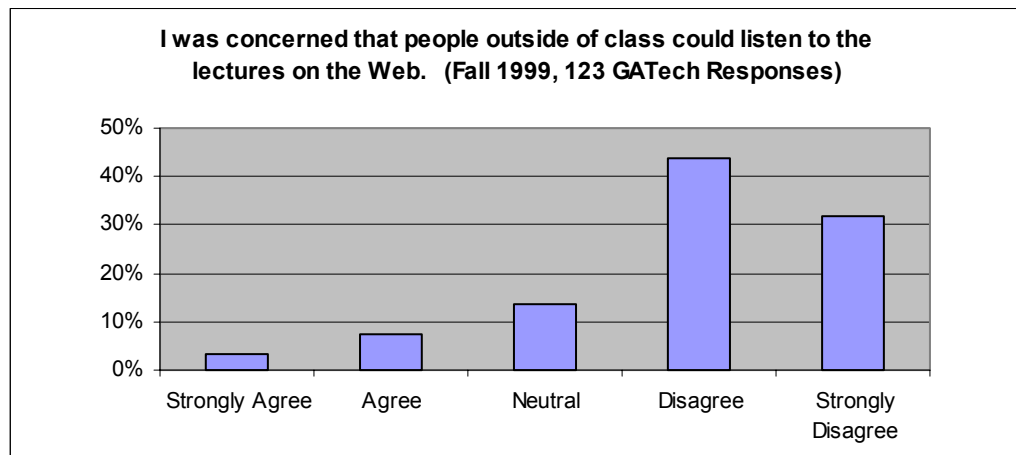
Figure 5-18: Student concerns about outsiders hearing recorded student voices.

5.3.4.1 Why We Cannot Ignore Privacy

In our brief survey, we found that a very small percentage of students are concerned about having their voice recorded. However, students were not in favor of only recording the instructor's voice, and moreover, were not concerned about being heard on the Web. Still, this small percentage cannot be ignored. We now have the technology to selectively mute individual student voices, or to create 'cones of silence' around a particular area. We could take care of student privacy concerns by first having designated areas of the room where audio is not recorded, and then later, provide

technology that allows students to selectively turn on and off the recording of their voice. This later solution seems the most general and most flexible as it also enables the instructor to go 'off the record' as well. While the raw percentages do not seem to merit it, we believe that any classroom recording system should take heed and allow students and instructors the option of not being recorded.

5.3.5 Performance Not Impacted

At the conclusion of our controlled experiments at KSU and GATech, we were unable to find any significant difference in grades based on whether or not a course uses eClass. At GATech, we found that students in the traditional section performed better (but not significantly) than their eClass counterparts on the midterm exam, but that the eClass section did better (but again, not significantly) on the final exam. The results from KSU were the opposite, with eClass students doing better on the midterm and worse on the final (but not significantly in either case). The grades from both schools are summarized in Table 5-11.

Table 5-11: Summary of exam performances.

School	Section	Exam 1	Exam 2	Final Exam
GATech	Access	81.5 (stdev = 7.5)	80.3 (stdev = 15.3)	N/A
GATech	No-Access	79.5 (stdev = 13.1)	79.0 (stdev = 14.6)	N/A
KSU	Access	77.3 (stdev = 13.5)	78.1 (stdev = 12.1)	122.3 (stdev = 16.2)
KSU	No-Access	80.4 (stdev = 13.7)	76.7 (stdev = 11.6)	124.1 (stdev = 19.5)

What does this imply? It means that at the least, eClass does not result in decreased exam performance. In other words, we do not seem to be disrupting the classroom with our research. Of course we don't seem to be helping much in terms of

grades either. But what about other factors related to studying? Figure 5-19 shows what students reported as answers to how eClass helps them.

Classroom 2000 helped me study/learn for the following activities. (All Semesters, 220 GATech Responses, 48 KSU Responses)

A bar chart showing percentages for: Study for Exams (~30%), Homework (~31%), Projects (~28%), Other (~4%), No Help (~6%). The y-axis ranges from 0% to 35%.
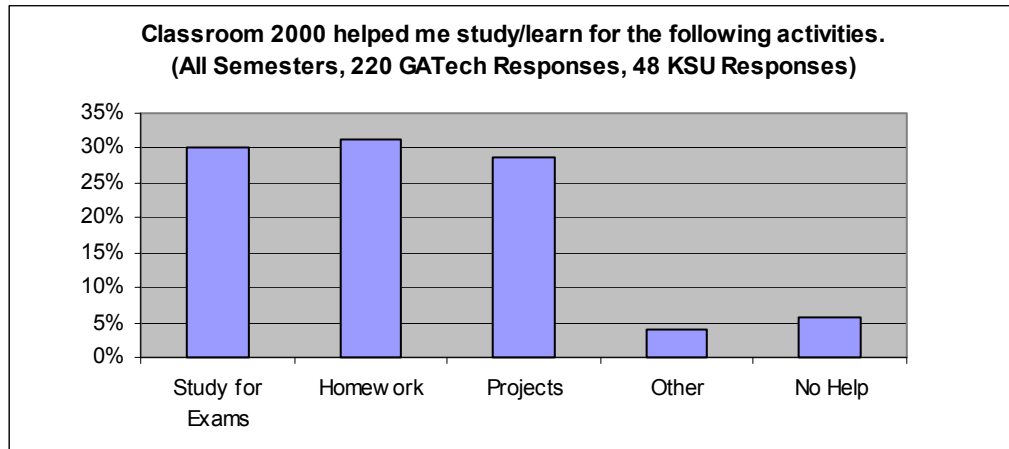
Figure 5-19: Ways in which eClass helped students.

We see that students are overall, split evenly among using eClass for help with exams, homework, and projects, all activities that are used for assessment. It could be that although eClass does not directly help exam scores, it does help in other areas where grading is a factor. In any case, it does not seem to hurt.

We considered that while eClass might not result in higher exam performances, maybe it helps students study more efficiently, allowing them to achieve the same level of performance with less work. When we asked students if this was in fact the case, we found that of 124 Tech students, 54% felt that eClass enabled them to study more efficiently with only 19% disagreeing. This was indeed encouraging, and when we asked these same students if they studied more, less, or about the same when using eClass, we found that 74% said they studied the same amount, with 6% reporting an increase and 19% indicating a decrease.

In the end, we cannot empirically say whether eClass has a positive or negative impact on student performance. We know that students use eClass to help with many different assessment activities, and after using the system for years, we have plenty of anecdotal evidence that eClass does help[7]. It is a great source of pride for the author that many students have directly said that they would not have passed a course without the help of eClass, so we do feel that we are making a positive contribution. However, we leave further analysis on this topic to other researchers.

5.3.6 Student Impact Conclusions

eClass affects the students in many ways. We have shown that

- Use of eClass does not result in decreased attendance, but that the system does make students feel more comfortable about missing a class when they must.

- Students take fewer notes when using eClass, but that they also tend to take more summary style notes.

- Students want to take their own notes and have them integrated with the captured notes.

- Privacy is not a strong concern among students, but we have argued for the acknowledgement of the few concerns that do exist.

Finally, we were unable to show that eClass has any impact on student performance, but believe strongly that it does help.

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[7] During the study, the author personally received around 4 emails a semester thanking him for building system, usually stating that the student felt s/he would not have passed the course without the use of eClass.

5.4   How the Notes Were Used

In this section, we will examine how the students used the notes in their study sessions. We begin by looking at overall use of the notes, showing that eClass is used extensively, and then look at how our augmented features such as audio, video, printing, and Web page capture are used. Finally, we look at why students access the notes and how students are using them to study for courses.

5.4.1   Notes Are Worth the Effort to Capture – They Are Heavily Used

Recall that we were able to identify 59,796 individual access sessions. In total, there were 2,335 classroom lectures captured. If we assume that there were 25 students enrolled for each course captured, we have more accesses than if every student in every course accessed every lecture once! Of course, some students did not access the notes as all, and others probably accessed them more than their peers, but on the whole, these numbers indicate that the notes were well used by the students.

Looking at the individual access sessions, we find that the average duration for an access session is 4 minutes, 30 seconds, but this is a conservative number. Many access sessions are less than one minute, for example, when a student is simply printing the notes, or quickly scanning through lectures to find a specific topic. If we look at study sessions that are longer than two minutes, we find that the average study session jumps to just over 13 minutes.

Although 4 minutes, 30 seconds per session does not seem like heavy use, let us put it in perspective. If we look at all of the accesses sessions (that we were able to capture) and treat them as one continuous session, we find that in just over 3½ years of capturing logs, the system was used for a total of just over 557 eight-hour days!

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5.4.2 Augmentation of Captured Notes Is Useful

We augmented the captured notes with three main services. Most obvious was that the notes were themselves indices into the audio or video of the course. Second, we captured Web pages visited during class, and third, we provided students with the ability to print out the captured notes. While printed notes lose the ability to replay the associated media or Web pages visited, they allow for a more portable interface, and are more easily integrated with the students' own notes.

5.4.2.1 Audio / Video Augmentation

Figure 5-20 shows that overall, 53% of students think that audio augmentation increases the value of the notes with only 13% disagreeing. The numbers for video augmentation are somewhat lower, but more people are in favor of it than are against it.
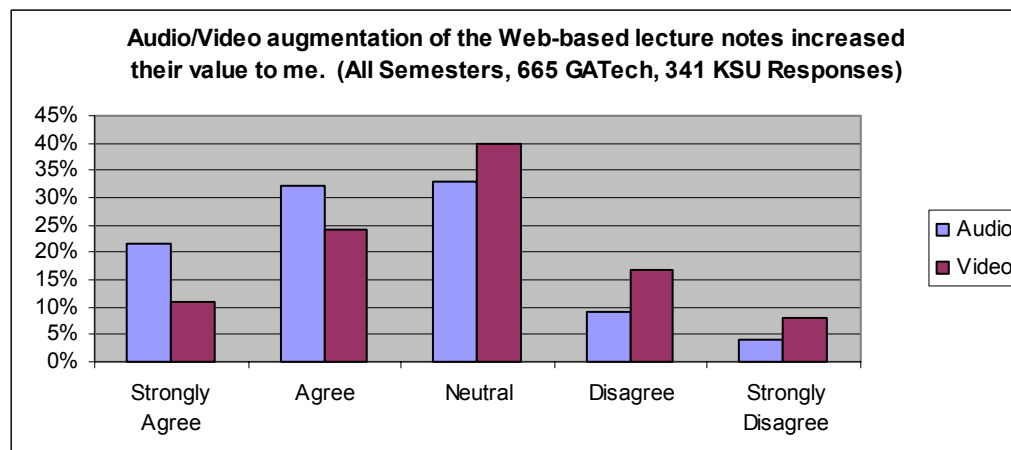
Figure 5-20: Student opinion of media augmentation of captured notes.

In practice, we found that the captured media were used, but not as much as we had expected. 10,612 study sessions (roughly 18% of all study sessions) accessed either

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the audio or video associated with the lecture. When a student does access the media in a study session, they access the media an average of 2.7 times per session. However, as shown in Figure 5-21, almost half (47%) of the students only initiate one media playback per study session.

 # Media Accesses Per Session (When Media Accesses Occur)
(All Semesters, 10,612 Study Sessions)
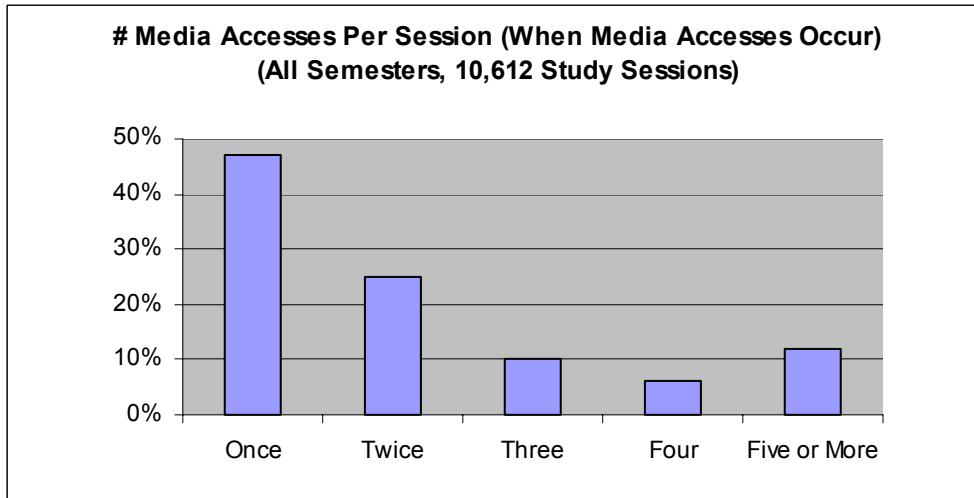
Figure 5-21: Breakdown of media accesses per study session (when media access occurs).

Recall that the average duration for an access session is 4 minutes, 30 seconds. We found that this figure varies widely based on whether or not the student accesses the captured media. Study sessions not accessing media lasted only an average of around 3 minutes, 51 seconds, while those that did access the media lasted an average of 12 minutes, 16 seconds. These results are consistent with those reported on the use of MANIC [71] where they found that study sessions were longer if the students accessed the captured audio. In our case, student study sessions that access the captured media last an average of 4 times longer than those that do not access the media.

Overall, students play the media for an average 6 minutes and 14 seconds per study session and the average duration of each media play is 3 minutes, 18 seconds. Figure 5-22 shows how these durations vary based on the number of media access per study session. We note that the total duration of media played increases as the number of media plays increases (up to an average of 13 minutes for sessions with five or more media accesses), but the average duration of *each* media access decreases. This indicates that the students might start to exhibit a foraging tendency when more than one media access is initiated. We discuss this observation further in the next section.
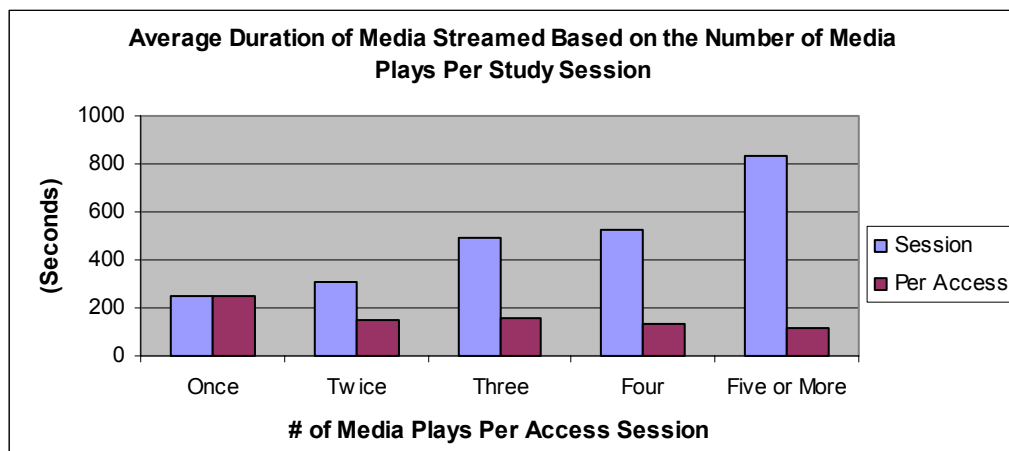
Figure 5-22: Average duration of media played per sessions based on the number of media plays.

To better understand how students were using the media in their study sessions, we look at when in a study session students were most likely to try and access the associated media. We found that 69% of media accesses occurred within the first five minutes of a study session (Figure 5-23).

When in Study Session Media Streams Accesses Occur
(8,915 Media Requests)
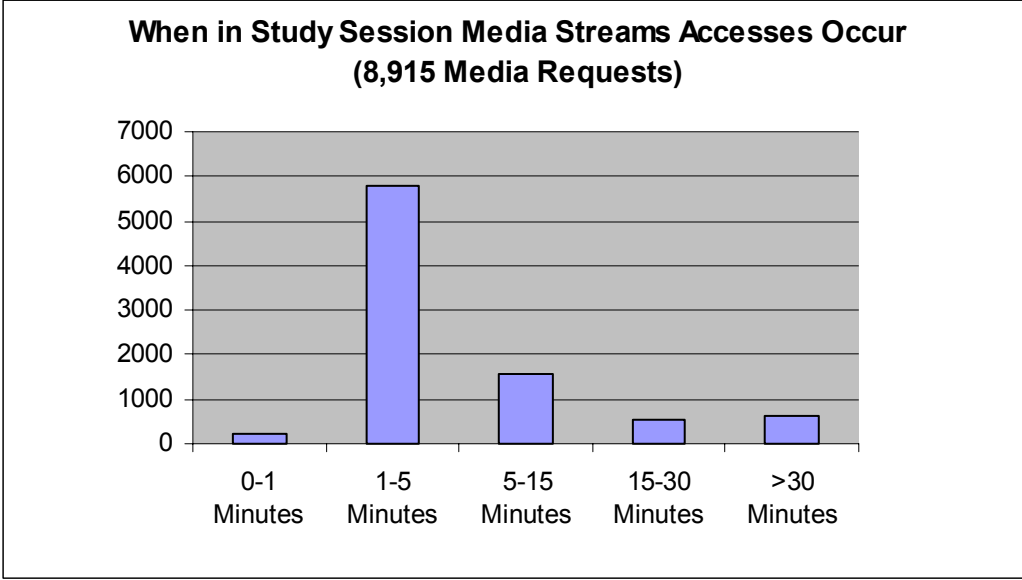
Figure 5-23: Breakdown of when in the study session students are accessing media.

Next, we looked at where in the media students are accessing. Figure 5-24 shows that 47% of all media accesses are within the first five minutes of the media.

Access Offsets into Media Streams
(8,915 Media Requests)
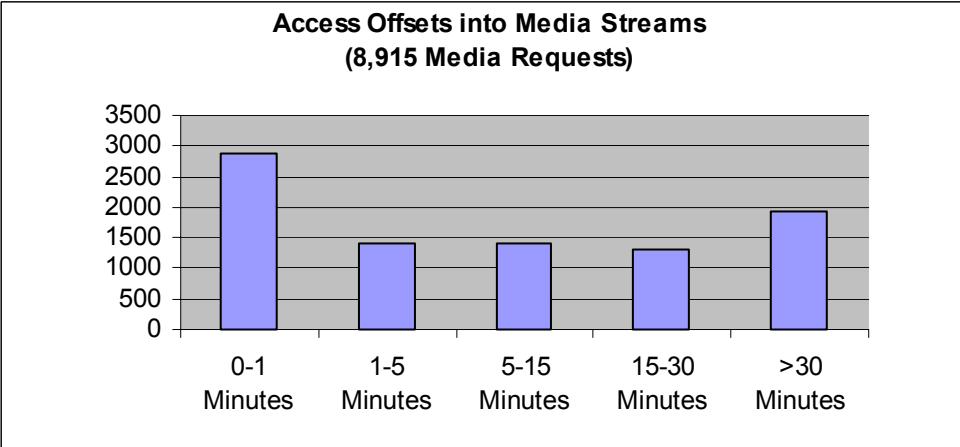
Figure 5-24: Breakdown of when in the media stream students are accessing.

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Our media server was a third party, on-demand streaming server, so we were not concerned with optimizing our media stream delivery, but this is a topic of interest to other researchers [16], [58]. We can use the data provided by these two graphs to provide suggestions for pre-fetching media. Since only 3% of the study sessions tried to access the media in the first minute but 69% tried in the first 5 minutes, and since nearly 1/2 of all media access occur in the first five minutes of the media, a reasonable pre-fetch policy would be to use the first minute of a study session to pre-load the first five minutes of the media to the client machine. But what can we say about pre-caching media after the first five minutes?

As expected, the longer a study session lasts, the further into the media accesses occur, but what is surprising is that after only 5 minutes of a study session, 40% of media accesses will refer to after the first 30 minutes into the media (Figure 5-25), indicating that students progress quickly through the captured lectures.
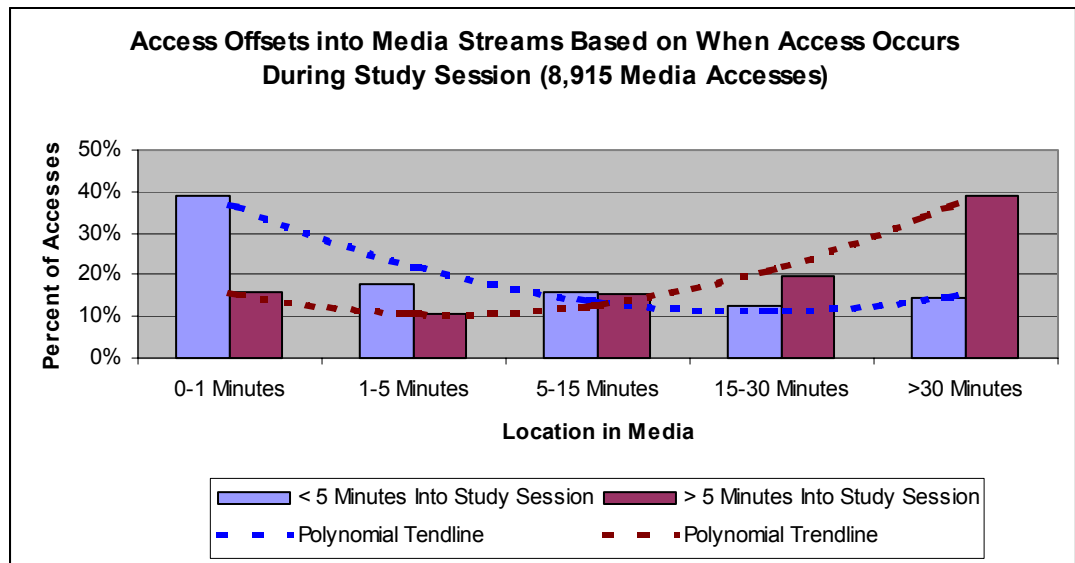
Figure 5-25: Distribution of media access offsets based on when in the study sessions media access occur.

As our intent was to better understand how students use the media in their study sessions, a more thorough analysis of media pre-caching is beyond the scope of this thesis. Nonetheless, in our limited analysis, we have shown that even though the first 5 minutes of the captured media is heavily accessed (almost 49% of accesses), accesses to the rest of the media account for the majority of accesses.

Until now, we have been looking at both audio and video accesses, but audio is by far the most popular medium with 24,323 accesses, whereas video only has 4,151 accesses. We believe there are several reasons for the 5-to-1 preference of audio over video. Perhaps the most significant is a direct result of our initial design requirement that the captured lecture notes should be accessible from a home computer using a 28.8 Kbps modem. It is possible to stream video over slower modem connections, and because of this requirement, we have been capturing low-quality video instead of high-quality video. So, the fidelity of the audio stream is higher than that of the video stream. The video stream was only captured at a resolution of 160x120 pixels at 10 frames / second. The end result was that the video was useful for knowing where the instructor was in the classroom, but not useful for reading what the instructor was pointing at or writing. We considered moving to a higher quality video stream, but found that 51% of the students (460 Tech, 211 KSU) were viewing the notes from their home computers as opposed to a lab (33%) or an office (13%). Since half of all access occurred from home, we felt it was still prudent to cater to the lowest common denominator. However as cable modems and high-speed networks are becoming commonplace in dormitories, the role of high-quality video again becomes an issue.

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To account for students studying using different bandwidths, we provided several different access interfaces to the notes. Our default interface would play audio and contained all of the slides in one window. A typical captured notes session can range from 10KB to 200KB, not including the audio/video, or any captured Web pages. Because of this, we provided a slow-access interface for the students that would show only one slide at a time instead of all them at once. Students could set individual preferences for viewing the notes all at once, or one at a time and for selecting audio or video as their medium of choice. We found that 68% of all accesses used our default settings, but that the next most popular interface choice was the slow-interface using audio. In all, only 14% of all access sessions utilized the video interface.

It is unclear as to whether the students did not find the video useful or if we failed to provide a useful video stream. We feel that although students overwhelmingly used audio over video, this result is more a reflection of our system and not the general usefulness of audio compared to video.

5.4.2.2 Print Augmentation

By having on-line notes, we can integrate pen and paper notes with audio, video, and other artifacts found in the classroom. Of course, one of the drawbacks to on-line notes is that they can only be viewed from a computer and not, say, on the bus ride home or in bed (not yet anyway). To account for this, we provided a printing function for students. Figure 5-26 shows that in general, students found it to be useful (56% agree, 25% neutral, 19% disagree), indicating that the enhanced online notes were also valuable in the printed, non-augmented form.

Printing captured lecture slides after class is a valuable feature of this system to me. (All Semesters, 642 GATech, 143 KSU Responses)
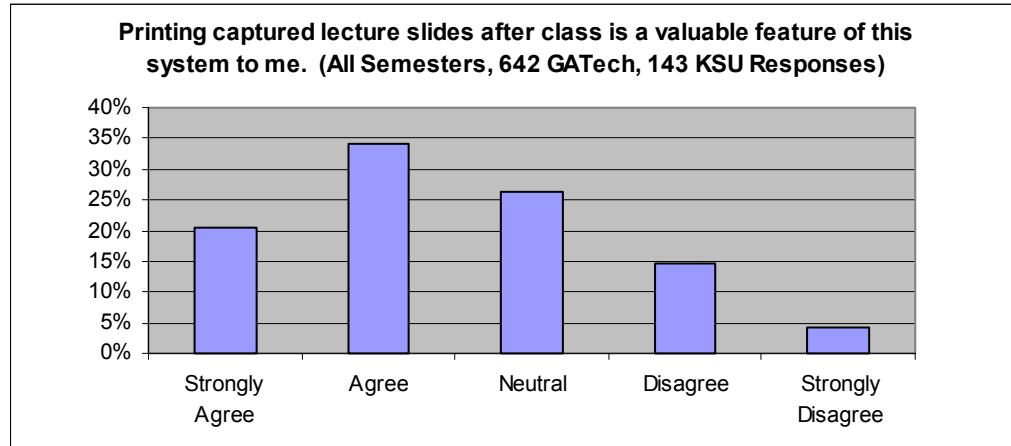
Figure 5-26: Student opinions about printing services.

We found that in actuality, 10% of all study sessions printed the notes. To be fair, this number could be much larger; we are counting the number of times a student printed from a special page we designed which structured four slides per printed page. Students could have chosen to print from our standard interface, with just one slide per page, and we could not detect that, but as luck would have it, printing from this method was unreasonably slow, so we do not think that it was greatly used.

5.4.2.3 Web Augmentation

Every time the instructor visits a Web page in the classroom, the corresponding URL is logged and presented in the capture notes interface. A student just needs to click on the hyperlink to visit the URL shown in class. We had always assumed that automated Web capture would be a useful service to the students. Figure 5-27 reveals that the students seem to think it is a good idea too, with 59% agreeing and only 8% disagreeing.

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Capturing Web pages browsed in class was a useful resource for later review. (All Semesters, 611 GATech Responses)
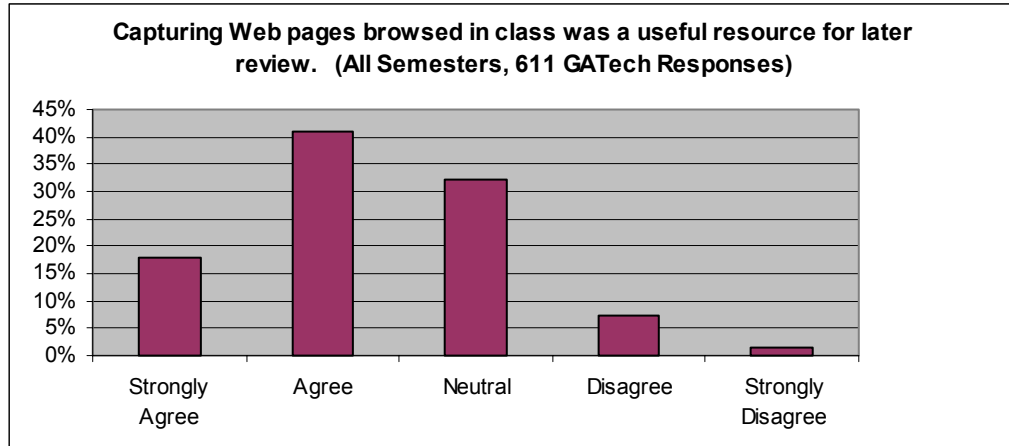
Figure 5-27: Student opinions of Web capture.

However, only 1.3% of all study sessions accessed captured Web pages from our interface. This number is quite lower than we expected. If we only look at the study sessions of lectures that contained captured Web pages (549 / 3,073 lectures and 19,568 / 59,796 sessions) we find that only 4% of those sessions visited a captured Web page. However, in those study sessions where a student does visit URLs, we found that they have an average of 2.2 Web visits per study session. This data indicates that students aren't typically interested in visiting Web sites shown in class during their study sessions, but when they do, they visit multiple sites.

As we expected, media was the most used of our automated note augmentations, and more specifically, audio was the most used. We were surprised at the large number of study sessions that involved printing the notes, because we did not anticipate printing to be so popular. The biggest shock, however, is that despite being well-used by instructors, Web page capture was infrequently used by the students. It could be that Web page capture really is not that useful, but it could also be that for it to be useful, more that just the URL visited needs to be captured. For example, if mouse movements

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and scrolling activity were captured, perhaps that would make the captured Web pages more useful. As eClass captured them however, they were not used much.

5.4.3 Slide-Level Media Granularity Is Sufficient

We had always assumed that eClass notes would be better than handwritten notes with a tape recorder because our notes offer the advantage of jumping right into the media at a desired location. The only question was what level of granularity is needed? Minimally, we could choose to index into the media at every slide change, or at the other extreme, we could provide an index for every pixel written on the board. Additionally, we can also provide a timeline for direct indexing into moments where no ink was written and no slide changes occurred. eClass offers interfaces that provide these methods for playing back media streams. Students can click on the ink to hear the audio at the time the ink was written, or they can play back the audio from the time a slide was visited in class (one of possibly multiple times), or they can index into the audio by clicking on the timeline and jumping to any arbitrary point. We have found that simply providing slide-level access into the media is sufficient because that is the most common method used by students and because students do not exhibit study strategies that require more precise indexing.

Table 5-12 highlights the different methods used to index into the media and their relative frequency of use. To generate this table, we looked at all media playing actions where we could identify the method of access. Not shown are access actions where the media access occurred, but the initiating method was unknown.   Overall, we were surprised to see that slide-level indexing was the most used as this method offered the

fewest number of indices into the media and did not support jumping directly to a topic within a slide.

Table 5-12: Methods used to index into media (when able to determine, 23,298 accesses).

Access Method	All Courses	Ink Density Ranking Among All Courses		
		Top 25%	*25% - 75%*	*Bottom 25%*
Ink	27%	28%	30%	18%
Slide	60%	55%	57%	63%
Timeline	15%	17%	13%	19%

We conclude from this that although ink-level access seems like a good idea, in practice, for college lectures, it does not seem to be heavily used. This might be explained by noting that our system captured the exact time ink was written on the board[8]. What would have been better is if the system captured the time of the beginning of the topic to which the ink refers.

For example, many instructors would write down a comment after discussing it, as a way of wrapping up that topic. In this case, clicking on the ink would not play the media in the desired location, but rather at the end of the material. Because not all instructors were consistent (some would write before they spoke, others after), we assume that students found it easier just to start the media at the point the slide was shown, and then just listen from there. In fact, we noticed a learned behavior among several instructors consisting of them making a checkmark next to a foil on a prepared slide before discussing that foil.

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[8] Actually, we used a crude ink-clumping algorithm based on nearness in time and space, similar to, but not as sophisticated as Chiu and Wilcox [18].

An obvious improvement of our system then, would be to predict when the ink written on a slide refers to something that was just discussed or is about to be discussed, rather than always assume that it refers to something that is about to be discussed. Analyzing the audio like Stifelman [73] and adjusting ink indices accordingly might be a good first step toward making the ink more usable. Our work leads us to conclude that providing higher indexing granularity is not as important as providing a higher semantic granularity.

5.4.4 Examining Salvaging Techniques During Study Sessions

Moran *et al.* [53] defines salvaging as "the new activity of working with captured records." Basically, salvaging consists of searching audio or video for key portions of a meeting so that an accurate record of the meeting can be produced. They go on to say that salvaging tools are shown to be valuable for dealing with free-flowing discussions of complex subject matter and for producing high-quality documentation. Recall they introduced two salvaging profiles, based primarily on experience using their system. The first profile, the beginner's, showed that the media was generally accessed linearly, without much jumping around. A later, advanced profile emerged as experience was gained that showed the user skimming and jumping through the audio, only playing back short segments at a time. These profiles from this study were based on one user. In this section, we will examine the salvaging techniques from all eClass users.

Initially, we believed that students using eClass would exhibit an advanced salvaging activity because we felt that the captured media was useful and because were providing many indices into the media. However, the classroom is different from a meeting, and students accessing the notes have different goals than the subjects in

Moran's work. In general, lectures are not free-flowing discussions but more resemble structured presentations. Although the subject matter may be complex, it is the job of the instructor to present it simply and clearly. Finally, the goal of a student accessing the notes is not to create a high-quality documentation of the lecture, but rather to go over details that were not fully understood. Understanding the material might be accomplished by creating a complete record of the lecture, but as we have shown, even if students do this, their average study session durations indicate that they are probably just examining in detail small parts of the lecture.

Further evidence that students did not exhibit an advanced salvaging behavior came when we observed that slide-level indexing was preferred over more precise indexing methods. (Accessing the media at the slide level is not conducive to advanced salvaging.)

We can gain further insight into how the media was used by examining individual access sessions. For our purposes, a media play is completely defined by three characteristics: ST^i_{begin} is the time in the study session that media playback begins for the ith media access, MT^i_{begin} is the initial offset into media for the ith media access, and DUR is the duration of the media played. Because we only provided real-time playback, the time in the study session where the media stops playing and the corresponding offset into the media are simply the respective start times plus the duration. In other words, for a media play, $ST^i_{end} = ST^i_{begin} + DUR$, and $MT^i_{end} = MT^i_{begin} + DUR$.

If there are x media plays in a study session, then there are x-1 media jumps (the first access is not considered a jump) in the study session. We can characterize these

jumps into the media as forward or backward. We define the jump distance for the xth media jump to be

$$JD^x, = MT^x_{begin} - MT^{x-1}_{end}$$

If *JD* is zero or positive, then this is characterized as a forward jump (*FJ*). If JD is negative, then it is a backward jump (*BJ*).

We can now map an individual student's study session to one of the five salvaging techniques presented by Moran *et al.* [53]. If a study session plays media, but has no jumps (#BJ = #FJ = 0), then it is characterized as *StraightThrough*. If a study session has no backward jumps, but has some forward jumps and the sum of all the jump distances is 0 (#BJ = 0, #FJ > 0, ΣJD = 0), then this is characterized as *StopStart*[9]. If a study session has no backward jumps, but has forward jumps and the sum of all the jump distances is larger than 0 (#BJ = 0, #FJ > 0, ΣJD > 0), then this is a *SkipAhead* session. If a study session has no forward jumps, but has backward jumps (#BJ > 0, #FJ = 0), this is a *Relisten* session. Finally, if a session has both forward and backward jumps (#BJ > 0, #FJ > 0), then this is characterized as a *Non-Sequential* session.

Finally, we can further characterize each session (rather than each action) by the method used to play back the media during that session. We provided three ways of initiating a media playback (ink, slide, timeline), but occasionally we were unable to identify how a student indexed into the media. The reason for this is that we have logs of

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[9] Our access interface did not provide a pause/restart option for students. Although our third party media player allowed for pausing and restarting, we were unable to log or otherwise detect this activity.

student sessions from older interfaces that were not equipped to capture this information. This gives us five types of session characterizations; the four just discussed: *ink*, *timeline*, *slide*, *unknown*, and a session containing two or more methods of indexing into the media: *mixed*. We further detailed mixed into four categories, *mixed(ink)*, *mixed(timeline)*, *mixed(slide)*, and *mixed(unknown)*, based on what was the dominant access method.

We were able to categorize the primary media access method for 4,616 access sessions. This is slightly less than 1/2 of all sessions that utilized the media. The reason for this is due to inconsistencies between our logs and the Real Server logs. Depending on the version of the media playback client used, the Real Server did not log the duration of media played. In generating session summaries, we ignored those sessions with indeterminate media duration. This typically occurred when a student accessed the system with an older client.

For each session we could categorize, we then determined the salvaging technique used. We start our analysis in this section by looking at the average number of media jumps per access session, and the frequency of forward and backward jumps.

Of the 4,616 access sessions 2,426 of them had at least one media jump for a grand total of 3,942 media jumps. There were 2,492 forward media jumps and 1,450 backward media jumps. A typical media access session had an average of 0.54 forward and 0.31 backward media jumps. For sessions with at least one media jump, these figures increased slightly to 1.8 and 1.3 respectively. MANIC [71] found in their analysis of student access sessions that forward jumps were seven times more likely than backward jumps. Although we found forward jumps in the media to be the most common, we

observed that they were only 1.7 times more likely, indicating a need for an access interface that supports both kinds of media jumps.

Figure 5-28 shows a histogram of media jump distances. The jump distances appear to be clustered around zero, but 53% of all media jumps are to a point more than 10 minutes forward or backward from the current point in the media. This indicates that students might be exhibiting more of a random access behavior (conducive to salvaging behavior) instead of playing the media straight through.
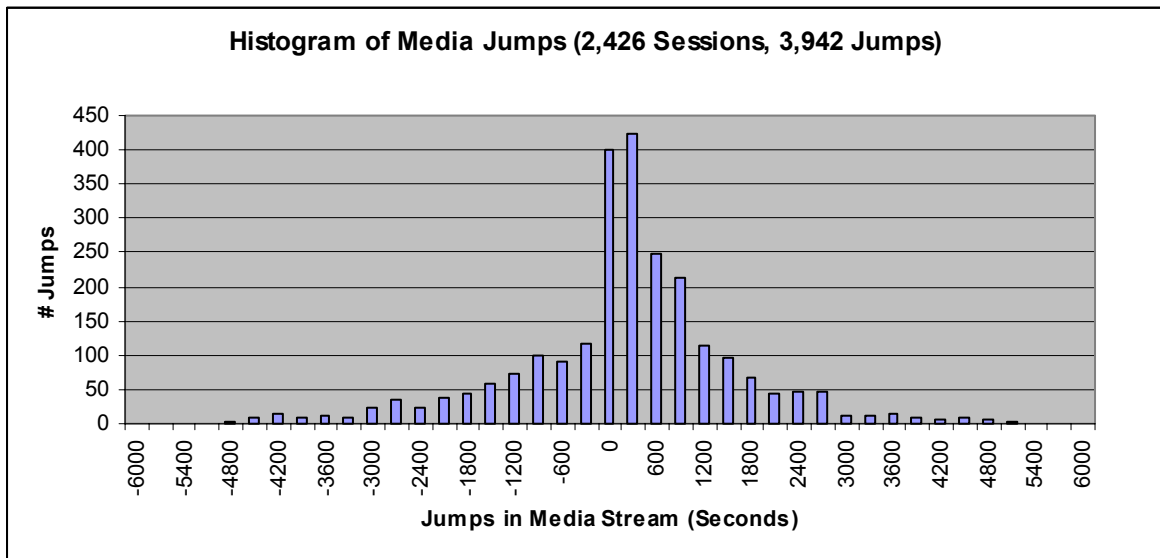
Figure 5-28: Distribution of jumps in the media. Negative values indicate backward jumps.

To better understand the salvaging activity of the students, we now look at the distribution of media access methods for each session. As shown in Figure 5-29, sessions where the media is indexed at the slide level are the most common, and also account for nearly 60% of the *mixed* sessions. Recall in Table 5-12, we listed the relative percentages for media accesses. In that table, *unknown* accesses were not accounted, and

the data listed represents individual accesses. In Figure 5-29, we are showing the classification of sessions. Though not immediately apparent, the relative percentages between *ink*, *slide*, and *timeline* individual accesses are nearly the same as the relative percentages between *ink*, *slide*, and *timeline* sessions.
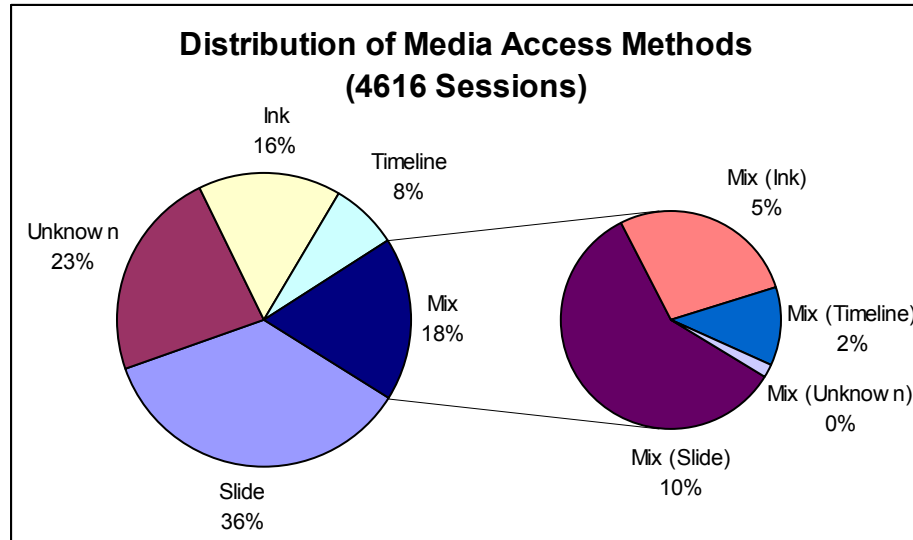
Figure 5-29: Distribution of media access methods, classified by sessions.

As stated earlier, we expected to find different salvaging techniques depending on the method of media access. Accessing the media at the slide level does not offer as many indices as accessing the media from the ink level, hence we would expect to see fewer jumps, and hence, less salvaging activity from slide-level accesses.

Figure 5-30 shows that surprisingly, over 62% of the media access sessions overall exhibited the *StraightThrough* salvage technique. It is interesting to note that *StraightThrough* was preferred regardless of the primary media indexing method. However, looking at sessions that used mixed media accessing methods shows that students in these sessions were more likely to jump around in the media stream. (It is not

possible to have a *StraightThrough* session with mixed media accesses because by definition, mixed access means more than one media play.)
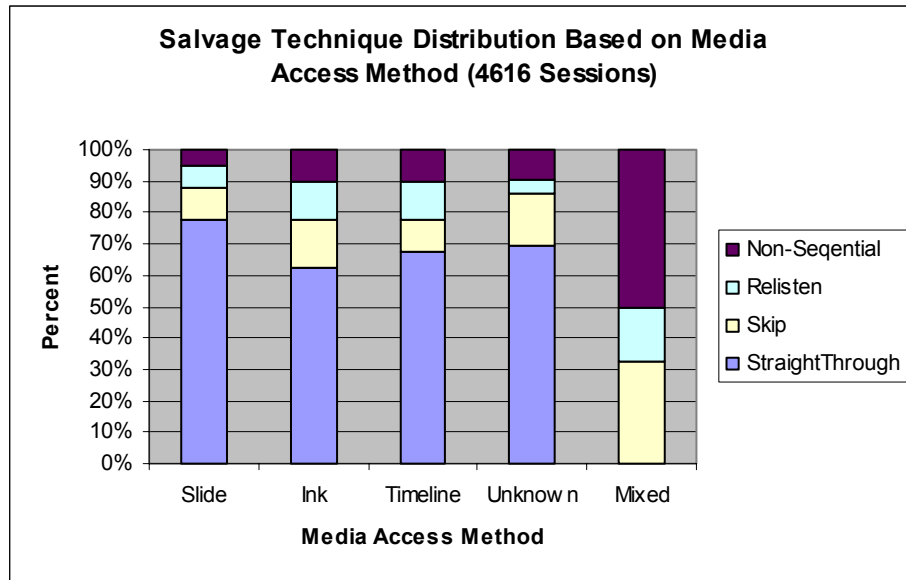
Figure 5-30: Distribution of salvage techniques based on media access methods used.

We concluded earlier that the indices provided at the slide-level granularity are sufficient for most student study sessions. When students use only one media access method, they generally just play the media straight through without much jumping around. However, if students use different media access methods in the same study session, we find that they tend to favor slightly a *Non-Sequential* salvaging techniques in their study. We do not know if a particular salvaging technique is 'better' than another for student learning. Such a study is beyond the scope of this thesis.

5.4.5 eClass is used for Exam Cramming . . . and More

Figure 5-31 shows a summary of session distributions for a typical course throughout the entire quarter. Overall, for this course, the number of access is fairly stable, around 30 accesses per week. The low points on the graph correspond to weekends where accesses are typically lower. The three sharp peaks in access occur around exam dates (two general exams and one final exam). Not surprisingly, as most students cram for exams, the system gets the most use around the time of exams.

What is also significant about this graph is that there are multiple peaks. The first peak shows the students used the system as a study aid for exams. The second and third peaks indicate that the students found the system useful as a study aid for the first exam and that they want to use it to help study for the upcoming exams. If the students did not feel like they received much benefit from the system, the second and third peaks should not be as pronounced.

The study session profile for cs4390 is not atypical. In fact, ANOVA tests show that the time between an exam date for a course and the date of a study session is one of the strongest predictors of note access $(F(1/659) = 29.68, p < 0.005)$ with 43% of all accesses for a course occurring within a week of an exam for that course.
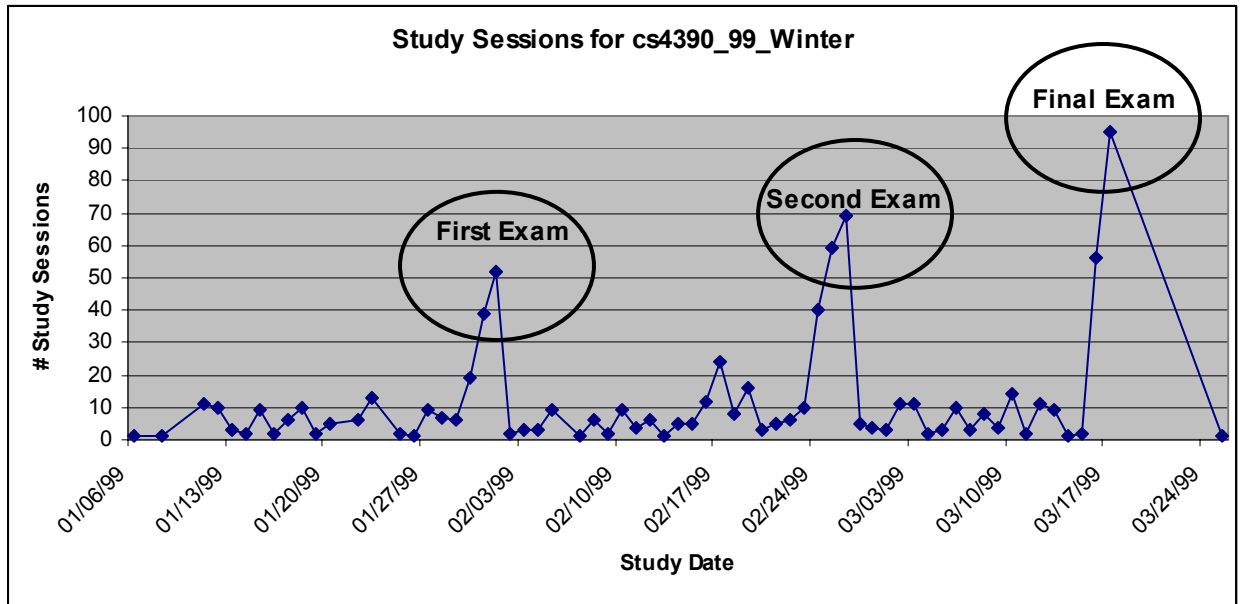
Figure 5-31: Access sessions for a typical course from the beginning to the end of the course.

We have looked for other correlations for note accesses as well. Among them include the amount of ink written for a course or a lecture, the instructor's experience with eClass, the student's experience with eClass, student opinions of eClass, if a course uses PowerPoint slides, and the nearness to the lecture.

We thought that the amount of ink written for a course (measured in number of pixels) might be a predictor of how many times the notes for that course were accessed. The data looked promising, and on first glance appeared to support this claim (Figure 5-32). Regression tests indicate that although we have failed to show any statistically significant correlation at our confidence level ($F(1/92) = 3.60$, $p = 0.061$), the data suggests that some correlation might exist. We then thought that perhaps the correlation might hold at the lecture level; a lecture with lots of ink might be accessed more than a lecture with little ink. At the lecture level, we were unable to find any correlation ($F(1/398) = 1.07$, $p = 0.30$).

Study Sessions Per Course Ordered By Ink Density
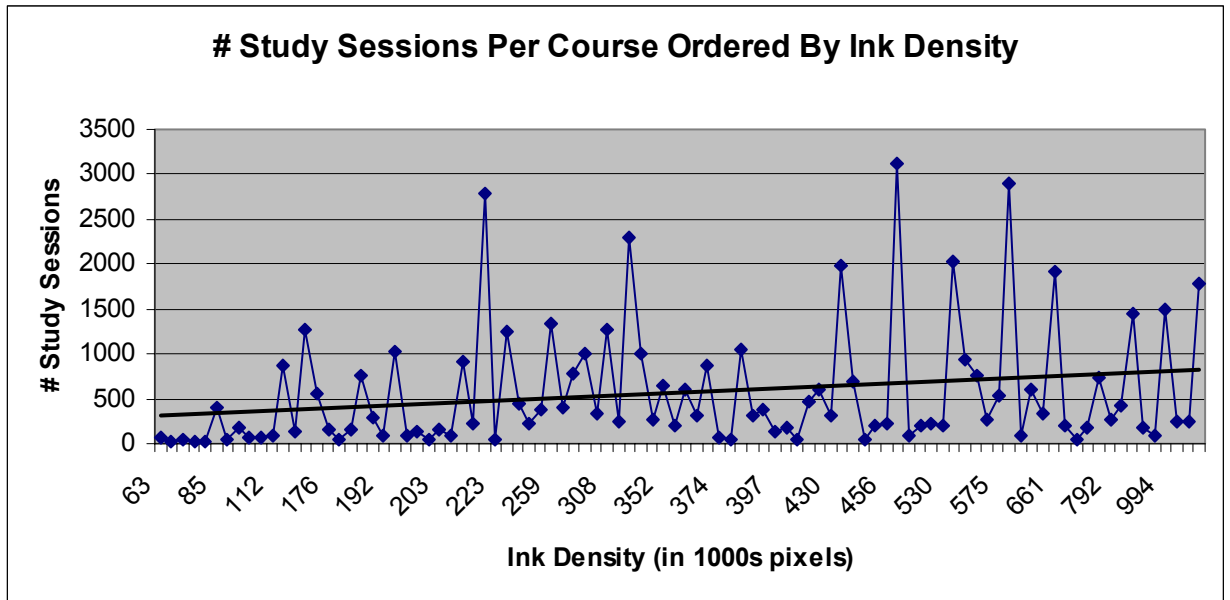
Figure 5-32: The number of study sessions increases gradually as the ink density for a course increases.

It seems likely that courses containing students who have a high opinion of eClass might have more accesses than other courses. We looked at courses whose students rated eClass favorably on the questionnaires and compared their accesses to those courses whose students were not as praising of eClass. We used responses from two questions to gauge student opinions. The first question was whether eClass made the lectures more engaging, and the second question was whether eClass helped them pay more attention to the lectures. We were unable to find any correlation between student opinions of eClass (based on these two questions) and the amount of note accesses ($F(1/27) = 0.62$, $p = 0.435$ and $F(1/45) = 0.03$, $p = 0.851$).

We were also unable to find any correlations between accesses and student experience with eClass, but we could establish a correlation between accesses and the instructor's experience with eClass. Figure 5-33 shows that as the number of semesters an instructor used eClass increased, so did the number of accesses the courses they taught

received ($F_{(1/93)}$ = 14.86, p < 0.005). It is unclear as to why this trend exists, but we think it might be related to the instructors with experience using eClass depending on the system more or using it more effectively. As a result, instructors with prior use see the benefits of students using the system and as such, make sure that the students use it more.
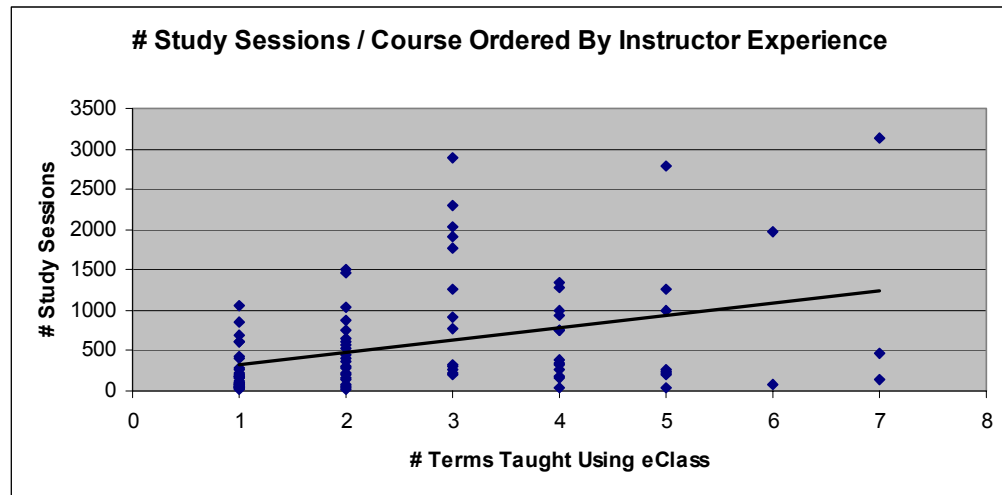
Figure 5-33: As instructor use increases, so does the number of study sessions.

We also found that courses that contained PowerPoint slides seem to have more accesses than courses that do not use them. Specifically, as the percentage of slides using PowerPoint increased, so did the number of access sessions to those lectures ($F_{(1/51)}$ = 8.33, p = 0.006). This is most likely the case because as the instructor uses more prepared information, it is easier for the students to access them on the Web than it is for them to copy down the slides.

Finally, we also discovered that accesses to a lecture are more likely to occur within a week of that lecture ($F_{(1/912)}$ = 121.98, p < 0.005). In fact, as Figure 5-34 shows, nearly 1/3 of all accesses to a lecture occur within a week of the date the lecture

was given. This is not so surprising when we recall that 54% of students said they were accessing the notes to review an attended or missed lecture.
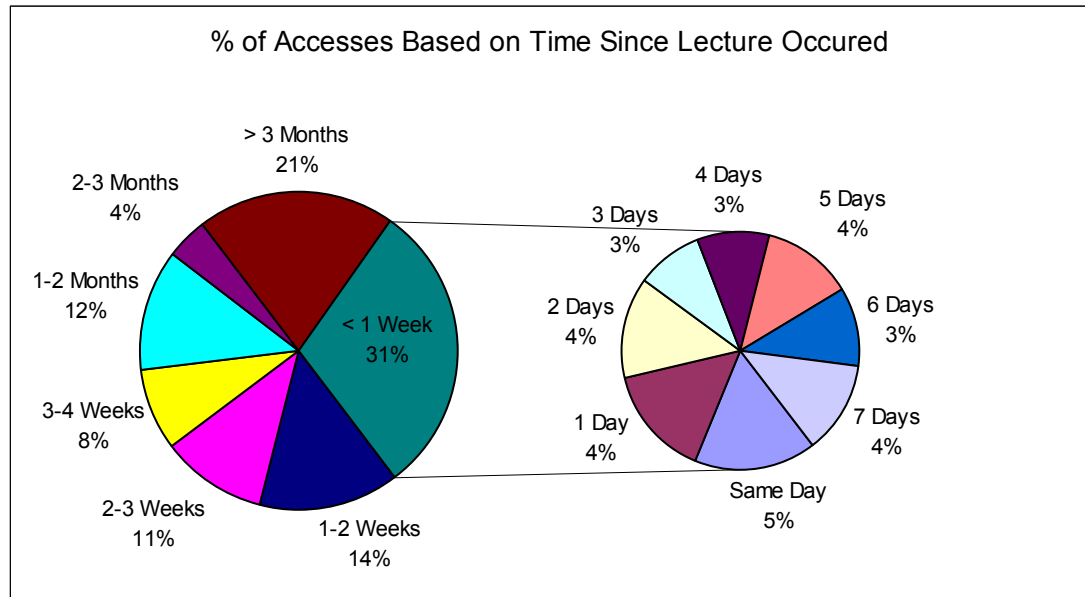
Figure 5-34: Distribution of access to a lecture.

To recap, we found four factors that determine online note accesses. The first two are the nearness to the lecture being accessed and nearness to the exam for the course. Additionally, instructor experience correlates positively with accesses, as does PowerPoint use or having prepared slides for a lecture presentation.

5.4.6 Future Accesses

Into our second year of research, we started to notice an interesting phenomenon. We found that lectures were being accessed after the course was long over. At first, it was just a small amount of accesses that were viewing older courses, but over time these slowly started to increase. We call these accesses 'after term' accesses because they occur after the term in which the class was taught.

Student questionnaires revealed that although 23% of students disagreed that they would access the notes at some point in the future, 46% of students indicated they would (689 Tech, 196 KSU responses). Table 5-13 shows that after-term accesses indeed occur.

Table 5-13: In-and out-term access summary.

Term	In-Term Accesses	After-Term Accesses	Average New Access / Semester	% After Term
Fall 98	4,357	989	198	18%
Winter 99	10,595	3,205	801	23%
Spring 99	8,163	1,854	618	19%
Summer 99	211	27	14	11%
Fall 99	9,702	899	899	8%
Spring 00	8,878	-	-	-

In fact, looking at all of the study sessions, we find that 21% of them are after term accesses. We reasoned that such a large percentage of after term accesses occurred because of the same course being offered in a later term. For example, a student might look at the materials for the same course taught the previous year. As it turns out, 77% of after term accesses are for courses that are not being repeated at the time of access. Said differently, less than 1/4 of after-term accesses occur because the same course is currently being taught (see Figure 5-35).

What this means is that after term accesses are legitimate and not just because of repeat courses. This indicates the importance of keeping lecture note repositories long after the course has completed. Testimonials from students who took classes taught in previous years are further evidence that the captured lecture notes continue to be of value to the students.

Breakdown of Accesses
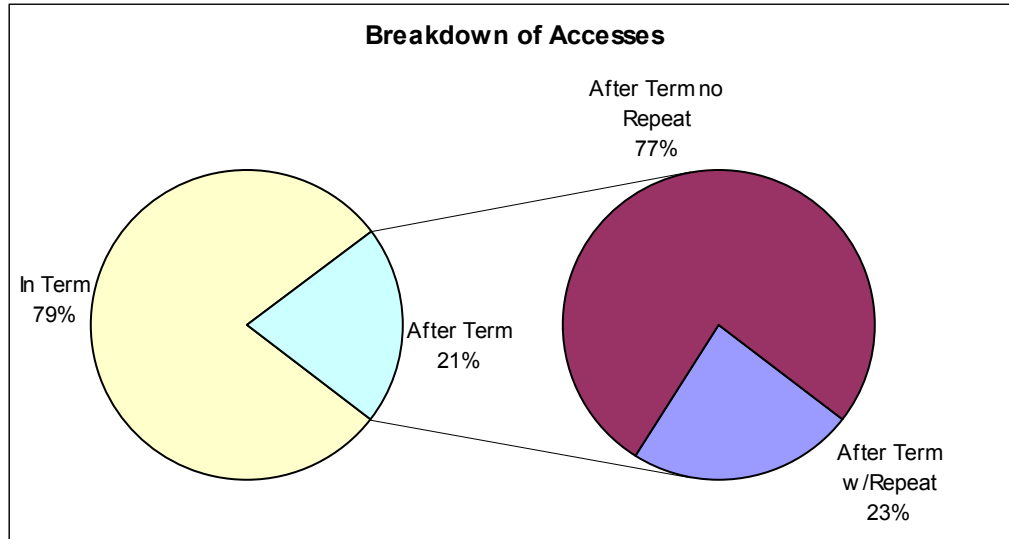
Figure 5-35: Breakdown of in- and after-term accesses.

5.4.7 Note Use Conclusions

In this section we showed that the online notes are used and that audio augmentation is desired and useful. We demonstrated that students find value in printing the online notes, even though they lose much of their functionality in printed form. We have seen that the notes are mostly used to review lectures shortly after they occurred and for exam cramming. Other factors that influence how much the notes for a course are accessed include the experience of the instructor and whether or not the course uses prepared slides. Finally, we showed that the notes have a usefulness that goes beyond the semester in which they were created, and not just because of repeat courses.

5.5 Impact on Teachers

In this section, we turn away from the students and look at the impact of eClass on the instructors. From the beginning of the project, we have relied on close

communication with the teachers. Most of the initial users of eClass were either working on the project or researchers in our larger group. As a result, there was a tight loop between instructor feedback and development of the system. This has been both a blessing and a curse. It has been a blessing because we were quickly able to build a system that fit a minimum set of needs for instructors, but a curse because we did not feel the need for more formal interaction and evaluations. Hence, many of our observations in the section come from frank discussions with instructors in informal settings. We have since performed formal questionnaires and interviews, but we cannot stress enough how useful it was to be immersed in the study with the instructors. Their guidance and feedback, though not well documented, was critical to the success of eClass.

5.5.1 Overall Effects

In general, we found instructors were happy to experiment with eClass and that they welcomed the use of technology in the classroom. For most, it was seen as a genuine effort be a better instructor. As anticipated, many instructors had a low tolerance for startup work before class. They wanted to walk into the classroom and just have everything working. They also did not want to engage in much effort preparing slides for use with eClass. Because we foresaw this requirement, we were able to quickly meet it and attract new users. What little extra work we did require was perceived as 'acceptable.' Recall that we spent great effort to make the system 'walk up and use' and despite this, instructors wanted still easier startup and integration!

When we asked instructors (16 responses) whether they felt like their workload increased using eClass we found that 31% of them agreed, 12% disagreed, and 57% said that it stayed the same. However, when we looked at the workload involved with giving

specific lectures (presentation, exercises, group discussion, project discussion, student presentations, pre-exam reviews, post-exam reviews), we found that only when instructors gave presentation-based lectures did they feel their workload increased using eClass. Additionally, of those who indicated that the workload increased, 80% said the extra work helped them to give better lectures.

eClass was able to accommodate instructors who had prepared slides and those who simply wrote on a blank board. The system was perhaps easier to use without prepared slides, but as we have shown, students tend to access more those lectures with prepared slides than those without. eClass was also perceived as being better than just handing out printed copies of the lecture before class. One calculus instructor mentioned that she preferred eClass to handing out prepared slides for two reasons. First, she estimated that about 30% of the problems she worked on the board were proposed by students in class, so it would not be possible to prepare these problems. Second, she felt that it was more important for the students to see her think through a problem then to simply solve it. Solving the problem in real time using eClass assured her of this.

Not surprisingly, the instructors using eClass felt that it helped the students. Some professors thought that taking fewer notes would help them, others reasoned that they should be able to pay better attention, but most summed it up as follows,

> *Students don't always catch everything. I use eClass to give them a chance to go back and listen again, connecting my notes, audio, and their notes together.*

Instructors report this feeling being reinforced by positive comments from students, and in some cases, students demanding that the professor use eClass! We found

that the more structured the subject matter, the more the instructor felt that eClass helped their students.

Most of the instructors did not feel compelled to visit the captured lectured notes other than to 'make sure everything got captured.' However, a few indicated that they have looked at presentations given by other instructors when teaching new material, or when preparing for a lecture. One professor indicated that teaching a new course was much easier due to the captured notes of a previous professor because she could see clearly the topics discussed and how they were integrated and presented.

During an interview, one instructor indicated that she did not see eClass as a substitute for attending class, but that she did not fear the next time she had to cancel a class because she could point the students to the captured lecture instead. Although admitting that it was not ideal, she concluded that, if necessary, it was better than nothing. Recall that we found this sentiment echoed in the student responses.

eClass definitely forced instructors to modify their movements in the classroom. eClass only had one markable surface, the electronic whiteboard. As a result, many instructors reported feeling tethered to this display. This was actually a learned effect. In the beginning, instructors, used to having an entire wall as a writing surface, would walk away from the board during the explanation of a topic, only to have to walk back over to it to continue with the lecture (marking and slide navigation controls were only available at the electronic whiteboard). Eventually, instructors stayed closer and closer to the corner of the room where the whiteboard was located. This was almost universally regarded as a bad thing, but one instructor felt that he could navigate around the room with smart use of the extended whiteboard displays. Clearly, the lesson here is that

eClass needs to support multiple writing surfaces and provide the ability to navigate the lecture from any location.

eClass also caused instructors to modify how and what they wrote in class. Some of these changes were because of the technology, and others were more of a result on how the system functioned. The electronic whiteboard was smaller than most whiteboards and had a lower resolution. As a result, many instructors would try to fit complete problems on one slide whereas without the technology, they would use multiple whiteboards. A few instructors complained that this caused their presentations to be more linear and not as random as they would prefer.

A similar complaint was that it was harder to build slides because creating successive slides which build on previous materials loses the annotations between slides. Another example of this occurred because eClass only captured what a slide looked like at the end of a lecture. If a marking was erased, it was forever lost in the captured record.

The lower resolution of the whiteboard caused many instructors to work on improving their handwriting. Many reported writing slower and more deliberately. Some instructors reported using colors to help compensate for this deficiency, but the only real solution is to employ higher resolution writing surfaces.

Some changes were brought about not due to the technology, but rather in the way that our classroom was implemented. For example, many professors reported changing how they lectured because for the captured ink to be useful, they needed to have it written before they talked about what they were writing. So, if an instructor makes an important point during class, unless he indicated with ink the topic he was discussing, it was harder to find that segment in the audio.

Also, having audio tied to the ink enabled instructors to fill in more details on slides while talking about them, without having them all prepared in advance. Many instructors reported creating more 'bullet-style' presentations because they felt more comfortable elaborating them verbally in class knowing that the audio was being captured. Not all instructors valued this approach, but many conceded that they were producing (before class) sparse slides and leaving room for in-class annotations.

Despite all of these effects, all the instructors surveyed said they would continue to use eClass. The system was viewed by instructors as more of an asset to the students, and worth the extra inconvenience to the instructor. We feel that this is so because instructors could use eClass without needing to use special software to prepare slides. (Of course, those instructors who simply wrote on a blank whiteboard had no extra preparation costs because of eClass.) We catered to PowerPoint users, to be sure, but instructors who used other foil presentation software could integrate their materials into eClass if they wanted. It was better for them to have the extra conversion effort than to have them use a different presentation package altogether.

5.5.2 Instructor Use of eClass and the Impact on Students

How an instructor uses eClass does not have that much effect on how the students feel about or use the system. Of course, we have already shown that PowerPoint use and instructor experience are positively correlated with increased online note access, but beyond that, there is not much effect. To illustrate this phenomenon, we will highlight the courses taught by one particular instructor, Dr. X.

Dr. X was aware of eClass and was among the first to teach using it. He has seen (and influenced) the system evolve and has used it in most of its incarnations. Traditionally, Dr. X would teach classes by writing on the whiteboard, and, he began using eClass in the same fashion. Starting in 1999 however, he began using PowerPoint slides and annotating on top of them instead of just writing on a blank whiteboard (see Figure 5-36). Dr. X indicated that his change in teaching style was due to teaching a different set of courses, and that if he were to go back to teaching the courses he originally taught using eClass, he would again change his teaching style to more writing on a blank whiteboard.
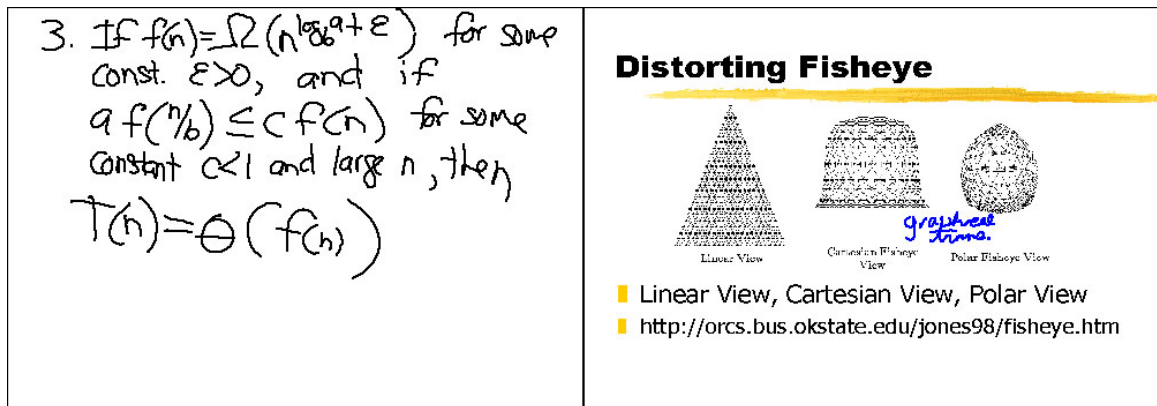
Figure 5-36: Example slides from Dr. X's two different presentation styles.

Representative slides from each teaching style are shown in Figure 5-36. Before using PowerPoint, each lecture taught by Dr. X had an average of 9 slides and an average of around 28,896 pixels. After using PowerPoint, his slide count jumped to an average of 23 and ink pixels dropped to an average of 6,625 pixels per lecture. This is shown graphically in Figure 5-37.
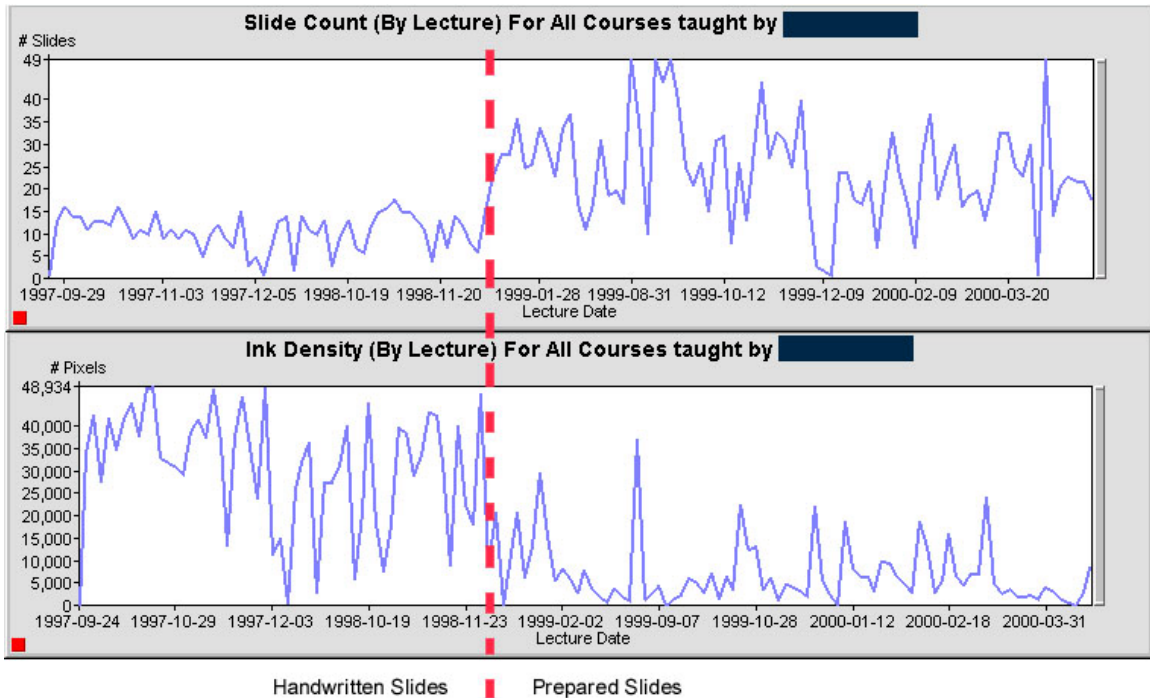
Figure 5-37: Slide counts and ink density metrics comparing Dr. X's two teaching styles.

Looking at the access logs for Dr. X's course shows that the students were relatively unaffected by his change in lecture style. Dr. X's courses averaged 458 accesses per course before his change, and jumped to 1,091 afterward. This is to be expected as we have shown that accesses increase with instructor experience and PowerPoint usage. However, the average number of media accesses before was 250 per course, and afterward, 260 per course. Students printed the notes an average of 115 times per course before and an average of 89 per course after. We were unable to find any significant difference (other than the number of accesses) in how students accessed Dr. X's captured lecture notes between his two different lecturing styles.

We were also unable to find any statistically significant differences in student questionnaire responses between his courses either. Although students in his courses

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with PowerPoint slides were generally more favorable of eClass, the differences were slight and not significant.

We were unable to find any differences in student use or opinions of eClass based on whether Dr. X used one teaching style over another, we cannot tell how it affected the students *during* class. Dr. X suspects that students might be more apt to daydream or miss class since he switched to the PowerPoint lectures, but we have no way to investigate these observations.

5.5.3 Teacher Impact Conclusions

In this section, we have shown that teachers are generally happy to experiment with eClass, but that they have a low tolerance for an increased workload. Despite this, the instructors that report having an increased workload report that they feel the extra effort causes them to give better presentations. We have shown that instructors say eClass provides a positive service to their students, and that the instructors will occasionally look at captured lectures from different teachers to aid in course preparations.

eClass does cause instructors to modify their writing and walking habits, causing them to create sparse foils and write down information before they discuss it. Instructors also feel tethered to the electronic whiteboard as it is the only writing surface. Still, instructors find eClass useful, and they are willing to keep using it in their classes.

CHAPTER VI

ATTEMPTS TO GENERALIZE CAPTURE AND ACCESS

At this point in the thesis, we have discussed the motivations behind eClass and why we needed to build a living laboratory to evaluate it. We saw how capture and access applications can be broken down into four phases (pre-production, capture, post-production, and access), and how we can treat information to be captured as a time-stamped stream of activity. We then showed how we built and evolved eClass over a four-year period. We have examined the difficulties in building applications in living laboratories and we have detailed the results of our evaluation.

In this chapter, we will see how we have begun to extend capture and access into other domains, and then how we can generalize it further into everyday objects. Along the way we will see how this has led to the idea of capture histories. Next we will discuss some visualization techniques and our opinions on providing effective access interfaces. This will lead us back to eClass, where we conclude with what we could have done better, what we did wrong, and what's left for the future.

6.1 Extending Capture and Access to Other Domains

Many of our everyday activities can benefit from access to previous captured experiences. Vannevar Bush was perhaps the first to write about the need for a generalized capture and access system when he introduced the concept of Memex [15]. Memex was intended to store the artifacts that we come in contact with in our everyday lives and the associations that we create between them. In our research group, we have

looked at how the capture and access of experiences can assist people in college lectures, academic conferences, software engineering design meetings, and impromptu meetings.

Capture and access made sense in the classroom, and as we have shown, it proved to be valuable. But the classroom is a very specialized circumstance. For starters, it is a very structured environment with well-defined roles and activities. This aids automated capture because we can take advantage of the structure. For example, classes occur at fixed meeting times in fixed locations. The material to be captured also exhibits structure; lectures consist of a collection of slides, usually prepared in advance and each slide usually has a title and several foils.

We found that eClass did not experience the same amount of use in meeting environments as compared to the classroom. Meetings generally have less structure than lectures, are usually led by a different people with dynamic roles, and in particular, we found that users were less tolerant of extra start-up work because, unlike the classroom, the benefit of capture is unclear. Workers don't often get quizzed or take tests based on materials presented in meetings.

In extending capture and access to other domains we have found five main barriers to informal capture and access applications.

- **Start-up cost**: To capture informal activities, there needs to be little or no start-up cost to the end users on the capture side.

- **Transparent interaction**: Ubiquitous computational services, such as automated capture, should be available whenever and wherever desired but enabled in ways that do not distract from everyday activities.

- **Lack of structure**: Informal settings generally have no predetermined structure, and can occur anywhere with any set of people and at any time.

- **Effective retrieval of captured experiences**: Because informal settings are not well defined, constructing an efficient and effective access interface is more difficult.

- **Demonstrated need for access of captured materials**: There is no point in capturing information if it is not going to be accessed.

Start-up cost and transparent interaction are issues related to capture. The lack of structure and the need for effective retrieval end up being access problems. The need for access of captured materials is required, but it does not otherwise affect us because we are assuming that this condition is already satisfied.

6.1.1 Supporting Informal Capture with DUMMBO

Firm believers of practicing what we preach, we tried to use eClass in all of our situations where a whiteboard was used. We quickly discovered that eClass was unsatisfactory in supporting meetings and free-form interactions. The start-up cost, though small in the classroom, was considerably higher in the meeting rooms and totally inappropriate for spur-of-the-moment gatherings. Because eClass relied on the structure of the classroom, it was often cumbersome to use in meeting environments. Most significantly, there often was not any benefit to the person doing all of the capture, as they were not likely to accesses the captured record. To address these problems, we created DUMMBO, a **D**ynamic, **U**biquitous, **M**obile **M**eeting **BO**ard.

Our intent with DUMMBO is to support more free-flowing, opportunistic situations, typified by informal spur-of-the-moment meetings in which a group of people brainstorm and document through the use of a whiteboard. In this situation, it now

becomes important to capture and interpret some contextual information to infer some structure in the free-flowing meetings and to facilitate effective review during the access phase.

DUMMBO is built to support group meetings that use a whiteboard. Our goal is to allow people to use a whiteboard in exactly the same way that they use any traditional whiteboard, while enabling the whiteboard to capture what is written on it. To enable an everyday device with capture capabilities, we need to augment the device or create a replacement for it. Electronic whiteboards are replacements for traditional whiteboards and allow for more powerful interactions such as cutting and pasting ink, emailing the contents of the whiteboard to someone, and erasing the screen with the push of a button. Augmenting the devices allows for much more powerful interactions, but it also increases the complexity of the device, often to the point where it is difficult for an untrained user to use the device. We want to enable everyday devices with capture capabilities but in a way that traditional use of the device is all that is required.

For most applications, the new interaction techniques with physical objects that must be learned are tolerable and make the device more powerful while retaining the familiarity and appeal of the physical object. DUMMBO was designed to explore a whiteboard application that has capture capabilities without need for user training. In fact, users of DUMMBO do not ever have to know they are interacting with any computational device.

Figure 6-1 shows the physical interface of the whiteboard environment we have created to support the kind of scenario described above. The interface is primarily a

plain-looking whiteboard. Also notice the rear of the whiteboard; the computer and audio

recording equipment is hidden from view.
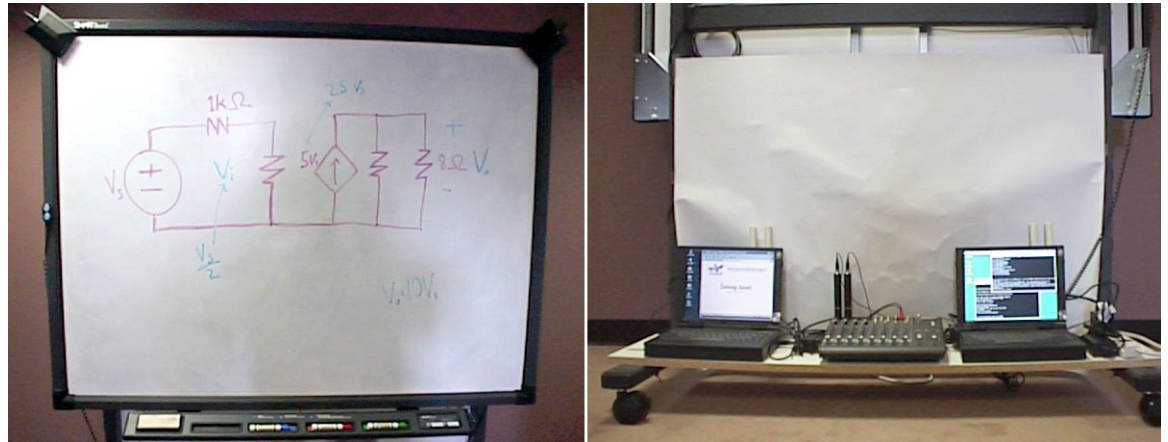
Figure 6-1: (Left) The front of DUMMBO. Notice the lack of any buttons, computer screens, or cameras. (Right) Rear-view of DUMMBO. The computational power of the whiteboard is hidden under the board behind a curtain.

DUMMBO consists of a digitizing whiteboard writing surface, microphones, and

a laptop computer that encodes the audio from a meeting and that records the writing and

erasing activity of the digitizing whiteboard surface. We used a SMARTBoard from

Smart Technology, Inc., that uses real dry erase markers and a real eraser. It looks and

functions exactly like a whiteboard except that unlike a traditional whiteboard, it has a

serial computer interface that makes it easy for a computer to record its activity. The

pens and eraser rest in special trays that detect when a tool is removed. Listening to tool

selection events and activity on the digitizing surface allows us to record and eventually

replay activity on the board. Audio is recorded using two high-quality condenser

microphones at the top corners of the whiteboard. The microphones are routed through a

mixer to increase the audio quality. When there is no activity around the board, the audio

is not recorded. When the computer detects whiteboard activity it begins to digitally record audio until a period of sufficient inactivity. The computer then records and relays to a database all whiteboard activity and audio recorded during that session.

The computer is connected to the Internet via a high-speed wireless network. The entire whiteboard package is mobile and fairly easy to roll from location to location. The only tether is a power cord that periodically needs to be attached to the wall to charge the laptop.

DUMMBO was designed be robust and highly automated in order to reduce the requirements on its users. All a group of people need to do is walk up to the whiteboard, pick up a pen and begin to write and discuss. When the meeting is over, they simply walk away. The entire session has been captured by DUMMBO. Persons who have never used a computer before can successfully capture impromptu meetings by doing exactly what they would do in a non-capture environment.

Once the data has been captured, a display device is needed to access the captured meeting. Figure 6-2 shows a Web interface to access the DUMMBO recorded activities. The user specifies information such as the approximate time and place of a gathering. A timeline of days for the month is displayed with a particular day highlighted if there was whiteboard activity in that day at that place. It can also indicate the people who were present at the board at any time. In this way, you can quickly see at a glance what days had activity. Above the days is an hour timeline that show the actual highlighted times of activity for the selected day. Selecting a session then brings up what the whiteboard looked like at the start of the session. The user can scroll forward and backward in time and watch the board update. This allows for quick searching for a particular time in the

lecture. Finally, the user can access the audio directly from some writing on the board, or request synchronized playback of ink and audio from any point in the timeline.
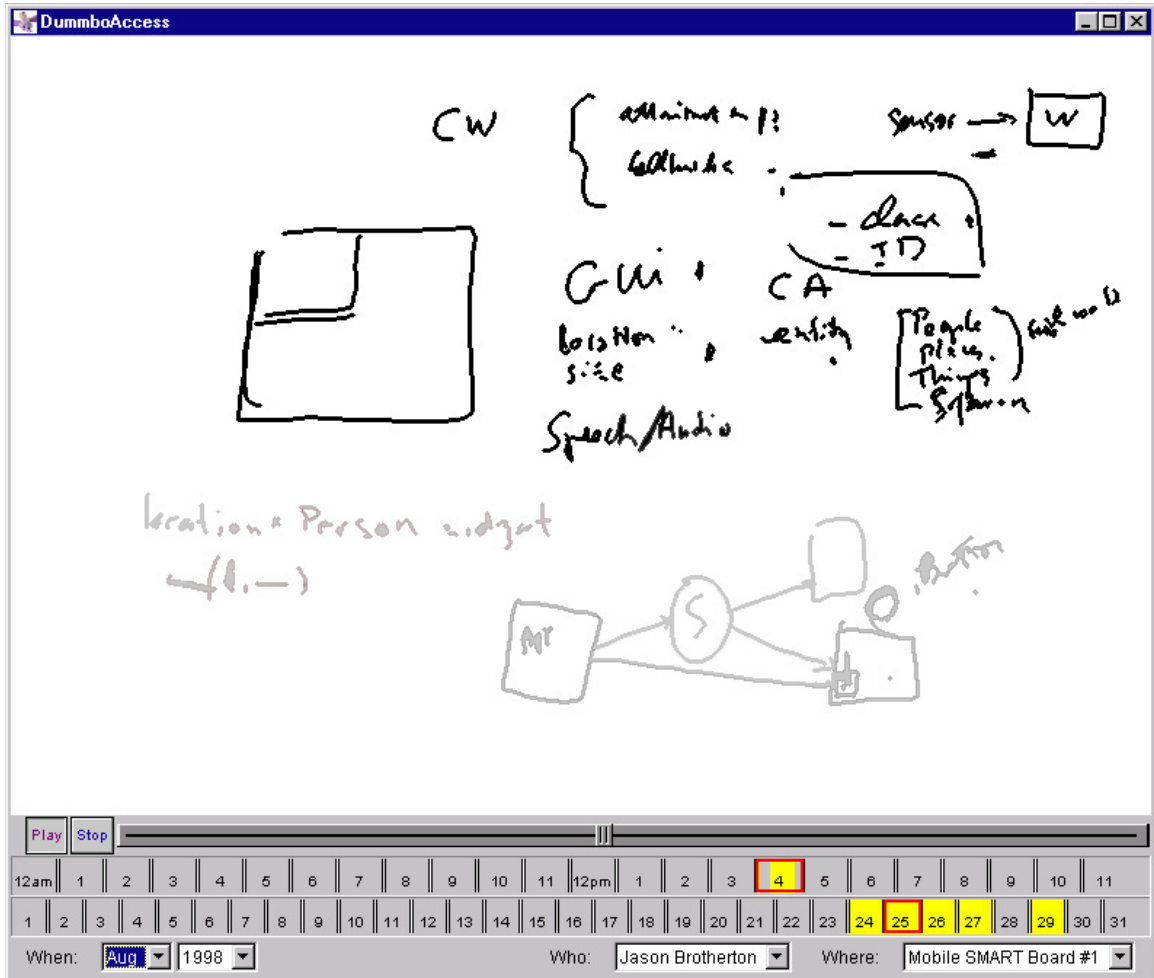
Figure 6-2: DUMMBO access interface. The user selects filter values corresponding to when, who, and where. DUMMBO then displays all days containing whiteboard activity. Selecting a day will highlight all the sessions recording in that day. Playback controls allow for live playback of the meeting.

This access interface shown in Figure 6-2, allows for quick and accurate browsing to answer vague questions like, "What did the circuit look like that Khai drew when I saw him in the afternoon of last week?" In the next section, we will answer more directly

how we addressed the problems of informal capture and access in the design of DUMMBO.

6.1.2 Overcoming Barriers to Capture and Access

Now that we have introduced the DUMMBO capture and access interfaces, we revisit the capture and access problems for informal and opportunistic applications. We have seen that the devices used and tasks performed for capture and access phases differ enough to warrant separate interfaces to support each phase. As a result, we partition the problems discussed in the Introduction into those that occur in the capture phase and those that occur in the access phase.

As we mentioned earlier, the first step in addressing problems that occur in the capture phase is identifying exactly what is being captured. For DUMMBO, we capture and timestamp significant events for an impromptu meeting. These are:

- the audio heard during a meeting;

- three different kinds of strokes: normal ink strokes, erase strokes, and hover strokes (A hover stroke indicates that the user was pointing or gesturing at the board with their finger and not a marker or eraser);

- the arrival and departure of people;

- the beginning and ending of sessions; and

- the location of the whiteboard as it moves from room to room.

These events are encoded and sent to a MySQL server. Because DUMMBO uses a wireless network, it is easily moved on demand. However, continuous connectivity is not always guaranteed, so when DUMMBO is used outside the wireless range, or during network failures, it stores events until the network connection resumes.

Some general principles developed from our previous research in structuring and interacting with data in freeform systems is that the data should not be structured prematurely. DUMMBO uses this philosophy when collecting data. Because we separate the capture interface from the design interface we can delay the interpretation of the captured data until it is time to visualize it during access.

We now address the two specific problems for capture of informal meetings mentioned in the Introduction.

6.1.2.1 Minimal start-up cost

Informal or spur-of-the-moment meetings occur spontaneously. Any barrier to the start-up of tools to capture these meetings (turning on recording devices, initializing programs, etc.) is sufficient to prevent their use. Our experience with eClass is that even for scheduled activities like classes, users are reluctant to spend a few minutes setting up the classroom. More than one user of the system has lamented that without some advance preparation, you cannot just walk in the room and use it. For spontaneous meetings, users are much less tolerant of any start-up time because the meetings are typically quick encounters. A two-minute preparation time becomes more significant for short meetings, plus it distracts the users away from the purpose of the meeting. A capture system should always be ready to record, and it should be able to do so without any explicit actions by the user.

One problem with minimizing start-up cost is figuring out when to start and stop recording without any explicit user commands. In a sense, one would like the whiteboard to be recording continuously. This works well for streams of information that produce no output when there is no activity. An example of such a stream is the pen stroke or ink

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stream created by using a pen. The audio stream, however, does not fit into this approach because the encoding we use (WAV format) does not compress silent recordings or ambient background noise. It is not efficient to record audio all the time, so the challenge then becomes how to determine when relevant audio is occurring and turn on the recording.

Many activities could be used to initiate a recording session: human presence near the board, a sudden and sustained increase in audio levels, and obviously whiteboard activity such as marking and erasing. Detecting audio levels seems like a good approach, however, many environments are inherently noisy and might lead to many falsely recorded meetings. DUMMBO currently begins a capture session whenever it detects a gathering of people around the board (more than two), or whenever someone actually starts writing or erasing on the whiteboard.

To detect presence around the whiteboard, we ask users to explicitly "dock" with the whiteboard using their own Java iButton from Dallas Semiconductor (Figure 6-3). Even though the act of explicitly docking with a whiteboard violates our goals of transparent interaction (see below), we chose the iButtons because in addition to providing human presence, they also provide identity easily and reliably. The explicit act of docking also provides the option to attend a meeting anonymously. The end of a meeting is inferred when there is no whiteboard activity for more than 15 minutes or when the group disperses.
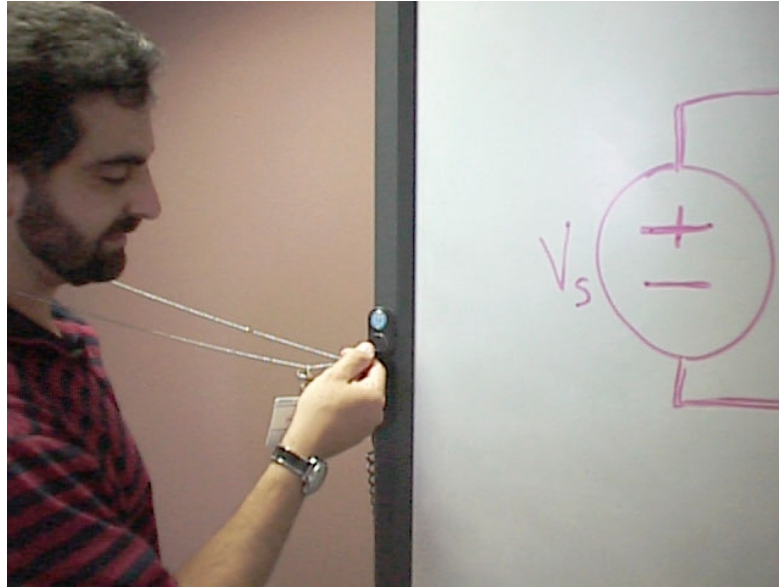
Figure 6-3: A user explicitly docking with DUMMBO to indicate his presence.

6.1.2.2 Transparent interaction.

The goal of DUMMBO is to make the computer invisible to the end user. People are accustomed to drawing and writing on whiteboards with various colored markers, erasing with fingers or an eraser, and possibly affixing items to the board with tape or magnets. Deviation from these standard tools and interactions will get in the way of the everyday activity of brainstorming or opportunistic discussion by unnecessarily bringing into the foreground requirements of the underlying computation. Furthermore, any additional interaction required by the capture system is likely to be ignored unless the cost of learning is minimal and the value-added capabilities are readily apparent and considered valuable.

The approach in DUMMBO is to limit the available activities to exactly match those of a traditional whiteboard. Because DUMMBO only supports the activities that naturally occur on a whiteboard and since it looks and feels just like a real whiteboard,

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the user can be any person who is familiar with whiteboards. No special training (or even awareness) of DUMMBO or computers is required.

There are, however, some problems with DUMMBO. The first problem is improper interpretation of erasing done with the finger, which we have noticed is very common. Since a SMARTBoard operates on a contact-closure surface, the only way to detect which tool (colored markers, eraser, finger) is in use is by when it leaves the pen tray. The correct time to use the finger is when all other tools are in the tray. Frequently, users erase with their finger while still holding a pen. The SMARTBoard incorrectly assigns this activity to the pen, and the system records the finger movements as ink! Better perceptive techniques are needed to determine which tool is being used, and some commercial alternatives use these techniques.

6.1.2.3 Addressing Access Problems

Focusing design effort to minimize start-up costs of capture presents more of a challenge in the access phase. Applications such as eClass have well-defined session boundaries to structure the artifacts produced for access. There is much less explicit knowledge of session boundaries when we aim to support informal and opportunistic meetings. Informal meetings can occur anywhere with any set of people and at any time. That which makes DUMMBO attractive to its end users is exactly what makes it challenging from a design perspective in creating effective access. However, without effective access interfaces and functionality, the entire system becomes much less useful to its end users, and will go unused.

All of the captured data is stored in a database, but rather than have users issue explicit queries to the data, we want to provide a more visual way to search for the

memory they are seeking. One objective in the access phase is to provide visualization techniques that maximize the user's capability to browse for pin-pointing captured activity of significance.

We determined that an effective way for someone to browse captured information was based on what information they are likely to recall on their own. For example, it is likely that rough time periods would be remembered ("I was talking to Jen about this yesterday or late last week after lunch"). It is also likely that you will remember some or all of the other people who were there during the gathering. You may also remember where the discussion occurred. This can be summed up as remembering high-level details about who, where, when, and what for a meeting. Based on this assumption of time, place and colleagues, we designed an interface to the access phase of DUMMBO that would provide easy ways to query the database of captured activity based on those parameters.

6.1.2.4 Inferring structure

The main idea behind the access interface in DUMMBO is to present the captured data such that the user can quickly and easily infer structure. The interface, shown in Figure 2, provides a representation of the whiteboard and of who, where, when filters to reduce the amount of information shown to the user, similar to dynamic queries [4]. A *where* filter picks a location that meetings could have occurred. A *when* filter narrows down the month to be searched. For each month, if any activity was recorded during a day, that day is highlighted. Selecting that day shows another timeline dividing the day into hours. Recorded activity is visualized along that daily timeline. By looking at the

daily timeline, the user can easily infer when meetings occurred. Simple visualizations of people present at various times can further assist who-related inquiries.

The end result of this style interface is that the human infers structure or meaning of the data by visually filtering it using decorated timelines. This helps facilitate searching to find a specific meeting, but doesn't help for understanding the details of the actual meeting.

6.1.2.5 Supporting Effective Retrieval

The purpose for the access interface that we promote is to provide a memory aid for those who were at the live experience. For the most part, these people do not want to relive the entire captured experience. Rather, they would like to locate some relevant part of the experience and play back parts of it. Once the meeting is found, the user must be able to effectively browse it to retrieve specific details.

DUMMBO supports two ways to browse. The first way allows the user to play back a meeting from a specified temporal location. It is desirable during playback to see all of the strokes in advance in a light color and have them animated to their true color as they are being written, as seen in Figure 6-2. Successful playback can be tricky, however, since the whiteboard provides a reusable surface and ink can be written, erased, and re-written several times in the same location. Techniques for detecting when the user is erasing the entire (or a small part of) the board can be used to segment the dynamic "single page" board into a collection of slides. One such technique, not yet implemented, creates a new "whiteboard page" if a certain threshold of ink is erased. The remaining unerased ink is "copied" onto the new page. When playing back the meeting, only

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information from the current page is shown in advance. Other pages can be shown as thumbnail images.

Another style of meeting browsing is based on the content of the whiteboard. In this case, the user is quickly looking through the history of the board for a diagram or certain text. The user can do this by dragging the timeline slider, just like a playback slider for audio or video streams. Once the desired image is obtained on the whiteboard, the user can point to the ink on the whiteboard to index into the audio. If the portion of whiteboard of interest was created over a long period of time, that information can be reflected on the timeline itself. This artifact-centric browsing can reveal different epochs during a session in which the ink of interest was the focus of attention. Examples of this browsing method occur regularly during prolonged discussions over diagrams.

6.1.3 Augmenting Devices with Capture Histories

As we have seen, the capture of information for later access often happens during live situations. These live experiences occur in places with people manipulating everyday artifacts and expressing ideas verbally and visually. In meetings and classrooms, we use devices such as electronic whiteboards to create and manipulate these artifacts along with microphones and video cameras to help to capture some of the verbal and visual activities.

An electronic whiteboard is one example of how a traditional device, the whiteboard, can be augmented to provide a record of its use for later access, in this case, the record is the ink written on it. In our everyday lives however, we use many devices, few of which can capture for us a record of their use. We believe that by enabling common devices to capture their own usage history and to provide structured access to

these histories we can create a new set of ubiquitous computing applications designed to enhance everyday experiences. These applications, made possible by the use of capture enabled devices and special purpose access methods, hold the promise of enhancing our lives by providing access to previous experiences wherever we need it, whenever we need it.

6.2 Approaches to Viewing Large Amounts of Captured Data

Capture and access applications can collect large amounts of information. Effective tools for browsing this data must be implemented, or the capture becomes too overwhelming for access. StreamWeaver was a first attempt at solving the integration and access problems. It attempts to define a media format and then to prepare a presentation of materials recorded in this format.

We have already seen some of the methods we have used to look at captured data repositories. Some of the methods we have implemented include a WICIWYS (What I Capture is What You See) interface (the intial eClass access applet), a less powerful interface that provides access at the lowest common denominator (the eClass HTML notes), and using a database to create dynamic notes based on user preferences (the current eClass access inteface). We have also created interfaces for browsing over non-structured captured information (DUMMBO).

DUMMBO facilitated finding a specific meeting among many unstructured recording sessions, however, the user-controlled playback of that meeting once found was simply a scroll bar. This lead to precision problems when attempting to navigate from within the lecture. To adjust for this, we created a Multi-Scale Timeline Slider as a new technique for the visualization and playback of long media streams that could be

decorated with significant events. Our Multi-Scale Timeline Slider allows users to precisely focus on a specific location in a very long media stream or set of streams based on significant events while also retaining the stream's entire context.

For example, a user might want to review a series of captured meetings that span a period of three months in order to discover what "deadlines" were discussed. This may be accomplished by annotating the video timeline with events marking where the word "deadline" was spoken. Thus, the user requires visualization of such events and control over playback of the stream. Our solution entails a timeline slider that scales time consistently, supports focus + context, and allows control over stream playback.

Traditional approaches to controlling media streams usually involve a simple slider. Moving the slider results in moving to a corresponding part in the media. However, this approach doesn't scale well to large amounts of media. One pixel in the slider might correspond to several minutes of media. For streams that are hundreds of hours, one pixel can represent several hours of media!

We need ways to browse large amounts of media, such as video, yet still have fine control of specific media segments. Infinite focus (and more precise control) can be achieved by using two timelines —one showing the entire media stream, and a second showing a more detailed user-defined subset of the stream. Examples of this are common in video and audio editing programs such as Adobe Premier and Cool Edit Pro. In these programs, the only context preserved is the spatial location of the focus region with respect to the entire media stream. This approach does not scale well to timelines that cover large time periods as clusters of events cannot be distinguished and browsed at different levels of granularity.

Our Multi-scale Timeline Slider (MTS) is shown in Figure 6-4 MTS allows a user to navigate a stream of information and events as well as control the playback of that stream. User controlled, multi-scale zoom is supported through a set of individual timelines that focus the stream context. The user interacts with the timelines by creating focus regions, manipulating existing focus regions, and manipulating the playback control.
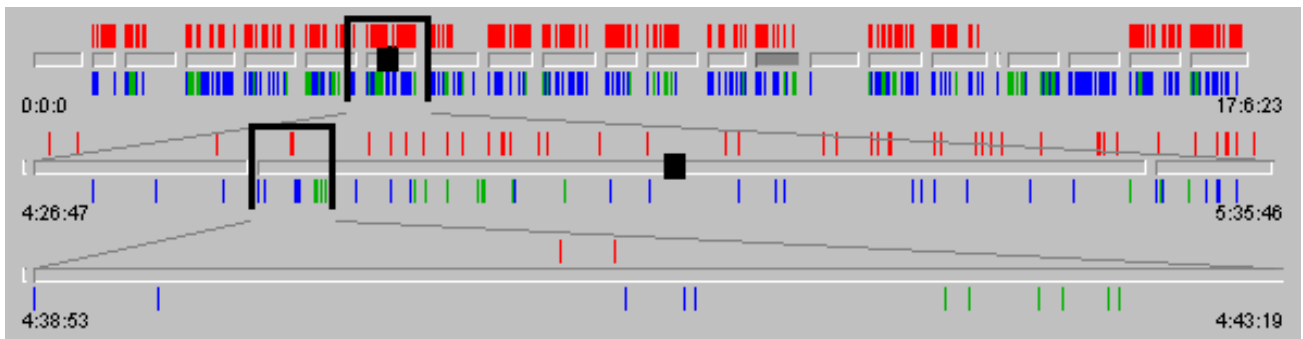
Figure 6-4: An example multi-scale timeline slider. The focus area on an upper timeline determines the lower timeline range. Events that are clustered in the upper timeline are more sparsely distributed in the focused slider in the bottom.

Multi-Scale Timelines.   The visualization consists of a series of individual timelines, where each subsequent timeline is a focused region of the previous timeline. Each timeline represents a series of ordered streams. The recessed gray rectangles on the timeline, shown in Figure 1, represent a stream. Each stream is annotated with events, drawn as colored lines and boxes above and below the stream.

Information is not added as the timeline becomes more focused. However, as focus increases, the individual streams and events spread out and are easier to distinguish.

User-Defined Focus.   The focus regions of the individual timelines are completely defined by the user. Right-clicking on a timeline creates a new, subordinate

timeline that is a zoomed view of a region of the original timeline. The focus region is represented as the area between two sliding bars. Each bar can be dragged to widen or narrow the region of focus. Additionally, the user can drag the whole region using the top bar of the focus region.

Playback Control. The playback of the streams is controlled through a traditional scrub on the individual timelines. The scrub will appear on all of the relevant timelines. Thus, the scrub is always on the topmost timeline, and appears on the lower timelines when it is in those focused regions. Notice in Figure 6-4 that the scrub appears on the top and middle timelines, but not the bottom one. Dragging the thumb in a focused timeline allows the user to specify a location in the media stream with greater precision.

We have demonstrated the use of this slider in a Java application to search a set of lecture audio streams for keywords. This application searches more than 17 hours of audio that contain thousands of events representing keyword locations, web page accesses, and slide accesses. The events above the streams represent keyword locations and the events below represent web page and slide accesses.

Space is an issue in any information visualization. As this widget is part of a larger interface for viewing streams, we want the widget to take up as little space as possible. Currently, each individual timeline vertically takes up 50 pixels. Thus, as more focused timelines are created, more vertical space will be required. We are investigating user-controlled collapsing of the individual timelines, where the context is visible in just a few pixels but interaction is reduced.

There are several other proposed expansions to this widget. The first is to allow multiple focus regions on each timeline. The next level timeline then becomes a

concatenation of those focus regions. This will allow browsing of multiple sections of the timeline at once. The second expansion is to show the temporal relationships between streams instead of just their ordering. This would mean laying out the streams based on their date or time of capture rather than abutting them together.

6.3 What Can Be Improved

There is no doubt that eClass has been a tremendous success for our research group. It has been accepted and demanded by instructors and students and several other researchers have used it. eClass, however, is far from perfect. There is much about eClass is that is now either inefficient or obsolete.

One major problem with eClass is that it was written in Java while the language was still in early development. As a result, we custom built (sometimes not very well) many libraries that are now a standard part of the system. Examples of these routines include our own object serialization, ftp functions, custom GUI components, and network functions. These routines are now easily replaced with the latest version of Java and Swing, Object Serialization, and Remote Method Invocation. As a result, many parts of our system are quite antiquated and inefficient and, ultimately, error-prone.

Reliability has always been a concern. Our software is reliable enough when used properly, but often fails in the face of unplanned events, like network outages. Moreover, the general reliability of eClass is affected when the physical equipment in the room is disturbed, such as audio cables being disconnected, or video cameras being turned off. We could easily improve reliability by fixing our code but, since our recording equipment is located in the classroom, we cannot avoid these types of failures. Therefore, one easy

way to improve our system is to have all equipment located outside the classroom where it is not as easily disturbed.

eClass has a few design flaws, with the major one being our networking model. The result is that eClass can only support one-way interactions between ZenPad and ZenViewer, and there can only be one writing surface (ZenPad) per classroom. Instructors would greatly benefit from the ability to annotate slides shown or to be able to control the presentation from a ZenViewer. Students would greatly benefit from the ability to take their own notes on top of the instructor's notes in real time. We were able to introduce student note-taking devices (StuPad, discussed below), but we had to cobble our system so much that we decided that it would be better just to rebuild the system.

The video quality eClass provides is very low. This was done because it was believed that video would provide more information than audio and therefore be more useful. In order to be able to still provide on-line note access to dialup modem users, we had to encode the video at such a poor rate to make it barely usable. Also, the instructor could not easily control the video cameras. It would have been nice to have camera control from within ZenPad so that the instructor could change camera angles, zoom in when needed, or even turn it off.

Although eClass can use PowerPoint presentations, it does so by creating static images of the presentation. This is fine for most users, but a few instructors have complained about the loss of any custom animations as a result of the conversion. Rather than build a whiteboard that can accept an impoverished version of PowerPoint slides, we should instead have augmented PowerPoint with ZenPad features. At the beginning of the project, however, we did not anticipate the widespread use of PowerPoint and, even if

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we had, we would not have been able to quickly build eClass or evaluate its use if we had chosen that route.

Collaborative Web sites (CoWebs) are quickly becoming commonplace for courses here at Georgia Tech. CoWebs [36], [37] are a collection of Web pages that anyone can edit using just their browser and without being familiar with HTML. We tried to integrate CoWeb technology into eClass with some success. Students and instructors were able to create content and have it linked from the eClass notes, but it required knowledge of HTML and was not very easy to do. We feel that the ability for students to post comments and content publicly was a great asset to eClass and something the students wanted, even if we did not do a good job of integrating the two technologies.

Keyword searching was not heavily used in our system, despite the fact that we think it was easy to use. One reason for the lack of use might be attributable to the ease with which topics could be scanned. For a course, each lecture usually had a germane title and, while viewing a lecture, it is very easy to scan all of the slides quickly. It might be that searching was not needed for students enrolled in a course, but is more useful to other viewers of the notes. One obvious way to improve our searching is to create a topic search rather than a keyword search, but we have not explored that option.

In the beginning of eClass, we wanted to give students electronic note-taking devices. After a few prototypes, we realized that the big win came from supporting the capture of the public information in the lecture first. Once we succeeded in building eClass and having it used regularly, we again turned to incorporating student annotations. This resulted in StuPad (shown in Figure 6-5), a note-taking device for students that had the ability to act like a ZenViewer, but with more navigational freedom [76]. A StuPad

server interfaced with eClass masquerading as a ZenViewer, and then interacted with all StuPad clients. In this way, a StuPad client could receive all the information of a ZenViewer without being tied to the architectural design of eClass.

The only problem with StuPad was in the expensive pen tablet computers that it required. We have since looked at less expensive (and less powerful) note-taking devices and are currently working on a new design of eClass based on a capture/access toolkit we are building. The new design will incorporate all of the improvements discussed above as well as enable future developments that we have not yet specified.
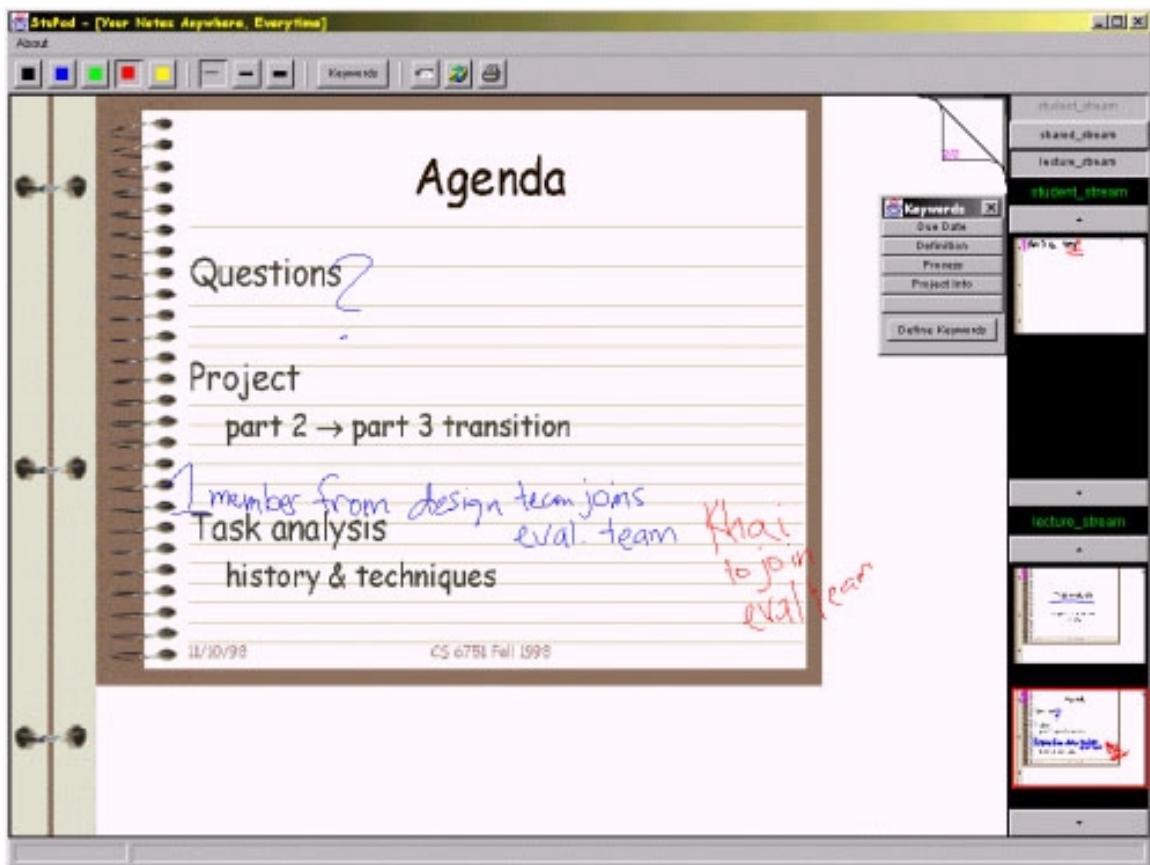
Figure 6-5: StuPad note taking interface. On the right, students view thumbnails of their own notes and the instructor's notes. Students have the ability with StuPad to share notes, take notes on a slide as the instructor is writing on it, and add keywords.

CHAPTER VII

Conclusions

Recall again our thesis statement:

Automated capture in the classroom can provide a detailed record of a lecture in the form of autonomously generated media-enhanced notes that students will regularly access in their review and study of college lectures.

In this thesis, we described the construction and use of eClass, an automated note taking classroom and on-line note access system. We highlighted our efforts in researching capture and access through our experiences with building, using, and evaluating eClass. We have shown that both students and teachers find the eClass technology worthwhile and a useful learning tool. Students feel that eClass helps to make lectures more interesting and helps increase attention. eClass helps to encourage more "summary style" note taking in the classroom, and its use does not result in decreased attendance, but it does relieve students from much of the worry of missing class. Although students report preferring eClass, we were unable to find any impact its use has on exam performance.

We have shown that students prefer eClass to other technological solutions and the eClass is easy enough to use and general enough to be used in a variety of courses with a variety of teaching styles. The online notes generated by eClass are mostly used for immediate lecture review and exam study, but they continue to be used well after the semester ends. We have shown that media-enhanced notes are useful to the students and that audio augmentation of notes is sufficient. Further, despite the increased granularity

that ink to audio link provides, students preferred to index into media streams at the slide-level. We have also seen that privacy is not much of a concern among students, but we have argued that it cannot be overlooked.

In addition to focusing on the classroom, we addressed the larger space of the capture and access and shown it to be a general research problem. We have shown that there are four phases to any capture and access application (pre-production, live capture, integration, access) and how we can simplify the access of captured materials by treating captured information as a collection of time-stamped streams. We touched briefly on the barriers to capture and access and attempted to overcome them in another similar domain, impromptu meetings, with the creation of DUMMBO.

Lately, we have begun to generalize the capture and access problem into a collection of history preserving devices and the access of their histories. The author will continue this work as he moves into the next step of his research career: exploring applications built through the use of everyday objects enabled with capture capabilities.

APPENDIX A

SUMMARY OF COURSES TAUGHT

Instructor	Title	Lectures	Slides	Level	Term	Access Sessions
Gregory Abowd	Introduction to Software Engineering	26	300	ugrad	Spring 1997	170
Chris Atkeson	Introduction to Artificial Intelligence	19	205	ugrad	Spring 1997	132
Irfan Essa	High Level Computer Vision	18	229	grad	Spring 1997	93
Chris Atkeson	Numerical Machine Learning	19	242	grad	Spring 1997	99
Meghan Burke	Calculus III	37	215	ugrad	Spring 1997	93
Mark Guzdial	Modeling and Design	23	103	ugrad	Summer 1997	81
John Stasko	Analysis of Algorithms	38	339	ugrad	Fall 1997	173
Mike McCracken	Software Engineering and Project Management	20	142	ugrad	Fall 1997	39
Gregory Abowd	Human-Computer Interaction - CS6751	24	366	grad	Fall 1997	277
Kishore Ramachandran	Advanced Operating Systems	16	105	ugrad	Winter 1998	91
Irfan Essa	Low-Level Computer Vision	16	220	grad	Winter 1998	319
Janet Kolodner	Case-Based Reasoning	16	83	grad	Winter 1998	53
David Smith	Introduction to Computing	20	123	ugrad	Spring 1998	699
Gregory Abowd	Introduction to Software Engineering	23	223	ugrad	Spring 1998	223
Gregory Abowd	Introduction to Software Engineering	21	233	ugrad	Spring 1998	49
Chris Atkeson	Introduction to Artificial Intelligence	20	197	ugrad	Spring 1998	202
Chris Atkeson	Robotics and Computer Vision	20	162	ugrad	Spring 1998	312
Greg Turk	Computer Graphics	20	281	ugrad	Spring 1998	179
Bill Ribarsky	Scientific Visualization	21	153	grad	Spring 1998	87
Janet Kolodner	Educational Technology	18	130	grad	Spring 1998	81
Spencer Rugaber	Programming Language Design	20	608	grad	Spring 1998	161
Irfan Essa	High Level Computer Vision	18	197	grad	Spring 1998	340
Dick Bass	Introduction to Electronics and Circuits	20	250	ugrad	Spring 1998	215
Mona Meddin	OMED Math	30	191	ugrad	Summer 1998	37
Mona Meddin	OMED Math	27	179	ugrad	Summer 1998	64
Jon Preston	Introduction to Computing	24	312	ugrad	Fall 1998	369
John Stasko	Introduction to Analysis of Algorithms	29	301	ugrad	Fall 1998	744
Kishore Ramachandran	Computer Organization	16	167	ugrad	Fall 1998	606
Kishore Ramachandran	Computer Organization	16	153	ugrad	Fall 1998	641
Chris Atkeson	Numerical Machine Learning	19	207	ugrad	Fall 1998	304
Bill Ribarsky	Computer Graphics	39	508	grad	Fall 1998	1030
Gregory Abowd	Human-Computer Interaction - CS6751	21	321	grad	Fall 1998	1276
Jon Preston	Introduction to Computing	18	310	ugrad	Winter 1999	1909
Gregory Abowd	Introduction to Software Engineering - CS3302	22	327	ugrad	Winter 1999	2782
Colin Potts	Introduction to Software Engineering - CS3302	20	149	ugrad	Winter 1999	402
Blair MacIntyre	Computer Graphics	33	533	ugrad	Winter 1999	863
Greg Turk	Advanced Techniques in Computer Graphics	25	339	ugrad	Winter 1999	1459
Kishore Ramachandran	Advanced Operating Systems	26	540	ugrad	Winter 1999	775
Colin Potts	Human Factors in Software Development	18	78	ugrad	Winter 1999	567
Janet Kolodner	Educational Technology	19	179	grad	Winter 1999	207

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Spencer Rugaber	Computer Language Design	24	496	grad	Winter 1999	880
Greg Turk	Computer Graphics	27	380	grad	Winter 1999	1500
John Stasko	Human-Computer Interaction	24	472	grad	Winter 1999	1265
Elizabeth Mynatt	Human-Computer Interaction	32	459	grad	Winter 1999	1052
William Riviera	Understanding and Constructing Proofs	22	254	ugrad	Spring 1999	612
Jon Preston	Introduction to Computing	16	257	ugrad	Spring 1999	755
Spencer Rugaber	Introduction to Software Engineering	28	273	ugrad	Spring 1999	2296
Chris Atkeson	Robotics and Computer Vision	19	195	ugrad	Spring 1999	190
Kishore Ramachandran	Advanced Operating Systems	22	481	ugrad	Spring 1999	1004
Bill Ribarsky	Scientific Visualization	28	535	grad	Spring 1999	919
Blair MacIntyre	Principles of UI Software	22	445	grad	Spring 1999	536
Leo Mark	Data Base Design	16	94	grad	Spring 1999	606
"Elizabeth Mynatt, Wendy Newstetter"	Human-Computer Interface II	23	191	grad	Spring 1999	456
Janet Kolodner	Conceptual Information Processing	19	159	grad	Spring 1999	40
Gregory Abowd	Mobile and Ubiquitous Computing	19	324	grad	Spring 1999	1974
Mark Guzdial	Computer Supported Cooperative Learning	22	66	grad	Spring 1999	222
Irfan Essa	Digital Video Special Effects	19	87	grad	Spring 1999	76
Meghan Burke	KSU Calculus I	22	196	ugrad	Spring 1999	331
Phil Hutto	Advanced Operating Systems	24	172	ugrad	Fall 1999	198
Blair MacIntyre	Computer Graphics	42	766	ugrad	Fall 1999	2896
Janet Kolodner	Educational Technology Foundations	30	320	grad	Fall 1999	255
Bill Ribarsky	Computer Visualization Techniques	31	411	grad	Fall 1999	384
Gregory Abowd	Human-Computer Interaction	44	616	grad	Fall 1999	3128
Elizabeth Mynatt	Human-Computer Interaction	39	598	grad	Fall 1999	2038
Gregory Abowd	Introduction to Graduate Studies	51	473	grad	Fall 1999	475
John Stasko	Information Visualization	28	743	grad	Fall 1999	755
Thad Starner	Computer Vision	39	379	grad/ugrad	Fall 1999	422
Chris Atkeson	Embedded Systems	27	176	ugrad	Spring 2000	255
Chris Shaw	Video Game Design	31	550	ugrad	Spring 2000	175
Irfan Essa	Digital Video Special Effects	28	130	ugrad	Spring 2000	138
Chris Atkeson	Robotics and Vision	26	331	ugrad	Spring 2000	221
Chris Atkeson	Machine Learning	25	333	ugrad	Spring 2000	210
Janet Kolodner	Educational Technology	26	244	ugrad	Spring 2000	245
John Stasko	User Interface Design	38	754	ugrad	Spring 2000	1253
Aaron Bobick	Pattern Recognition	23	396	ugrad	Spring 2000	274
Mani Subramanian	Intro to Network Management	57	1126	ugrad	Spring 2000	398
Spencer Rugaber	Programming Languages	33	854	grad	Spring 2000	1343
Blair MacIntyre	Principles of UI Software	33	570	grad	Spring 2000	928
Bill Ribarsky	Visual Methods of Science and Engineering	37	707	grad	Spring 2000	1002
Greg Turk	3D Modeling and Graphics	39	538	grad	Spring 2000	1776
"Thad Starner, Elizabeth Mynatt"	Mobile and Ubiquitous Computing	25	465	grad	Spring 2000	260

APPENDIX B

INSTRUCTOR USE SUMMARY

Instructor[10]	Courses Taught	Instructor	Courses Taught
Gregory Abowd	11	Mike McCracken	2
Chris Atkeson	9	Thad Starner	2
Ben Setzer	8	Jeremey Cooperstock	2
Irfan Essa	8	Mark Guzdial	2
Janet Kolodner	6	William Riviera	1
Meghan Burke	6	Phil Hutto	1
Kishore Ramachandran	5	Dan Singhal	1
John Stasko	5	Leo Mark	1
Bill Ribarsky	5	Sven Koenig	1
Jon Preston	5	Aaron Bobick	1
Greg Turk	4	Dick Bass	1
Blair MacIntyre	4	Mani Subramanian	1
Elizabeth Mynatt	4	Leonard Schulman	1
Spencer Rugaber	4	David Smith	1
Mona Meddin	3	Craig Tovey	1
Wendy Newstetter	3	Chris Shaw	1
Colin Potts	3	Andy VanDamme	1

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[10] There were 12 courses with 'anonymous' instructors, all of them accounted for by impromptu meetings, demo courses, and other developmental uses.

APPENDIX C

QUESTION LIST AND χ^2 SUMMARY

Here, we list every question asked on our surveys, indicating the number of individual responses for each question, and the χ^2 p-values (when significant) for each of the factors discussed in chapter 5.1. The reader is reminded that just because a p-value shows statistical significance, it might be due to an unobservable trend. A χ^2 test of significance simple says students answered the question differently. It does not indicate what that difference might be. When observable, trends are reported in chapter 5.

Question	# Responses	School	Grade Level	Student Experience	Instructor Experience	Ink Density	Access Ranking	PowerPoint Usage	Total Slide Count
Have you taken any previous classes using Classroom 2000?	935	N/A							
The classroom lecture was more engaging or interesting to me as result of the use of technology in class and the availability of notes afterwards.	582						0.027		
Because captured lecture notes are available after class, I was able to better pay attention to the lecture.	887		0.005	< 0.005			0.006	0.035	
The lecturer used the Classroom 2000 technology effectively in class.	581		0.018	0.025	0.023	< 0.005	0.01	0.005	< 0.005
This type of course is well-suited to Classroom 2000 technology.	582					< 0.005			
Briefly describe your note-taking practices in classes not using Classroom 2000 technology.	543	N/A							
Have your note-taking practices in this class changed as a result of Classroom 2000? If yes, briefly describe the change.	547	N/A							
Have you ever accessed the class Web page? (if no, skip the rest of this section)	538	N/A							
How often did you access the captured lecture notes from class Web page?	490								
How often did you try to access the audio associated with the captured lecture notes?	98								
Were you successful in attempts to access the audio associated with the captured lecture notes?	120	N/A							
Why did you access the lecture notes? Check all that apply.	460	0.018						0.021	0.056
Where did you access lecture notes? Check all that apply.	472	0.054	< 0.005	0.047	0.046	< 0.005		0.060	0.050

Question	# Responses	School	Grade Level	Student Experience	Instructor Experience	Ink Density	Access Ranking	PowerPoint Usage	Total Slide Count
All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.	535								
Classroom 2000 technology will encourage students to skip lectures.	759		0.013						
Classroom 2000 made me less worried about missing class.	762	< 0.005	< 0.005	0.052	0.060	0.035			
I expect to access materials from this class in the future.	884		< 0.005			< 0.005			
If so, when do you think you'll access them (check all that apply)?	78								
I expect to access materials from another class I did not attend in the future.	124			0.031					
If so, when do you think you'll access them (check all that apply)?	75								
The Web notes took too long to load and navigate through to be useful.	520	0.005	0.005		< 0.005	0.019	0.040	< 0.005	< 0.005
I considered the class Web page to be a reliable and complete source of information during this class.	137		0.030		0.030			0.030	
I trust that captured lecture notes will be available after every class.	392			0.026	0.012			0.014	< 0.005
I depend on having captured lecture notes available after every class.	349		< 0.005						
Audio augmentation of the Web-based lecture notes increased their value to me.	512	< 0.005				0.031	< 0.005	0.010	< 0.005
Video augmentation of the Web-based lecture notes would increase their value to me.	398	0.050	0.056		< 0.005	0.031	0.055	< 0.005	
Audio/Video augmentation (when available) of the Web-based lecture notes increased their value to me.	341		< 0.005	0.041					
Printing captured lecture slides after class is a valuable feature of this system to me.	785	0.008							
The value of captured lecture notes would be greatly enhanced if my own notes were included.	552	0.014							
Capturing Web pages browsed in class was a useful resource for later review.	612		< 0.005						
In your experience with this class, rank the importance of the following material in terms of how it helped you to succeed in learning the material for this course. Assign a 1 to the most important item and 7 for the least important.	718	N/A							
What features inside the class did you find most useful?	367	N/A							
What features inside the class did you find least useful, or even distracting?	299	N/A							
What would you most like improved or added to capabilities of Classroom 2000?	394	N/A							
IF your class had prepared lectures, AND you could print them before class and then take notes on top of them during the lecture, would you take notes this way?	189		0.006					0.030	
The availability of prepared lectures (printed out) before class would make it unnecessary to access the captured notes after class.	147								
If you accessed the captured notes, were you more likely to print them out instead of view them on-line?	142								
For this class, what did you perceive as the main presentation tool?	213								

Question	# Responses	School	Grade Level	Student Experience	Instructor Experience	Ink Density	Access Ranking	PowerPoint Usage	Total Slide Count
I feel that the Classroom 2000 technology helped me learn the material covered in this course.	348					0.010			
Was the professor's handwriting readable when you reviewed the captured lecture notes?	224								
The material presented in this class followed a clear, organized structure.	439	< 0.005	< 0.005		< 0.005		< 0.005	0.010	
Was the instructor's handwriting on notes useful to you after class?	218				0.025				
Access to captured lecture notes from Classroom 2000 helped me study for exams in this class.	222						0.014		
The services of Classroom 2000 helped me to succeed in this class	224			0.055					
How were you most likely to access the captured notes?	328	0.018						0.021	0.056
I was less likely to ask questions in class because I knew that my voice would be recorded.	124								
I would be more comfortable with Classroom 2000 if only the instructor's comments were recorded instead of everyone's comments being captured.	124								
Because of Classroom 2000, the amount of time I spent studying/working for this class compared to a similar class I have taken without Classroom 2000 ...	124				0.044				
The captured lecture notes enabled me to study more efficiently than in other similar classes.	124								
The ability to search the captured notes was useful to me.	124								
I was concerned that people outside of class could listen to the lectures on the Web.	124								
I would rather have ONLY the captured notes over just having ONLY my own notes.	124								
Classroom 2000 helped me study/learn for the following activities.	143	N/A							
Given the choice of taking a class with Classroom 2000 technology, or taking the same class in which all of the presented material was printed and given to me before the lecture, I'd prefer Classroom 2000.	123								
Given the choice of taking a class with Classroom 2000 technology, or taking the same class which was broadcast on demand over cable in a high-quality format, I'd prefer Classroom 2000.	123								
I studied less for this class because of the existence of the captured lecture notes.	115								
My own notes taken in class were more useful to me than the captured lecture notes.	115								
If you accessed the captured lecture notes, briefly describe how you used them to study for this class.	92	N/A							

APPENDIX D

DISTRIBUTION OF QUESTIONNAIRE RESPONSES

In this appendix, we list the same data as in APPENDIX C QUESTION LIST AND χ^2 SUMMARY, but in more detail by giving a graph of the overall distribution on how each question was answered. We also give a brief description of any observable trends present in significant χ^2 p-values.

The classroom lecture was more engaging or interesting to me as result of the use of technology in class and the availability of notes afterwards.
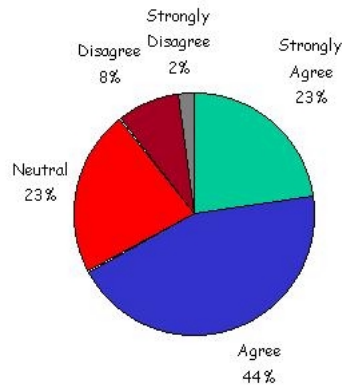
Possible Factors

- School: $p = 0.159$
- Level: $p = 0.086$
- Stud. Experience: $p = 0.566$
- Inst. Experience: $p = 0.634$
- Ink Density: $p = 0.300$
- Access: $p = 0.027$
- PPT: $p = 0.0691$
- Slides: $p = 0.353$

(582 responses)

Students in courses ranking in middle 1/3 are more likely to Strongly Agree instead of Agree.

Overall

Because captured lecture notes are available after class, I was able to better pay attention to the lecture.

Possible Factors

- School: p= 0.282
- Level: p= 0.005
- Stud. Experience: p = 0.000
- Inst. Experience: p = 0.058
- Ink Density: p =0.099
- Access: p = 0.006
- PPT: p = 0.035
- Slides: p = 0.541

(887 responses)

Undergraduates are less likely to Strongly Agree and more apt to be neutral.
Students with experience are more likely to Strongly Agree.
Students in middle 1/3 are more likely to Agree and less likely to Disagree.
Classess with PPT were more likely to Agree and less likely to be Neutral.

Overall

213

All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.

Possible Factors

- School: p= 0.151
- Level: p= 0.338
- Stud. Experience: p = 0.321
- Inst. Experience: p = 0.398
- Ink Density: p =0.306
- Access: p = 0.744
- PPT: p = 0.164
- Slides: p = 0.068

(535 responses)

Overall

I feel that the Classroom 2000 technology helped me learn the material covered in this course.
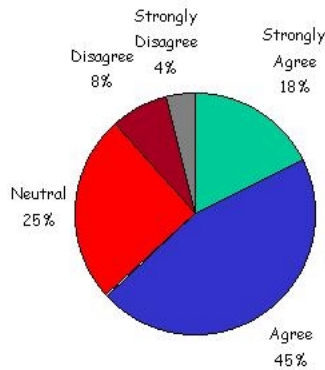
Possible Factors

- School: p= N/A
- Level: p= 0.129
- Stud. Experience: p = 0.472
- Inst. Experience: p = 0.809
- Ink Density: p =0.010
- Access: p = 0.360
- PPT: p = 0.197
- Slides: p = 0.276

(348 responses)

Students in the middle 1/3 of ink density were more likely to Agree than be Neutral, students in bottom 1/3 were more likely to be Neutral and less likely to Disagree.

Overall

214

The services of Classroom 2000 helped me to succeed in this class.

Possible Factors

- School: p= N/A
- Level: p= 0.207
- Stud. Experience: p = 0.055
- Inst. Experience: p = 0.270
- Ink Density: p =0.038
- Access: p = 0.487
- PPT: p = 0.579
- Slides: p = 0.720

(224 responses)

Strongly Disagree 2%
Strongly Agree 11%
Disagree 11%
Neutral 28%
Agree 48%

Students in the middle 1/3 of ink density were more likely to Agree and Strongly Agree, students in the bottom 1/3 were more likely to be Neutral than Disagree.

Overall

Given the choice of taking a class with Classroom 2000 technology, or taking the same class in which all of the presented material was printed and given to me before the lecture, I'd prefer Classroom 2000.
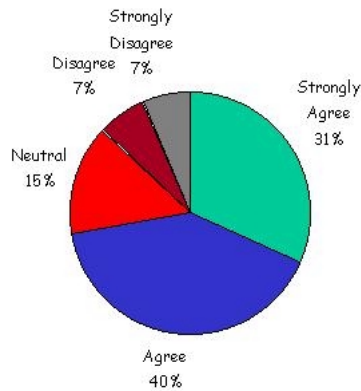
Possible Factors

- School: p= N/A
- Level: p= N/A
- Stud. Experience: p = 0.850
- Inst. Experience: p = 0.757
- Ink Density: p =0.335
- Access: p = N/A
- PPT: p = 0.572
- Slides: p = N/A

(123 responses)

Strongly Disagree 7%
Disagree 7%
Neutral 15%
Strongly Agree 31%
Agree 40%

Overall

Given the choice of taking a class with Classroom 2000 technology, or taking the same class which was broadcast on demand over cable in a high-quality format, I'd prefer Classroom 2000.

Strongly Disagree 2%
Disagree 4%
Neutral 24%
Strongly Agree 28%
Agree 42%

Possible Factors

- School: p= N/A
- Level: p= N/A
- Stud. Experience: p = 0.801
- Inst. Experience: p = 0.954
- Ink Density: p =0.673
- Access: p = N/A
- PPT: p = 0.843
- Slides: p = N/A

(123 responses)

Overall

I trust that captured lecture notes will be available after every class.

Strongly Disagree 1%
Disagree 5%
Neutral 17%
Strongly Agree 23%
Agree 54%
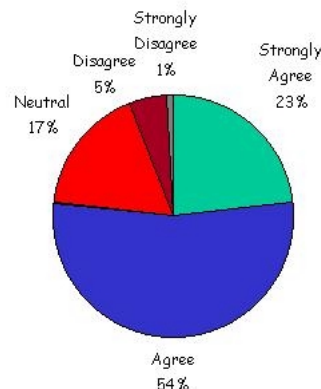
Possible Factors

- School: p = 0.171
- Level: p = 0.071
- Stud. Experience: p = 0.026
- Inst. Experience: p = 0.012
- Ink Density: p = 0.143
- Access: p = 0.084
- PPT: p = 0.014
- Slides: p = 0.000

(391 responses)

Students with experience are more likely to Agree, students who are more likely to be Neutral.
Students with Instructors with experience are more likely to Agree, those who tend toward Neutral.
Students with PPT courses are more likely to Strongly Agree.
Students with courses having many slides are more likely to Strongly Agree and Agree, courses with small slide numbers tend to be Neutral.

Services

216

I depend on having captured lecture notes available after every class.

Possible Factors

- School: p = N/A
- Level: p = 0.000
- Stud. Experience: p = 0.621
- Inst. Experience: p = 0.563
- Ink Density: p = 0.839
- Access: p = 0.506
- PPT: p = 0.0726
- Slides: p = 0.845

(349 responses)

Graduate students are more likely to Agree and Strongly Agree, undergrads are more likely to disagree.

Services

Audio augmentation of the Web-based lecture notes increased their value to me.

Possible Factors

- School: p = 0.001
- Level: p = 0.065
- Stud. Experience: p = 0.113
- Inst. Experience: p = 0.088
- Ink Density: p = 0.031
- Access: p = 0.001
- PPT: p = 0.010
- Slides: p = 0.004

(512 responses)

KSU students more likely to be neutral, less likely to Strongly Agree or Agree.
Students in courses in top 1/3 of ink density more likely to Agree, less likely to Disagree.
Students in courses in middle 1/3 of access rank more likely to Agree, less likely to Disagree, be Neutral.
Students in courses with PPT more likely to Agree, less likely to be Neutral.
Students in courses in top ⅓ of slides more likely to Strongly Agree, less likely to Disagree.

Services

217

Video augmentation of the Web-based lecture notes would increase their value to me.

Possible Factors

- **School: _p_ = 0.050**
- Level: _p_ = 0.056
- Stud. Experience: _p_ = 0.248
- **Inst. Experience: _p_ = 0.003**
- **Ink Density: _p_ = 0.031**
- Access: _p_ = 0.055
- **PPT: _p_ = 0.001**
- Slides: _p_ = 0.246

(398 responses)

KSU students more likely to be Agree, GT students more likely to Disagree.
Students w/prof w/experience more likely to Disagree, those w/o not to Agree.
Students in courses in top 1/3 of ink density more likely to Agree.
Students in courses with PPT more likely to Agree, less likely to be Neutral.
Students in courses in top ½ of slides more likely to Disagree, Strongly Disagree – rest tend toward Neutral. **Services**

Audio/Video augmentation (when available) of the Web-based lecture notes increased their value to me.

Possible Factors

- School: _p_ = N/A
- **Level: _p_ = 0.001**
- **Stud. Experience: _p_ = 0.041**
- Inst. Experience: _p_ = 0.396
- Ink Density: _p_ = 0.684
- Access: _p_ = 0.823
- PPT: _p_ = 0.273
- Slides: _p_ = 0.964

(341 responses)

Grad students more likely to be Strongly Agree, Agree, ugrad more likely to be Neutral.
Students w/prev experience more likely to Agree, rest more likely to be Neutral.

Services

218

Printing captured lecture slides after class is a valuable feature of this system to me.
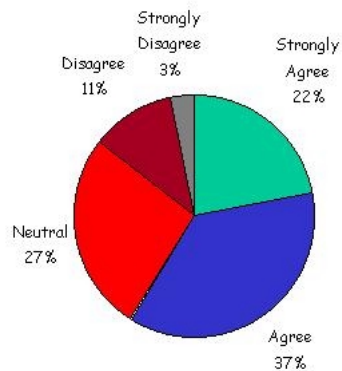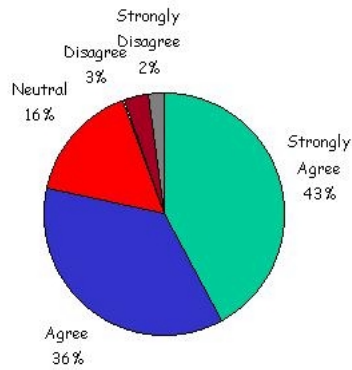

Possible Factors

- School: $p = 0.008$
- Level: $p = 0.122$
- Stud. Experience: $p = 0.135$
- Inst. Experience: $p = 0.28$
- Ink Density: $p = 0.786$
- Access: $p = 0.640$
- PPT: $p = 0.156$
- Slides: $p = 0.376$

(785 responses)

KSU students more likely to be Neutral.

Services

The value of captured lecture notes would be greatly enhanced if my own notes were included.
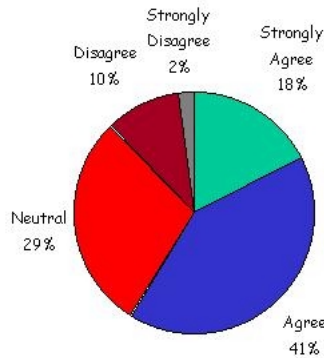
Possible Factors

- School: $p = 0.014$
- Level: $p = 0.094$
- Stud. Experience: $p = 0.103$
- Inst. Experience: $p = 0.325$
- Ink Density: $p = 0.343$
- Access: $p = 0.309$
- PPT: $p = 0.161$
- Slides: $p = 0.742$

(552 responses)

KSU students more likely to be Neutral, Disagree – GT students more likely to Agree.

Services

219

Capturing Web pages browsed in class was a useful resource for later review.
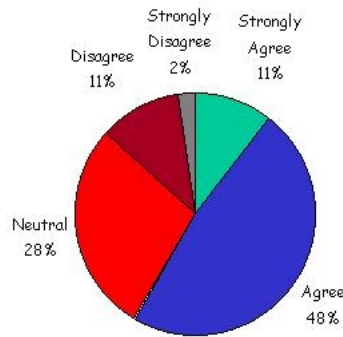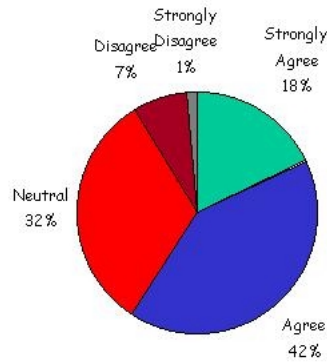

Possible Factors

- School: p = N/A
- Level: p = 0.000
- Stud. Experience: p = 0.131
- Inst. Experience: p = 0.648
- Ink Density: p = 0.649
- Access: p = 0.639
- PPT: p = 0.046
- Slides: p = 0.113

(611 responses)

Grad students more likely to Strongly Agree, less likely to be Neutral.
Students in courses with PPT more likely to Strongly Agree, less likely to be Neutral.

Teachers as knowledge navigators!   **Services**

This type of course is well-suited to Classroom 2000 technology.

Possible Factors

- School: p = 0.418
- Level: p = 0.324
- Stud. Experience: p = 0.301
- Inst. Experience: p = 0.064
- Ink Density: p = 0.000
- Access: p = 0.329
- PPT: p = 0.735
- Slides: p = 0.052

(582 responses)

Students in courses in bottom 1/3 of ink density more likely to Disagree than Agree.

Instructor Use

220

The lecturer used the Classroom 2000 technology effectively in class.
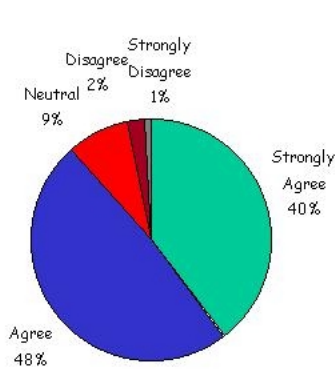
Possible Factors

- School: $p = 0.390$
- Level: $p = 0.018$
- Stud. Experience: $p = 0.025$
- Inst. Experience: $p = 0.023$
- Ink Density: $p = 0.004$
- Access: $p = 0.01$
- PPT: $p = 0.005$
- Slides: $p = 0.003$

(581 responses)

Grad students, students w/prev experience, students w/prof w/experience more likely to SA, others A.
Students in courses in bottom 1/3 of ink density more likely to be Neutral, less likely to SA.
Students in courses in bottom 1/3 of access rank more likely to be Neutral than Strongly Agree.
Students in courses with PPT, top ⅓ in slide count are more likely to Strongly Agree, others A.

Instructor Use

I considered the class Web page to be a reliable and complete source of information during this class.

Possible Factors

- School: $p = 0.730$
- Level: $p = 0.030$
- Stud. Experience: $p = 0.076$
- Inst. Experience: $p = 0.030$
- Ink Density: $p = 0.209$
- Access: $p = N/A$
- PPT: $p = 0.030$
- Slides: $p = 0.167$

(137 responses)

Grad students more likely to SA, A, ugrad more likely to be Neutral.
Students w/prof w/experience more likely to SA, others more likely to be Neutral.
Students in courses with PPT are more likely to Strongly Agree and Agree, others Neutral.

Instructor Use

221

The material presented in this class followed a clear, organized structure.

Strongly
Disagree
Disagree   Strongly
5%   Disagree   Agree
2%   19%

Neutral
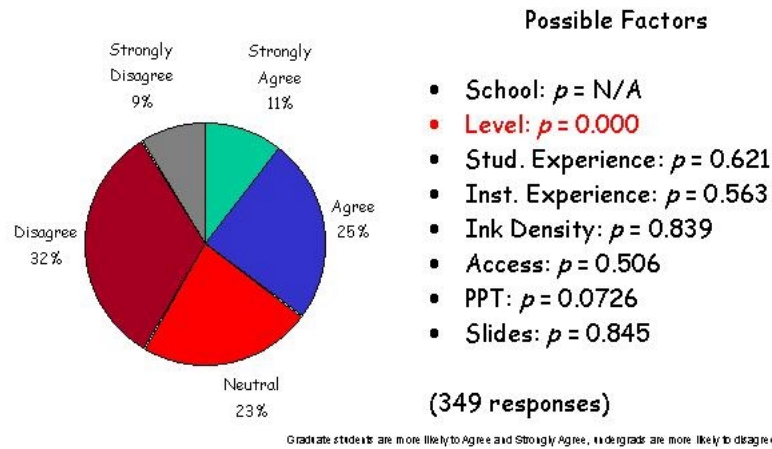25%

Agree
49%

Possible Factors

- School: $p = 0.000$
- Level: $p = 0.000$
- Stud. Experience: $p = 0.203$
- Inst. Experience: $p = 0.000$
- Ink Density: $p = 0.070$
- Access: $p = 0.001$
- PPT: $p = 0.010$
- Slides: $p = 0.170$

(389 responses)

KSU students more likely to SA, GT A.
Grad students more likely to A, tgrad be Neutral.
Students w/prof w/experience tend to SA and A, others tend to Neutral.
Students in courses in bottom 1/3 of access rank more likely to be Neutral than Strongly Agree.
Students in courses without PPT are more likely to D and SD, others SA.

Instructor Use

I was less likely to ask questions in class because I knew that my voice would be recorded.

Strongly
Agree
3%   Agree
3%   Neutral
11%

Strongly
Disagree
39%

Disagree
44%

Possible Factors

- School: $p = N/A$
- Level: $p = N/A$
- Stud. Experience: $p = 0.515$
- Inst. Experience: $p = 0.712$
- Ink Density: $p = 0.196$
- Access: $p = N/A$
- PPT: $p = 0.531$
- Slides: $p = N/A$

(124 responses)

In Class Experience

222

I would be more comfortable with Classroom 2000 if only the instructor's comments were recorded instead of everyone's comments being captured.

Possible Factors

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.583
- Inst. Experience: p = 0.624
- Ink Density: p = 0.747
- Access: p = N/A
- PPT: p = 0.745
- Slides: p = N/A

(124 responses)

In Class Experience

I was concerned that people outside of class could listen to the lectures on the Web.
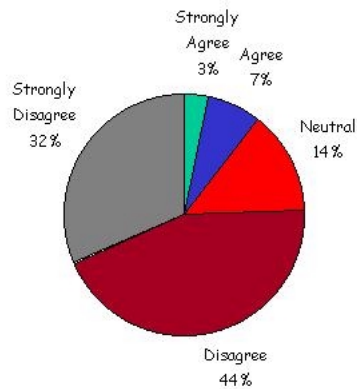
Possible Factors

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.214
- Inst. Experience: p = 0.868
- Ink Density: p = 0.307
- Access: p = N/A
- PPT: p = 0.705
- Slides: p = N/A

(123 responses)

In Class Experience

223

I would rather have ONLY the captured notes over just having ONLY my own notes.

Possible Factors

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.785
- Inst. Experience: p = 0.074
- Ink Density: p = 0.329
- Access: p = N/A
- PPT: p = 0.143
- Slides: p = N/A

(124 responses)

Pie chart: Strongly Agree 5%, Agree 18%, Neutral 23%, Disagree 31%, Strongly Disagree 23%

In Class Experience

I expect to access materials from this class in the future.

Possible Factors

- School: p = 0.196
- Level: p = 0.000
- Stud. Experience: p = 0.112
- Inst. Experience: p = 0.323
- Ink Density: p = 0.004
- Access: p = 0.450
- PPT: p = 0.171
- Slides: p = 0.334

(884 responses)

Pie chart: Strongly Agree 10%, Agree 36%, Neutral 31%, Disagree 18%, Strongly Disagree 5%

Grad students more likely to SA and A, others Neutral.
Students in courses in top 1/3 of Ink density more likely to be Neutral, less likely to SA.

Access

224

If so, when do you think you'll access them?

Possible Factors

Other
13%

Study
Related
Course
47%

Work
27%

Ph.D.
Qualifier
13%

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.650
- Inst. Experience: p = 0.752
- Ink Density: p = 0.031
- Access: p = N/A
- PPT: p = 0.390
- Slides: p = N/A

(79 answers, 119 responses)

No discernable trend.

Access

I expect to access materials from another class I did not attend in the future.

Possible Factors

Strongly
Disagree
6%

Strongly
Agree
15%

Disagree
23%

Neutral
16%

Agree
40%

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.031
- Inst. Experience: p = 0.882
- Ink Density: p = 0.460
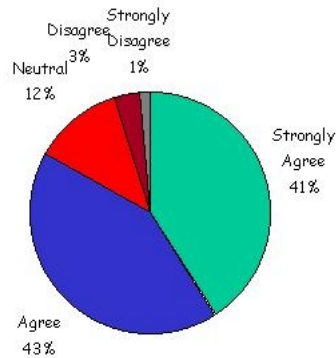- Access: p = N/A
- PPT: p = 0.797
- Slides: p = N/A

(124 responses)

Grad students, students w/o it prev experience more likely to SA and A.

Access

225

If so, when do you think you'll access them?

Possible Factors

Pie chart:
- Other 15%
- Work 18%
- Ph.D. Qualifier 16%
- Study Related Course 51%
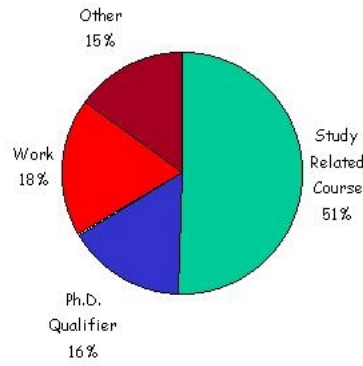
No discernable trend.

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.117
- Inst. Experience: p = 0.554
- Ink Density: p = 0.034
- Access: p = N/A
- PPT: p = 0.720
- Slides: p = N/A

(75 answers, 119 responses)

Access

The Web notes took too long to load and navigate through to be useful.

Possible Factors

Pie chart:
- Strongly Disagree 14%
- Strongly Agree 3%
- Agree 10%
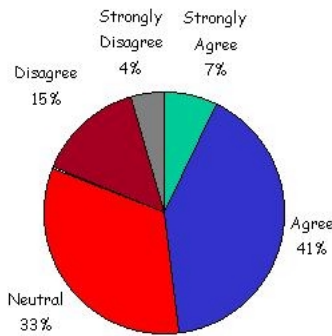- Neutral 28%
- Disagree 45%

- School: p = 0.005
- Level: p = 0.005
- Stud. Experience: p = 0.096
- Inst. Experience: p = 0.002
- Ink Density: p = 0.019
- Access: p = 0.040
- PPT: p = 0.002
- Slides: p = 0.002

(518 responses)

Tech tend toward D, KSU toward N.
U grad tend toward N.
Students students w/prof w/experience more likely to D.
Students in courses in middle 1/3 of Ink density more likely to D.
Students in courses with PPT more likely to SD.
Students in courses in top ⅓ in slide count are more likely to Strongly Disagree, others SA.

Access

226

The availability of prepared lectures (printed out) before class would make it unnecessary to access the captured notes after class.

Possible Factors

- School: p = N/A
- Level: p = 0.91
- Stud. Experience: p = 0.190
- Inst. Experience: p = 0.719
- Ink Density: p = 0.714
- Access: p = N/A
- PPT: p = 0.667
- Slides: p = 0.719

(147 responses)

Access

Was the instructor's handwriting on notes useful to you after class?

Possible Factors

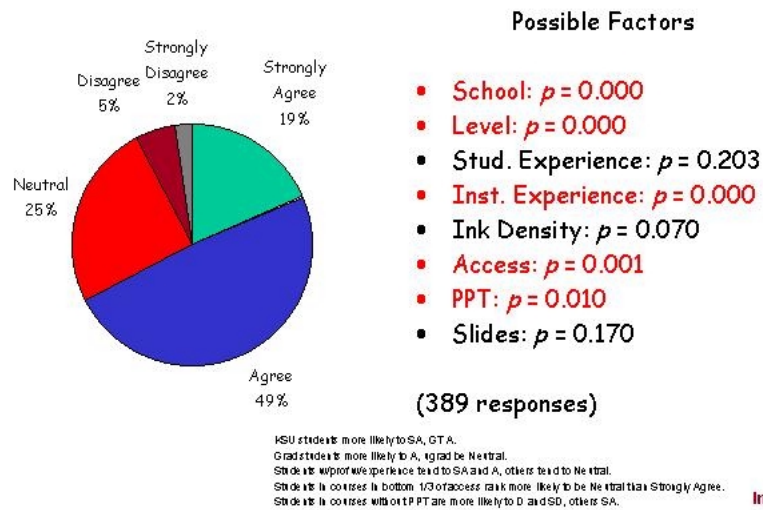- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.443
- Inst. Experience: p = 0.025
- Ink Density: p = 0.179
- Access: p = N/A
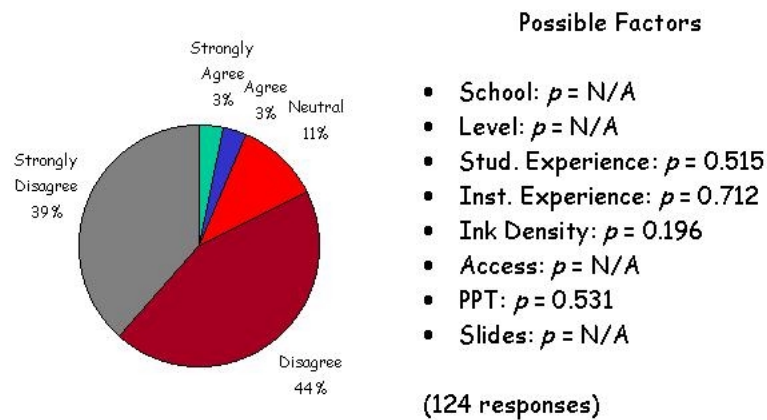- PPT: p = 0.263
- Slides: p = N/A

(124 responses)

Students w/prof w/experience more likely to A, others D.

Access

227

Was the professor's handwriting readable when you reviewed the captured lecture notes?

Possible Factors

No 10%
N/A 5%
Yes 21%
Mostly 64%

(224 responses)

- School: p = N/A
- Level: p = 0.030
- Stud. Experience: p = 0.025
- Inst. Experience: p = 0.000
- Ink Density: p = 0.001
- Access: p = 0.000
- PPT: p = 0.105
- Slides: p = 0.214

Grad students, students w/prev use experience, students w/prof use experience more likely to SA, others N.
Students in courses in top 1/3 of ink density more likely to be Neutral, less likely to SA.
Students in courses in bottom 1/3 of access rank more likely to A and D.

Access

Access to captured lecture notes from Classroom 2000 helped me study for exams in this class.

Possible Factors

Disagree 10%
Strongly Disagree 2%
Strongly Agree 18%
Neutral 26%
Agree 44%

(182 responses)

- School: p = N/A
- Level: p = 0.529
- Stud. Experience: p = 0.064
- Inst. Experience: p = 0.651
- Ink Density: p = 0.857
- Access: p = 0.014
- PPT: p = 0.045
- Slides: p = 0.901

Students in courses in bottom 1/3 of access rank more likely to SA or D.
Students in courses in top 1/3 of access rank more likely to A, less likely to be N.
Students in courses with PPT are more likely to SA and A, others N.

Access

Because of Classroom 2000, the amount of time I spent studying/working for this class compared to a similar class I have taken without Classroom 2000 . . .

Other
2%

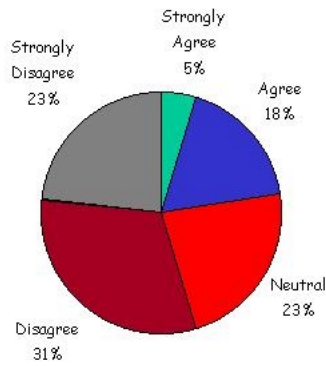Increase
6%
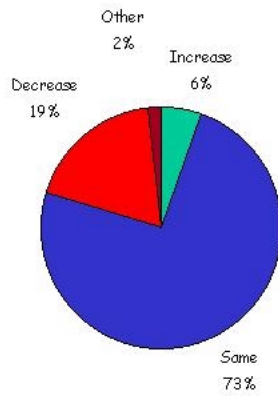
Decrease
19%

Same
73%

Possible Factors

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.682
- Inst. Experience: p = 0.044
- Ink Density: p = 0.116
- Access: p = N/A
- PPT: p = 0.148
- Slides: p = N/A

(124 responses)

Students w/prof w/experience more likely to say Decrease, others Same.

Access

The captured lecture notes enabled me to study more efficiently than in other similar classes.

Strongly
Disagree
6%

Strongly
Agree
21%

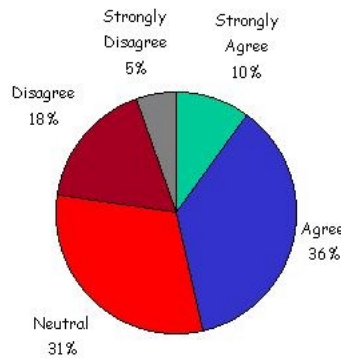Disagree
13%

Neutral
27%

Agree
33%
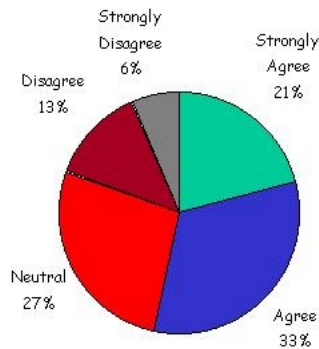
Possible Factors

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.726
- Inst. Experience: p = 0.365
- Ink Density: p = 0.098
- Access: p = N/A
- PPT: p = 0.206
- Slides: p = N/A

(124 responses)

Access

The ability to search the captured notes was useful to me.
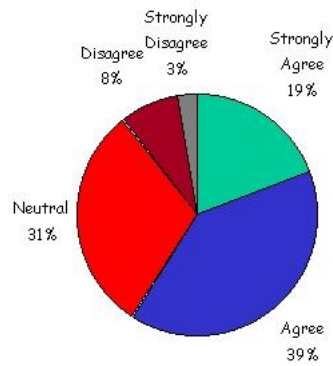
Possible Factors

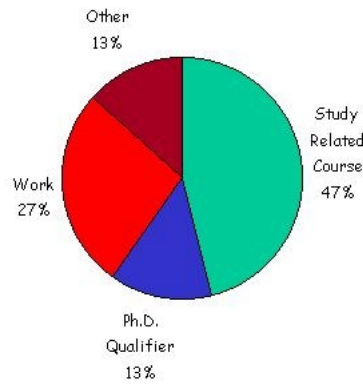- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = 0.211
- Inst. Experience: p = 0.181
- Ink Density: p = 0.113
- Access: p = N/A
- PPT: p = 0.130
- Slides: p = N/A

(114 responses)

Access

I studied less for this class because of the existence of the captured lecture notes.
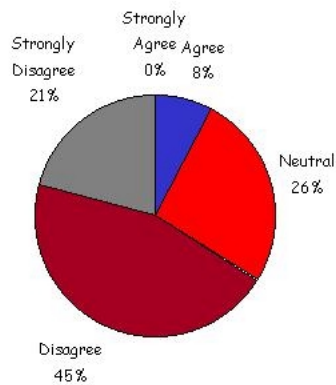
Possible Factors

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = N/A
- Inst. Experience: p = N/A
- Ink Density: p = N/A
- Access: p = N/A
- PPT: p = N/A
- Slides: p = N/A

(115 responses)

Access

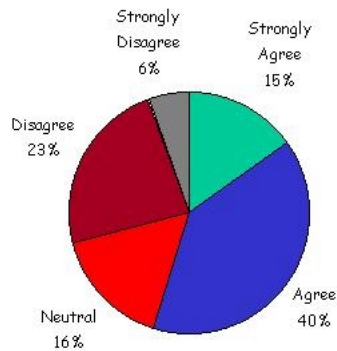My own notes taken in class were more useful to me than the captured lecture notes.
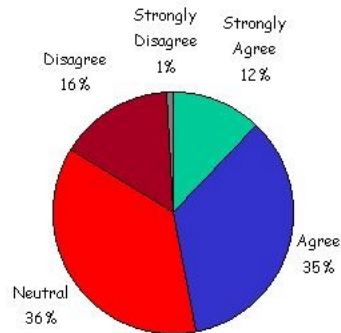
Possible Factors

- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = N/A
- Inst. Experience: p = N/A
- Ink Density: p = N/A
- Access: p = N/A
- PPT: p = N/A
- Slides: p = N/A

(115 responses)

Access

How often did you access the captured lecture notes from class Web page?
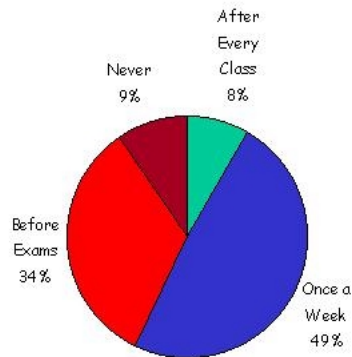
Possible Factors

- School: p = 0.159
- Level: p = 0.061
- Stud. Experience: p = 0.052
- Inst. Experience: p = 0.117
- Ink Density: p = 0.027
- Access: p = 0.151
- PPT: p = 0.000
- Slides: p = 0.000

(486 responses)

Students in courses in middle 1/3 of Ink density more likely to be Before Exam.
Students in courses with PPT more likely to be Before Exams, who tend to Once A Week.
Students in courses with top ⅓ number slides tend toward After Every Class, students in bottom tend toward Never.

Access

231

How often did you try to access the audio associated with the captured lecture notes?

Possible Factors

Pie chart:
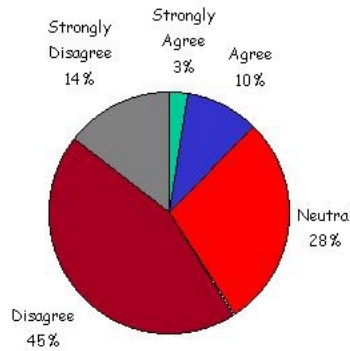- Didn't Know 7%
- Never 15%
- Sometime 45%
- Every Time 33%
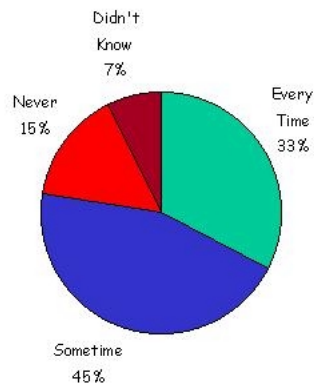
- School: p = N/A
- Level: p = N/A
- Stud. Experience: p = N/A
- Inst. Experience: p = N/A
- Ink Density: p = N/A
- Access: p = N/A
- PPT: p = N/A
- Slides: p = N/A

(98 responses)

Access

Why were you most likely to access the captured notes?

Possible Factors

Pie chart:
- Follow Up 9%
- Review Attended Lecture 21%
- Help with Homewrk, Project 21%
- Review Missed Lecture 22%
- Study Exam 27%
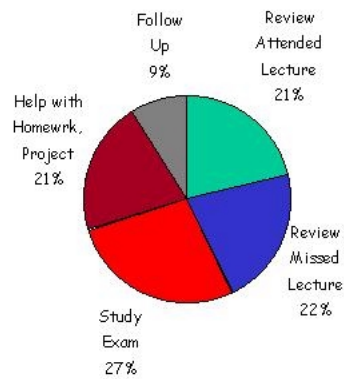
- School: p = 0.018
- Level: p = 0.087
- Stud. Experience: p = 0.374
- Inst. Experience: p = 0.438
- Ink Density: p = 0.440
- Access: p = N/A
- PPT: p = 0.021
- Slides: p = 0.056

(461 answers, 1102 responses)

Students in courses with PPT more likely to Study Exam.

Access

232

Where were you most likely to access the captured notes?
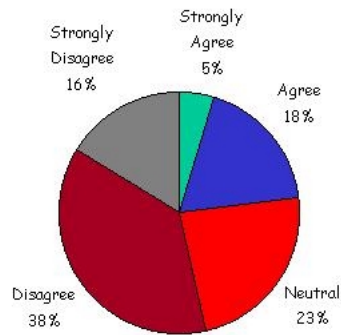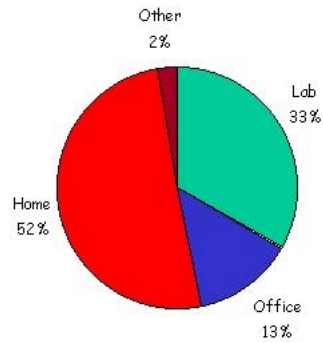

Possible Factors

- School: $p = 0.054$
- Level: $p = 0.000$
- Stud. Experience: $p = 0.047$
- Inst. Experience: $p = 0.046$
- Ink Density: $p = 0.004$
- Access: $p = N/A$
- PPT: $p = 0.060$
- Slides: $p = 0.050$

(473 answers, 671 responses)

Grad students tend toward Office, ug rads toward Home.
Students w/experience and students w/last w/experience tend toward Office.
Students in courses in top 1/3 of ink density tend toward Home.

Access

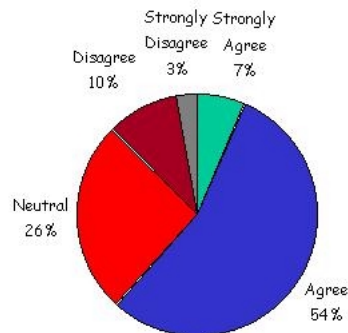## How were you most likely to access the captured notes?
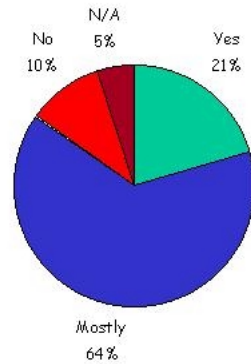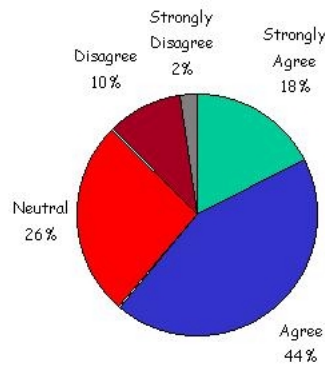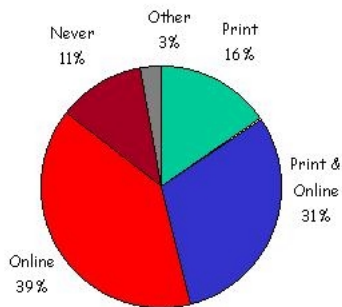

Possible Factors

- School: $p = N/A$
- Level: $p = 0.003$
- Stud. Experience: $p = 0.393$
- Inst. Experience: $p = 0.050$
- Ink Density: $p = 0.043$
- Access: $p = 0.296$
- PPT: $p = 0.182$
- Slides: $p = 0.792$

(419 responses)

Grad students tend toward Print & Online.
Students in courses in bottom 1/3 of ink density more likely to be toward Never.

Access

233

IF your class had prepared lectures, AND you could print them before class and then take notes on top of them during the lecture, would you take notes this way?
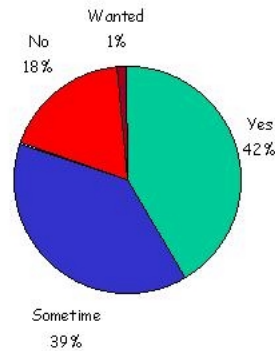
Possible Factors

- School: p = N/A
- Level: p = 0.006
- Stud. Experience: p = 0.978
- Inst. Experience: p = 0.918
- Ink Density: p = 0.426
- Access: p = N/A
- PPT: p = 0.030
- Slides: p = 0.414

(147 responses)

Ugrads tend toward Yes, Grad students toward No.
Students in courses without PPT tend toward Yes, with PPT tend toward No.
Indicates that our assumption about students not want to copy is true, and that eClass Does a good job of what it is supposed to do.

Access

Classroom 2000 helped me study/learn for the following activities.
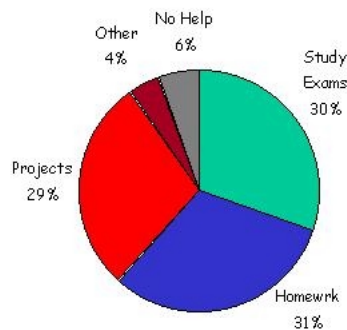
Possible Factors

- School: p = 0.335
- Level: p = N/A
- Stud. Experience: p = 0.731
- Inst. Experience: p = 0.328
- Ink Density: p = 0.095
- Access: p = N/A
- PPT: p = 0.099
- Slides: p = N/A

(144 answers, 268 responses)

Access

234

APPENDIX E

THE QUESTIONNAIRES

KSU Spring 2000

KSU Student Questionnaire
Calculus 1, Spring 2000
Instructor: Dr. Meghan Burke

Your name (optional): _____

During the absence of the instructor for the last two weeks of the semester, pre-recorded versions of the planned lectures were made available for you. Your feedback on these lectures is invaluable to us to determine the effectiveness of this service.

Your answers to this questionnaire will in **no way** affect your grade in this class. We appreciate your frank and honest answer to all questions. Thank you.

Did you view the pre-recorded lectures *during the normal lecture period*? If so, how many?
____ Yes (for ___ lectures)
____ No

Did you view or listen to any lectures *outside of the normal lecture period* for this course?
____ **Yes**, I accessed all lectures outside of the normal lecture period.
____ **Yes**, I accessed some of the lectures outside of the normal lecture period.
____ **No**, I never accessed any lectures outside of the normal lecture period.

The pre-recorded lecture and printed notes were sufficient for me to learn the material.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
The pre-recorded lectures and printed notes were of no value to me in learning the material.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
I would have liked to access other lectures in the same way as these pre-recorded lectures.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Having a substitute lecturer would have been better than these pre-recorded lectures.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

What did you like about the pre-recorded lectures and/or printed notes?

What did you not like about the pre-recorded lectures and/or printed notes?

What would you change about the way the pre-recorded lectures were presented?

Classroom 2000 Student Questionnaire
KSU, Fall Quarter 1999

Class: _____
Instructor: _____

General Background
Your Name (optional): _____

> Would you be willing to talk to us further about your experience with
>
> Classroom 2000?
>
> _____ Yes, feel free to contact me at (e-mail address):

In-class experience

The classroom lecture was more engaging or interesting to me as result of the use of technology during the lecture and the availability of captured lecture notes afterwards.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Because captured lecture notes are available after class, I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The lecturer used the Classroom 2000 technology effectively in class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

This type of course is well-suited to Classroom 2000 technology.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Briefly describe your note-taking practices in classes similar to this class but not using Classroom 2000 technology.

Have your note-taking practices in this class changed as a result of Classroom 2000? If yes, briefly describe the change.

After class experience

Have you ever accessed the captured lecture notes? ____ Yes ____ No (if no, skip to next section)

How often did you access the captured lecture notes produced by the Classroom 2000 system?
_____ after every class
_____ once a week or more
_____ less than once a week
_____ usually just before exams

Were you successful in attempts to access the audio associated with the captured lecture notes?
_____ always
_____ most of the time
_____ sometimes
_____ never
_____ I did not know that audio was available.

How often did you try to access the audio associated with the captured lecture notes?
_____ every time I viewed the captured lecture notes on-line
_____ occasionally when I viewed the captured lecture notes on-line
_____ I never wanted to access the audio.
_____ I did not know that audio was available.

Why did you access the captured lecture notes? Check all that apply.
_____ review a lecture after attending it
_____ review a lecture that was missed
_____ study for exam
_____ get help with a homework/project assignment
_____ follow up on an interesting point
_____ other (please describe) _____

Where did you access captured lecture notes? Check all that apply.
_____ in a public lab at school
_____ in a private or shared office (for example, at work)
_____ at home
_____ other (please describe) _____

General reactions

All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 technology will encourage students to skip lectures.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 made me less worried about missing class.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I expect to access the captured lecture notes from this class in the future.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The captured lecture notes took too long to load and navigate through to be useful.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I trusted that captured lecture notes would be available after every class.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Audio augmentation of the Web-based lecture notes increased their value to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Printing captured lecture notes after class is a valuable feature of this system to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I studied less for this class because of the existence of the captured lecture notes.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

My own notes taken in class were more useful to me than the captured lecture notes.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

In your experience *with this class*, rank (1, 2, 3) the **three most important** of the following material in terms of how it helped you to succeed in learning the material for this course.

_____ class lectures
_____ assigned readings
_____ homework assignments
_____ discussions with other students
_____ discussions with instructor/TA outside of class
_____ class project work
_____ other (please describe): _____

Classroom 2000 helped me study/learn for the following activities.

____ Study for exams   ____ Homework ____ Projects   ____ Other (describe) _____
____ Didn't help at all

If so, how?

If you accessed the captured lecture notes, briefly describe how you used them to study for this class.

What features of Classroom 2000 did you find most useful in this class, and why?

What features of Classroom 2000 did you find least useful, or even distracting, in this class, and why?

What would you most like improved or added to capabilities of Classroom 2000?

Thanks for completing this survey. If you have any questions, contact
Gregory Abowd by email at abowd@cc.gatech.edu

Classroom 2000 Student Questionnaire
Brown, Fall Quarter 1999

Class: _____
Instructor: _____

General Background
Your Name (optional): _____

> Would you be willing to talk to us further about your experience with
>
> Classroom 2000?
>
> _____ Yes, feel free to contact me at (e-mail address):

In-class experience

The classroom lecture was more engaging or interesting to me as result of the use of technology during the lecture and the availability of captured lecture notes afterwards.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Because captured lecture notes are available after class, I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The lecturer used the Classroom 2000 technology effectively in class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

This type of course is well-suited to Classroom 2000 technology.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Briefly describe your note-taking practices in classes similar to this class but not using Classroom 2000 technology.

Have your note-taking practices in this class changed as a result of Classroom 2000? If yes, briefly describe the change.

After class experience
Have you ever accessed the captured lecture notes? ____ Yes ____ No (if no, skip to next section)

How often did you access the captured lecture notes produced by the Classroom 2000 system?
_____ after every class
_____ once a week or more
_____ less than once a week
_____ usually just before exams

Were you successful in attempts to access the audio associated with the captured lecture notes?

_____ always

_____ most of the time

_____ sometimes

_____ never

_____ I did not know that audio was available.

How often did you try to access the audio associated with the captured lecture notes?

_____ every time I viewed the captured lecture notes on-line

_____ occasionally when I viewed the captured lecture notes on-line

_____ I never wanted to access the audio.

_____ I did not know that audio was available.

Why did you access the captured lecture notes? Check all that apply.

_____ review a lecture after attending it

_____ review a lecture that was missed

_____ study for exam

_____ get help with a homework/project assignment

_____ follow up on an interesting point

_____ other (please describe) _____

Where did you access captured lecture notes? Check all that apply.

_____ in a public lab at school

_____ in a private or shared office (for example, at work)

_____ at home

_____ other (please describe) _____

General reactions

All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 technology will encourage students to skip lectures.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 made me less worried about missing class.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I expect to access the captured lecture notes from this class in the future.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The captured lecture notes took too long to load and navigate through to be useful.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I trusted that captured lecture notes would be available after every class.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Audio augmentation of the Web-based lecture notes increased their value to me.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Printing captured lecture notes after class is a valuable feature of this system to me.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I studied less for this class because of the existence of the captured lecture notes.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

My own notes taken in class were more useful to me than the captured lecture notes.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

In your experience *with this class*, rank (1, 2, 3) the **three most important** of the following material in terms of how it helped you to succeed in learning the material for this course.

_____ class lectures
_____ assigned readings
_____ homework assignments
_____ discussions with other students
_____ discussions with instructor/TA outside of class
_____ class project work
_____ other (please describe): _____

Classroom 2000 helped me study/learn for the following activities.

____ Study for exams　　____ Homework ____ Projects　　____ Other (describe) _____
____ Didn't help at all

If so, how?

If you accessed the captured lecture notes, briefly describe how you used them to study for this class.

What features of Classroom 2000 did you find most useful in this class, and why?

What features of Classroom 2000 did you find least useful, or even distracting, in this class, and why?

What would you most like improved or added to capabilities of Classroom 2000?

Thanks for completing this survey. If you have any questions, contact
Gregory Abowd by email at abowd@cc.gatech.edu

Classroom 2000 Student Questionnaire
GATech, Fall Quarter 1999

Class: _____
Instructor: _____

General Background
Your Name (optional): _____

> Would you be willing to talk to us further about your experience with
>
> Classroom 2000?
>
> _____Yes, feel free to contact me at (e-mail address):
>
> _____No, please do not contact me.

In-class experience
Because captured lecture notes are available after class, I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Do you have any additional comments?

I was less likely to ask questions in class because I knew that my voice would be recorded.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
I would be more comfortable with Classroom 2000 if only the instructor's comments were recorded instead of everyone's comments being captured.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
The material presented **in this class** followed a clear, organized structure.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

After class experience
The captured teacher's annotations were useful to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Because of Classroom 2000, the amount of time I spent studying/working for this class compared to a similar class I have taken without Classroom 2000 **. . .**
____ Increased   ____ Remained about the same   ____ Decreased
The captured lecture notes enabled me to study more efficiently than in other similar classes.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
The ability to search the captured notes was useful to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
____ I did know that I could search the captured notes
I was concerned that people outside of class could listen to the lectures on the Web.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
I would rather have **ONLY** the captured notes over just having **ONLY** my own notes.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

General reactions

I felt that the Classroom 2000 technology helped me learn the material covered in this course.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

Classroom 2000 helped me study/learn for the following activities.
____ Study for exams ____ Homework ____ Projects ____ Other (describe) _____
____ Didn't help at all
If so, how?

I expect to access materials **from this class** in the future.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree
If so, when do you think you'll access them (check all that apply)?

____ For a related class ____ Studying for Ph.D. qualifiers ____ At work
____ Other (Please describe)

I expect to access materials **from another class I did not attend** in the future.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree
If so, when do you think you'll access them (check all that apply)?
____ For a related class ____ Studying for Ph.D. qualifiers ____ At work
____ Other (Please describe)

I **depended** on having captured lecture notes available after every class.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

Audio/Video augmentation (when available) of the Web-based lecture notes increased their value to me.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

For **this class** printing captured lecture slides after class is a valuable feature of this system to me.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

Capturing Web pages browsed in class was a useful resource for later review.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

Given the choice of taking a class with Classroom 2000 technology, or taking the same class in which all of the presented material was printed and given to me before the lecture, I'd prefer Classroom 2000.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

Given the choice of taking a class with Classroom 2000 technology, or taking the same class which was broadcast on demand over cable in a high-quality format, I'd prefer Classroom 2000.
____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

In your experience *with this class*, rank (1, 2, 3) the **three most important** of the following material in terms of how it helped you to succeed in learning the material for this course.
_____ class lectures
_____ assigned readings
_____ homework assignments
_____ discussions with other students
_____ discussions with instructor/TA outside of class
_____ class project work
_____ other (please describe): _____

How were you most likely to use the captured notes?
____ I would always print the captured notes and never review them on-line.
____ I would review notes on-line and also print them out for later review.
____ I always reviewed notes on-line and never printed them out.
____ I never reviewed the captured notes, either on-line or printed.
____ other (please specify): _____

Thanks for completing this survey. If you have any questions, contact abowd@cc.gatech.edu

Classroom 2000 Privacy Questionnaire
GATech, Fall Quarter 1999

Anonymous feedback. This page will be removed from your exam prior to being viewed by the instructor. The answers will in no way affect your grade in this class.

What aspects of this class do you find most beneficial for learning?

What aspects of this class do you find least beneficial for learning?

The recording of audio and video in the classroom is an invasion of privacy that impairs my ability to perform well in this class.

____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

I am less likely to ask questions or otherwise speak up in class because of the recording.

____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

The value of the captured lecture notes to me is greater than my concern that their capture will invade my personal privacy in the classroom

____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

I am concerned that people outside of this class may listen to the lecture material.

____ Strongly agree ____ Agree ____ Neutral ____ Disagree ____ Strongly disagree

Smart Environments Workshops: Survey on Use of Technology
July 1999

Your Name (optional): _____

> Would you be willing to take another (probably on-line) survey in a few
>
> weeks to give us more information about the effectiveness of the captured
>
> proceedings for this workshop?
>
> _____ Yes, feel free to contact me at (print e-mail address):
>
> _____ No, please do not contact me.

General presentations

Because captured presentations were available afterwards, I was better able to pay attention during the general sessions.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Did your note-taking practices in the general presentations change because you knew captured presentations were going to be available afterwards?

____ Yes, a lot   _____ Yes, somewhat   _____ No, not at all

Please explain your answer.

I felt more inclined to participate in discussions because of the use of the capture technology.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Breakout groups

The capture technology in the breakout group meetings facilitated better discussion.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Did your note-taking practices change during the breakout sessions because you knew the discussion and whiteboard and scribe notes would be available afterwards?

____ Yes   _____ No

Please explain your answer.

The printed breakout scribe notes were useful for facilitating understanding across breakout groups.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

CoWeb

I have created a page or edited the content of a page in this workshop's CoWeb.

_____ Yes   _____ No

I expect to create a page or edit the content of a page in this workshop's CoWeb.

_____ Yes   _____ No

The linking between CoWeb pages and captured presentations and discussions increased the value of the CoWeb discussion pages.

_____ Strongly agree   _____ Agree   _____ Neutral   _____ Disagree   _____ Strongly disagree

Future Use

This workshop was more useful for me because of the capture, access and collaborative technology used.

_____ Strongly agree   _____ Agree   _____ Neutral   _____ Disagree   _____ Strongly disagree

I anticipate playing an active role in the generation of the final report for this workshop.

_____ Yes   _____ No   _____ Maybe

I expect to access the captured material from this workshop in the future.

_____ Strongly agree   _____ Agree   _____ Neutral   _____ Disagree   _____ Strongly disagree

How long should the workshop materials be made available to participants?

_____ Not past workshop   _____ For 2-3 months   _____ As long as possible

The technology used in this workshop would be effective if used at a conference.

_____ Strongly agree   _____ Agree   _____ Neutral   _____ Disagree   _____ Strongly disagree

How would you improve the **capture technology** for use in future workshops of this kind? Include comments on the use of the technology during the workshop and the access interface to the captured presentations accessed outside the workshop hours.

How would you improve the **CoWeb technology** for use in future workshops?

Classroom 2000 Student Questionnaire
McGill University, Spring Semester 1999

Class: _____
Instructor: _____

1.   What is your name (for internal identification only)

2.   Did you attend class on the days that C2000 was being used?

2.1   List the dates and describe why you used the C2000

3.   Did you use the C2000 at home?

3.1   List the dates and describe why you used the C2000

3.2   What kind of computer and Internet connection speed do you have at home?

4.   Did you use C2000 at a university computer

4.1   List the dates and describe how you used the C2000.

5.   What was your initial understanding of how C2000 was to be used, i.e., for what purpose?

6.   If you used it in class as a presenter, identify the features in C2000 that you believe helped or hurt your presentation.

7.   If you used it in class as a viewer (ie, observing another team's performance) identify the features in C2000 that you believe helped or hurt your understanding and evaluation of the team.

8.   If you used out of class, identify the features in C2000 that you believe helped or hurt your **self** evaluation skills.

9.   If you used out of class, identify the features in C2000 that you believe helped or hurt your **peer** evaluation skills.

10. What is your overall experience of using C2000 in terms of technical ease or difficulty of use.

11. How often per week and for what purposes do you use the computer?

12. How do you feel about learning and using new computer based technologies?

13. Have your used PowerPoint before this course?

14. Do you feel comfortable using PowerPoint?

15. Do you feel confident about your oral presentation skills?

16. Do you believe that **peer** evaluation helps your oral presentation skills?

17. Do you believe that reflective logs improve your communication skills?

Classroom 2000 Student Questionnaire
Spring 1999

Class:
Instructor:

General Background

Your Name (optional):

We would like to discuss some details about your experience with Classroom 2000. Would you be willing to talk to us further?
_____ Yes, feel free to contact me at (e-mail address):
_____ No, please do not contact me.

What is your major field of study?

We define **Classroom 2000 technology** to be the capturing whiteboard, the projected previous notes used during lectures, as well as the audio-enhanced captured lecture notes available via the Web after class.

Have you had a class before that used Classroom 2000 technology? If yes, please list the course number, term and year, including this current term.

In-class experience
The classroom lecture was more engaging or interesting to me as result of the use of technology in class and the availability of notes afterwards.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Because captured lecture notes are available after class, I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
The lecturer used the Classroom 2000 technology effectively in class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
This type of course is well-suited to Classroom 2000 technology.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Briefly describe your note-taking practices in classes similar to this class but not using Classroom 2000 technology.

Have your note-taking practices in this class changed as a result of Classroom 2000? If yes, briefly describe the change.

After class experience

Have you ever accessed the class Web page? _____ Yes _____ No (if no, skip to next section)

How often did you access the captured lecture notes produced by the Classroom 2000 system?
_____ after every class
_____ once a week or more
_____ less than once a week
_____ before exams
_____ never

Were you successful in attempts to access the audio associated with the captured lecture notes?
_____ always
_____ sometimes
_____ never
_____ I did not know that audio was available.

How often did you try to access the audio associated with the captured lecture notes?
_____ every time I viewed the captured lecture notes on-line
_____ sometimes when I viewed the captured lecture notes on-line
_____ I never wanted to access the audio.
_____ I did not know that audio was available.

Why did you access the captured lecture notes? Check all that apply.
_____ Review a lecture after attending it
_____ Review a lecture that was missed
_____ Study for exam
_____ Get help with a homework/project assignment
_____ Follow up on an interesting point
_____ other (please describe) _____

Where did you access captured lecture notes? Check all that apply.
_____ in a public lab
_____ in a private or shared office (for example, at work)
_____ at home
_____ other (please describe) _____

General reactions

All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 technology will encourage students to skip lectures.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 made me less worried about missing class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I expect to access the captured lecture notes from this class in the future.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The captured lecture notes took too long to load and navigate through to be useful.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I trusted that captured lecture notes will be available after every class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Audio augmentation of the Web-based lecture notes increased their value to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Printing captured lecture notes after class is a valuable feature of this system to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I studied less for this class because of the existence of the captured lecture notes.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

My own notes taken in class were more useful to me than the captured lecture notes.

____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

In your experience *with this class*, rank the importance of the following material in terms of how it helped you to succeed in learning the material for this course. Assign a 1 to the most important item and 7 for the least important.

_____ class lectures
_____ the textbook or other assigned readings
_____ homework assignments
_____ discussions with other students
_____ discussions with instructor outside of class
_____ class project work
_____ other (please describe): _____

If you accessed the captured lecture notes, briefly describe how you used them to study for this class.

What features of Classroom 2000 did you find most useful in this class, and why?

What features of Classroom 2000 did you find least useful, or even distracting, in this class, and why?

What would you most like improved or added to capabilities of Classroom 2000?

Thanks for completing this survey. If you have any questions, contact Gregory Abowd at abowd@cc.gatech.edu.

GA Tech Spring 1999

Classroom 2000 Student Questionnaire
Spring Quarter 1999

Class: _____

Instructor: _____

General Background
Your Name (optional): _____

Would you be willing to talk to us further about your experience with

Classroom 2000?

_____ Yes, feel free to contact me at (e-mail address):

_____ No, please do not contact me.

In-class experience
Because captured lecture notes are available after class, I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Additional comments?

For **this class,** what did you perceive as the **main** presentation tool?
____ Prepared slides   _____ Web pages   _____ Ink on a blank whiteboard   _____ Other

Additional comments?

I feel that the Classroom 2000 technology helped me learn the material covered in this course.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

After class experience
Was the professor's handwriting readable when you reviewed the captured lecture notes?
_____ Yes, always   _____ Yes, but not always   _____ No   _____ Doesn't apply
The material presented **in this class** followed a clear, organized structure.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Was the instructor's handwriting on notes useful to you after class? Please explain.

General reactions
Classroom 2000 technology will encourage students to skip lectures.

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____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　　 ____ Strongly disagree

Classroom 2000 made me less worried about missing class.
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly disagree

I expect to access materials from this class in the future.
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly disagree

I **depend** on having captured lecture notes available after every class.
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly disagree

Audio/Video augmentation (when available) of the Web-based lecture notes increased their value to me.
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly disagree

For **this class** printing captured lecture slides after class is a valuable feature of this system to me.
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly disagree

Any comments?

The value of captured lecture notes would be enhanced if my own notes were included.
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly disagree

Capturing Web pages browsed in class was a useful resource for later review.
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly disagree

Access to captured lecture notes from Classroom 2000 helped me study for exams in this class.
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly　 disagree
____ does not apply

The services of Classroom 2000 helped me to succeed in this class
____ Strongly agree　　　 ____ Agree　　　 ____ Neutral　　　 ____ Disagree　 ____ Strongly disagree

In your experience *with this class*, rank (1, 2, 3) the **three most important** of the following material in terms of how it helped you to succeed in learning the material for this course.
_____ class lectures
_____ assigned readings
_____ homework assignments
_____ discussions with other students
_____ discussions with instructor/TA outside of class
_____ class project work
_____ other (please describe): _____

How were you most likely to access the captured notes?
____ I would always print the captured notes and never review them on-line.
____ I would review notes on-line and also print them out for later review.
____ I always reviewed notes on-line and never printed them out.
____ I never reviewed the captured notes, either on-line or printed.
____ other (please specify): _____

Thanks for completing this survey. If you have any questions, contact abowd@cc.gatech.edu

GA Tech Winter 1999 (Online)

Student Questionnaire, Winter 1999

All information provided will be held in strictest confidence. Your name will never be revealed to any instructors.
We encourage you to give us your name, but you may omit it if you wish.

General Background

Your Name:
Class:
Instructor:

We might like to discuss some details about your experience with Classroom 2000. Would you be willing to talk to us further?
    Yes, feel free to contact me at the following email address:
    No, please do not contact me.

What is your major field of study?

We define Classroom 2000 technology to be the interactive whiteboard, extended whiteboard, and tracking Web browser used during lectures, as well as the captured lecture notes available via the Web after class.

For classes held in Room 102, these captured lecture notes are made available with audio and/or video augmentation. For classes held in Room 101, the captured lecture notes did not have audio or video augmentation. Students in classes without audio or video augmentation can skip questions regarding those features of the system.

Have you had a class(es) before that used Classroom 2000 technology? If yes, please list each course, including course number, quarter and year. Please include classes taken this current quarter.

Please indicate your answer to the following questions.

In-Class Experience

  1. The classroom lecture was more engaging or interesting to me as result of the use of technology in class and the availability of notes afterwards.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
2. Because captured lecture notes are available after class, I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
3. The lecturer used the Classroom 2000 technology effectively in class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
4. This type of course is well-suited to Classroom 2000 technology.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
5. Briefly describe your note-taking practices in classes not using Classroom 2000 technology.

  6. Have your note-taking practices in this class changed as a result of Classroom 2000? If yes, briefly describe the change.

After Class Experience

7.Have you ever accessed the class Web page?
   Yes
   No (if no, skip to next section)

8.How often did you access the captured lecture notes from class Web page?
   After every class
   About once a week
   Only before exams
   never

9.Why did you access the captured lecture notes? Check all that apply.
   Review a lecture after attending it
   Review a lecture that was missed
   Study for exam
   Get help with a homework / project assignment
   Follow up on an interesting point

10.Where did you access captured lecture notes? Check all that apply.
   in a public lab
   in a private or shared office
   at home (network connection, such as in campus dorm)
   at home (dial-up modem connection)
   other (please describe):

General Reactions

11.All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
12.Classroom 2000 technology will encourage students to skip lectures.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
13.Classroom 2000 made me less worried about missing class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
14.I expect to access materials from this class in the future.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
15.The Web notes took too long to load and navigate through to be useful.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
16.I trust that captured lecture notes will be available after every class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
17.Audio augmentation of the Web-based lecture notes increased their value to me. (Skip if your class did not have audio recorded.)
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
18.Video augmentation of the Web-based lecture notes increased their value to me. (Skip if your class did not have video recorded.)
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
19.Printing captured lecture slides after class is a valuable feature of this system to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
20.The value of captured lecture notes would be greatly enhanced if my own notes were included.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
21.Capturing Web pages browsed in class was a useful resource for later review.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

22. In your experience with this class, rank the importance of the following material in terms of how it helped you to succeed in learning the material for this course. Assign a 1 to the most important item and 7 for the least important.

      class lectures
      class lectures
      assigned readings
      homework assignments
      discussions with other students
      discussions with instructor/TA outside of class
      class project work
      other (please describe)

23. What features inside the class did you find most useful?

24. What features inside the class did you find least useful, or even distracting?

25. What would you most like improved or added to capabilities of Classroom 2000?

26. IF your class had prepared lectures, AND you could print them before class and then take notes on top of them during the lecture, would/did you take notes this way?

      Yes, I would always do this
      I might do this occasionally
      No, I wouldn't do this

27. The availability of prepared lectures (printed out) before class would make it unnecessary to access the captured notes after class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

28. If you accessed the captured notes, were you more likely to print them out instead of view them online?

      I would always print the captured notes and never review them on-line.
      I would review notes on-line and also print them out for later review.
      I always reviewed notes on-line and never printed them out.
      I never reviewed the captured notes, either on-line or printed.
      other (please specify):

Thanks for completing this survey!
If you have any questions, contact abowd@cc.gatech.edu

Classroom 2000 Student Questionnaire
Fall Quarter 1998

Class:
Instructor:

General Background

Your Name:

We would like to discuss some details about your experience with Classroom 2000. Would you be willing to talk to us further?
_____ Yes, feel free to contact me at (e-mail address):
_____ No, please do not contact me.

What is your major field of study?

We define **Classroom 2000 technology** to be the interactive whiteboard, extended whiteboard, and tracking Web browser used during lectures, as well as the audio- and video-enhanced captured lecture notes available via the Web after class.

Have you had a class before that used Classroom 2000 technology? If yes, please list the course number, quarter and year, including this current quarter.

In-class experience

The classroom lecture was more engaging or interesting to me as result of the use of technology in class and the availability of notes afterwards.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Because captured lecture notes are available after class, I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
The lecturer used the Classroom 2000 technology effectively in class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
This type of course is well-suited to Classroom 2000 technology.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Briefly describe your note-taking practices in classes not using Classroom 2000 technology.

Have your note-taking practices in this class changed as a result of Classroom 2000? If yes, briefly describe the change.

After class experience

Have you ever accessed the class Web page? _____ Yes _____ No (if no, skip to next section)

How often did you access the captured lecture notes from class Web page?
_____ After every class
_____ About once a week
_____ Only before exams
_____ never

Why did you access the captured lecture notes? Check all that apply.
_____ Review a lecture after attending it
_____ Review a lecture that was missed
_____ Study for exam
_____ Get help with a homework/project assignment
_____ Follow up on an interesting point

Where did you access captured lecture notes? Check all that apply.
_____ in a public lab
_____ in a private or shared office
_____ at home
_____ other (please describe) _____

General reactions

All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 technology will encourage students to skip lectures.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 made me less worried about missing class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I expect to access materials from this class in the future.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The Web notes took too long to load and navigate through to be useful.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I trust that captured lecture notes will be available after every class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Audio augmentation of the Web-based lecture notes increased their value to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Video augmentation of the Web-based lecture notes increased their value to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Printing captured lecture slides after class is a valuable feature of this system to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The value of captured lecture notes would be greatly enhanced if my own notes were included.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Capturing Web pages browsed in class was a useful resource for later review.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

In your experience *with this class*, rank the importance of the following material in terms of how it helped you to succeed in learning the material for this course. Assign a 1 to the most important item and 7 for the least important.

_____ class lectures
_____ assigned readings
_____ homework assignments
_____ discussions with other students
_____ discussions with instructor/TA outside of class
_____ class project work
_____ other (please describe): _____

What features inside the class did you find most useful?

What features inside the class did you find least useful, or even distracting?

What would you most like improved or added to capabilities of Classroom 2000?

IF your class had prepared lectures, AND you could print them before class and then take notes on top of them during the lecture, would you take notes this way?
____ yes, I would always do this
____ I might do this occasionally
____ no, I wouldn't do this

The availability of prepared lectures (printed out) before class would make it unnecessary to access the captured notes after class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

If you accessed the captured notes, were you more likely to print them out instead of view them on-line?
____ I would always print the captured notes and never review them on-line.
____ I would review notes on-line and also print them out for later review.
____ I always reviewed notes on-line and never printed them out.
____ I never reviewed the captured notes, either on-line or printed.
____ other (please specify): _____

Thanks for completing this survey. If you have any questions, contact abowd@cc.gatech.edu

Classroom 2000 Student Questionnaire
Spring Quarter 1998

Class:
Instructor:

General Background

Your Name:

We would like to discuss some details about your experience with Classroom 2000. Would you be willing to talk to us further?
_____ Yes, feel free to contact me at (e-mail address):
_____ No, please do not contact me.

What is your major field of study?

We define **Classroom 2000 technology** to be the interactive whiteboard, extended whiteboard, and tracking Web browser used during lectures, as well as the audio- and video-enhanced captured lecture notes available via the Web after class.

Have you had a class before that used Classroom 2000 technology? If yes, please list the course number, quarter and year, including this current quarter.

In-class experience

The classroom lecture was more engaging or interesting to me as result of the use of technology in class and the availability of notes afterwards.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Because captured lecture notes are available after class, I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
The lecturer used the Classroom 2000 technology effectively in class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
This type of course is well-suited to Classroom 2000 technology.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Briefly describe your note-taking practices in classes not using Classroom 2000 technology.

Have your note-taking practices in this class changed as a result of Classroom 2000? If yes, briefly describe the change.

After class experience

Have you ever accessed the class Web page? _____ Yes _____ No (if no, skip to next section)

How often did you access the captured lecture notes from class Web page?
_____ After every class
_____ About once a week
_____ Only before exams
_____ never

Why did you access the captured lecture notes? Check all that apply.
_____ Review a lecture after attending it
_____ Review a lecture that was missed
_____ Study for exam
_____ Get help with a homework/project assignment
_____ Follow up on an interesting point

Where did you access captured lecture notes? Check all that apply.
_____ in a public lab
_____ in a private or shared office
_____ at home
_____ other (please describe) _____

General reactions

All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 technology will encourage students to skip lectures.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 made me less worried about missing class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I expect to access materials from this class in the future.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The Web notes took too long to load and navigate through to be useful.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I trust that captured lecture notes will be available after every class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Audio augmentation of the Web-based lecture notes increased their value to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Video augmentation of the Web-based lecture notes increased their value to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Printing captured lecture slides after class is a valuable feature of this system to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The value of captured lecture notes would be greatly enhanced if my own notes were included.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Capturing Web pages browsed in class was a useful resource for later review.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

In your experience *with this class*, rank the importance of the following material in terms of how it helped you to succeed in learning the material for this course. Assign a 1 to the most important item and 7 for the least important.

_____ class lectures
_____ assigned readings
_____ homework assignments
_____ discussions with other students
_____ discussions with instructor/TA outside of class
_____ class project work
_____ other (please describe): _____

What features inside the class did you find most useful?

What features inside the class did you find least useful, or even distracting?

What would you most like improved or added to capabilities of Classroom 2000?

Classroom 2000 Student Questionnaire
Fall Quarter 1997

Class:
Instructor:

General Background

Name (optional):

We would like to discuss some details about your experience with Classroom 2000. Would you be willing to talk to us further?
_____ Yes, feel free to contact me at (e-mail address):
_____ No, please do not contact me.

What is your major field of study?

Have you had a class before that used Classroom 2000 technology? If yes, please list which classes.

In-class experience

The classroom lecture was more engaging or interesting to me as result of Classroom 2000 technology.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
I was able to better pay attention to the lecture.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
The lecturer used the Classroom 2000 technology effectively in class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
This type of course is well-suited to Classroom 2000 technology.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree
Briefly describe your note-taking practices in classes not using Classroom 2000 technology.

Have your note-taking practices in this class changed as a result of Classroom 2000? If yes, briefly describe the change.

After class experience

Have you ever accessed the class Web page? _____ Yes _____ No (if no, skip the rest of this section)

How often did you access lecture notes from the syllabus on the Class Web page?
_____ After every class
_____ About once a week
_____ Only before exams
_____ never

Why did you access the lecture notes? Check all that apply.
_____ Review a lecture after attending it
_____ Review a lecture that was missed
_____ Study for exam
_____ Get help with a homework/project assignment
_____ Follow up on an interesting point

Where did you access lecture notes? Check all that apply.
_____ in a public lab
_____ in a private or shared office
_____ at home

General reactions

All things being otherwise equal, I would prefer to take a class that uses Classroom 2000 technology over the same class that does not.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 technology will encourage students to skip lectures.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Classroom 2000 made me less worried about missing class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I expect to access materials from this class in the future.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The Web notes took too long to load and navigate through to be useful.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

I considered the class Web page to be a reliable and complete source of information during this class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Audio augmentation of the Web-based lecture notes increased their value to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Video augmentation of the Web-based lecture notes would increase their value to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

Printing slides from the Web was a valuable feature of this system to me.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

The value of Web notes would be greatly enhanced if I were able to take electronic notes in class.
____ Strongly agree   ____ Agree   ____ Neutral   ____ Disagree   ____ Strongly disagree

What features would you most like improved or added to Classroom 2000?

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VITA

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