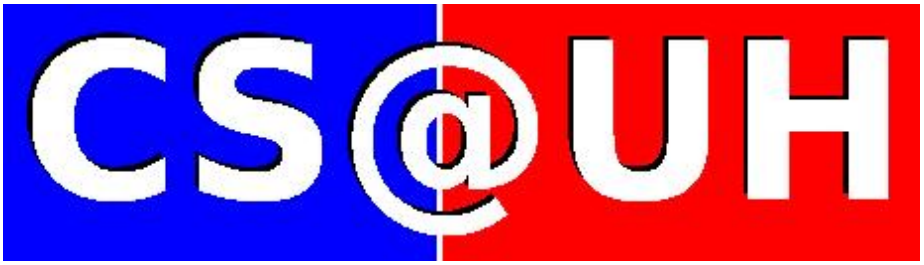

EXPERIENCE WITH TABLET PC VIDEO BASED HYBRID COURSEWORK IN COMPUTER SCIENCE

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Abstract

Online learning, defined broadly as recording and delivering classroom experience with technology, has tremendous potential. However, success to date has been very limited in science and engineering. We believe this is because traditional video recording is cumbersome and not suitable for technical lectures and removing live classroom interaction is detrimental to learning. Employing Tablet PCs with slide presentation software has made it simple and convenient to develop and record high quality lectures. We employ such videos in a hybrid model of coursework. All lectures are made available as online videos, but limited classroom interaction is an important component; the classroom is used for review of lecture material, examinations, demonstrations, tutorials, and hands-on sessions. The hybrid framework is particularly suitable for students with logistical difficulties, e.g., because of work schedule. This paper is an evaluation of the hybrid learning approach as applied to upper level computer science coursework. We report our experience in teaching a suite of hybrid courses at the University of Houston and discuss the detailed feedback we received from the students who participated in the courses.

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Categories and Subject Descriptors: K.3 [**Computers and Education**]: General

General Terms: Measurement, Design, Experimentation, Human Factors

Additional Key Words and Phrases: Hybrid learning, Online learning, Video lectures, Tablet PC

1. INTRODUCTION

Emerging technologies to deliver coursework have the potential to make "anywhere anytime" learning a reality by improving the quality as well as the flexibility of the education experience. However, traditional distance learning has met with limited success to date, especially in science and engineering. University of Houston (UH) has enrollments in distance education programs approaching 10,000 in a student body of approximately 35,000. However, only a small fraction of this enrollment is in science and engineering. In particular, the appeal, deployment and success of distance learning has been very limited in computer science. At the same time, there is no question that a large fraction of students in computer science at UH have part-time or full-time jobs and can benefit from more convenient and flexible courses. Further, there is a significant demand for some computer science courses among IT professionals. In fact, some UH faculty teach courses similar to UH curriculum courses at local corporations on a regular basis.

In our view, there are two fundamental reasons for the limited success of distance learning in science and engineering. We discuss these as follows:

Model: Classroom interaction between the students and the instructor, and among students, is critical for learning. Most traditional online/video courses virtually eliminate this human interaction. This makes the approach restrictive and suitable only for students who simply cannot come to a campus.

Delivery mechanism: The common delivery mechanisms for distance learning at

UH (and elsewhere), are web based delivery of textual and graphical content and video delivery of classroom lectures. We explain these briefly:

Web-based delivery: This model typically involves posting lecture notes and other material on a web site, often supported by chat room type interaction under the control of an e-learning management system like WebCT. While this has substantial value, it is not intended to be a classroom alternative as live classroom interaction, illustrations and discussions are not delivered, which is a crucial limitation of this approach.

Video delivery: Lectures are recorded with a video camera and broadcast on special cable TV channels or made available on videotapes or other media. While this model is adequate for many subject areas, we believe it is not a good match for scientific lecture material for the following reasons: First, projected overheads with details are not captured well on video. Second, illustrations have to be made on a separate platform and the instructor finds it awkward to go back and forth between overheads and illustrations. We believe these are the reasons video delivered courses are more popular in, e.g., business and law, than in computer science. Finally, one person is needed for manning the camera which has a crucial negative impact on the cost and ease of deployment.

This paper reports our experience with a "hybrid" model for computer science courses. This hybrid model has the following key features:

(1) Lectures are recorded with Tablet PCs in a live class and made available to students in hybrid sections with internet streaming. This largely overcomes the problems with camera based video.

(2) There is a strong emphasis on the relatively small number of face to face classroom sessions that are mandatory. This implies a regular, albeit less frequent, instructor-student and student-student contact and the social environment for learning is maintained.

The broad objective of this project is to get the best of both worlds: technology is applied to develop high quality lecture material that students can access at their own convenience. At the same time, all components of teaching for which human interaction is beneficial, are done in the classroom.

This paper reports on faculty and student experience in teaching a suite of senior level hybrid computer science courses. Quantitative results are based on detailed questionnaires completed by the students at the end of each course. The results characterize the quality of the technology employed, the benefits and limitations of the hybrid approach, how it changed the education experience, and how it can be improved. The main purpose of this experience report is to provide some guidance to instructors who may wish to offer similar hybrid courses in the future. The paper discusses distribution of coursework between mandatory classroom sessions and recorded video lectures, reports on how students perceive and study for hybrid courses, and offers some tips on keeping students engaged.

2. BACKGROUND

Distance learning has grown tremendously over the past decade with rapidly increasing offerings of online courses and online degrees [Oblinger and Hawkins 2005].

Over the past few years, the emphasis has shifted from specialized "virtual universities" to online offerings from mainstream universities. Potential pitfalls of internet based education have been well documented [Hirscheim 2005; Reasons 2004]. The importance of face-to-face interaction to complement online delivery has been recognized in a variety of diverse fields, and this is considered a key factor in student retention [Mueggenburg 2003; Riffell and Sibley 2004; Santovec 2005; Young 2002]. Hybrid delivery that combines classroom and online learning addresses several problems in online education and improves the learning experience. For example, examinations and labwork are problems in online education [Esche 2005; Thomas 2003] that are naturally resolved in a hybrid approach. Electronic material has been employed to enhance and improve classroom learning in computer science, e.g., to emphasize key concepts [Eckerdal et al. 2006], and to allow students to better concentrate during lectures by delivering notes in an electronic format [Wirth 2003].

A relatively new classroom technology is the employment of Tablet PCs for teaching. Software systems that allow easy mixing of hand annotations with prepared viewgraphs during a lecture include the Classroom Presenter [Anderson et al. 2004], Ubiquitous Presenter [Wilkerson et al. 2005] and Write-On [Tront 2006]. This mode of teaching also allows easy recording and delivery of active classroom lectures. Hence it has become practical to provide the entire classroom experience online, in addition to the text and pictures typically employed in traditional hybrid coursework.

A model of hybrid education based on recorded Tablet-PC based lectures, along with regular but infrequent class meetings, has the potential to fundamentally improve the learning experience. For instance, the major shortcomings of online education identified by students as reported in [Hirscheim 2005] center around the loss of classroom experience including student questions, class discussions and professor's views and perspective. While these can be addressed to a large extent with the hybrid model proposed in this paper, there are many intangibles in such a hybrid approach. The impact of reduced interaction with the instructor has to be studied although there is some evidence that the quality of the interaction is not affected by reducing the number of class meetings [Riffel and Sibley 2003]. Learning skills, motivation, and maturity of students are especially important for hybrid coursework [Rosbottom 2001]. The best methodololgy for organizing an online or a hybrid course ultimately depends on the course content [Clear et al. 2000].

This paper presents a study that evaluates the value of online Tablet PC based lectures as teaching material and the associated hybrid education model. One of the goals is to develop insight into the diverse challenges in developing and deploying hybrid coursework.

3. HYBRID COURSE STRUCTURE

A hybrid course in our framework has the bulk of the classroom lectures available online, but regular, although infrequent, classroom meetings are mandatory. In most instances, a *hybrid section* is taught concurrently with a regular *classroom section*. All lectures from the classroom section are recorded and posted online immediately. These lectures are the primary access to the classroom discussion

for hybrid section students, but they also serve as supplementary material for all students in all sections of a course. We have also taught pure hybrid courses with no concurrent classroom section. In this case, the online lecture material is either based on a previous semester or is recorded by the instructor outside of the class.

3.1 Lecture recording and delivery

The basic content of a hybrid course consists of recorded classroom lectures made available on the web as streaming videos. Typically the instructor prepares a lecture as a set of (Powerpoint) viewgraphs and employs the Tablet PC for teaching. The instructor can add annotations during a lecture by writing directly on the Tablet PC screen with an electronic stencil. This approach to teaching is becoming popular as it freely mixes prepared content with hand illustrations and has been discussed in [Berque et al. 2004; Golub 2004]. We employed the Classroom Presenter [Anderson et al. 2004] from the University of Washington for teaching with a Tablet PC and found the writing experience very natural. The entire lecture is recorded on the Tablet PC itself. The audio consisting of instructor's speech, including questions from the students in the class, is fed into the Tablet PC through one or more microphones. Off the shelf software –we used Camtasia and Camstudio for this purpose– is employed to record the computer screen and the audio as a video file. The lectures are then made available to the students as streaming video. The students in a hybrid class can access the lectures at their own convenience and proceed interactively at their own pace. The students can stream the lectures directly, or download the lectures and play them on their machine. Currently a lecture is a single video file, but in the future they will be indexed allowing the students to jump to specific topics.

The distribution of the recorded lecture videos is managed by the VClass appication within VNET, which is a modern web-based operating system and applications platform suite presently being developed and employed at the University of Houston [Baez-Franceschi et al. 2004]. VClass provides all the tools needed to stream lectures without the need for technical support-personnel or special equipment. File upload to the server is an easy step that can be done on any web browser's window. Files are automatically processed on the server for streaming and published to the web. In addition, professors have the ability to post any course related material, such as notifications, notes, or practice problems, within VClass.

3.2 Hybrid organization

Classroom interaction remains an important component of all hybrid courses. Course content is divided into *modules*, with a semester long course typically consisting of 4 to 8 modules. Students in hybrid sections typically have one classroom meeting per module with additional classroom meetings as needed.

Class time is utilized for activities for which direct personal interaction is important. Each instructor has to decide how to best use the limited class time. Activities best suited for the live class include addressing student questions about video lectures, discussions that center around student participation, discussion of current research topics, descriptions of projects and assignments, show and tell demonstrations, and field trips. All examinations, quizzes, and student presentations demonstrations are in the classroom or at designated locations. We present

some specific examples of how class time was used in some of the courses:

—When teaching a programming language, it is instructive to show the interepretation/execution of practical examples in-class. This was the case for teaching PROLOG and LISP in the *Artificial intelligence* class.

—The students of the *Computer graphics* course must complete an individual project that involves 3-D modeling, lighting, animation, and texturing. The project is developed in stages, with each stage terminating with a newer, more complex version of the implementation. Each stage is introduced in an in-class session that includes a relevant worked example and defines the expectations of the stage. The students are required to present their results of each stage either in class or personally to the instructor.

—The *Computer Networks* course content is broadly divided into 5 "layers"; the application, transport, network, link, and physical layers. The in-class sections are employed to address questions from a layer that has been covered and provide an introduction to the next layer.

We also note that having lectures available as videos offers distinct advantages. As an example, for teaching *Unit Testing* and *Refactoring* in the *Software Engineering* course, a fully functional application was developed using the test first coding approach and an IDE during a recorded lecture. The lecture was immediately followed with an exercise where students would create a similar application. Access to the previous lecture where the concepts and approaches were illustrated was a valuable resource. Similarly in the *Computer Networks course*, the video of a guest lecture deliverd by an expert on *Sockets Programming* served as an important resource for a subsequent sockets programming assignment.

The instructors employed several methods to make sure that students stayed on top of the recorded video lectures. In general, homework and quizzes were used on regular basis. Some instructors embedded questions in the recorded sessions, asking students to post responses to the instructor or a class message board. Beside ensuring that the students watch recorded lectures in a timely fashion, this also often leads to online discussion compensating for the direct in-class interaction.

4. EVALUATION

The hybrid framework was employed to teach 3 different courses; *Introduction to Computer Networks*, *Interactive Computer Graphics*, and *Software Engineering*. All of these are senior level undergraduate courses. The courses on computer networks and computer graphics have been taught twice with the hybrid framework and additional courses are currently being taught. The class sizes for these were relatively small and the total enrollment in all these courses was approximately 50. At the end of each semester, the students were invited to discuss the class organization with the instructor. They were also asked to fill out a questionnaire to evaluate the hybrid framework. The questions focused on the technology employed for online lectures, the hybrid model and how it affected the learning experience, and suggestions for improvement. We discuss the key points from student evaluations and discussions, along with the experience of the instructors.

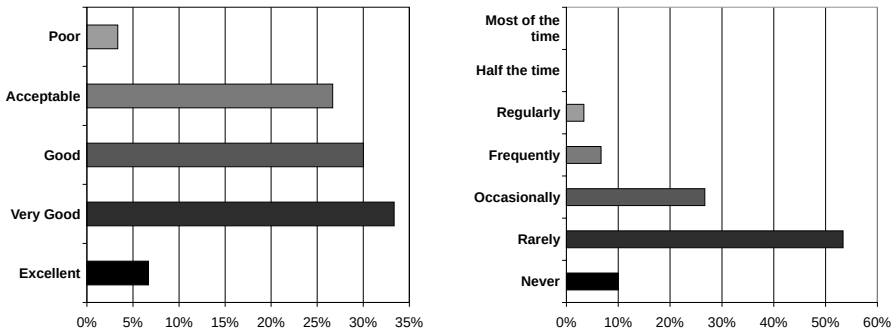
4.1 General observations

Our goal is to employ the hybrid model to provide flexibility to students without impacting, and perhaps even improving, their educational experience. The instructors did not notice any significant difference in the grades achieved and dropout rates for hybrid and regular students, although there is not enough data to make a conclusive judgment.

When a hybrid class was taught as a separate section of the regular class, students in all sections were free to attend regular lectures in the class or receive the same lectures online. While no attendance records were kept and the pattern varied across classes, typically a quarter to over half of the enrolled students would attend a given lecture. Approximately 20-30 percent of the classes were mandatory and virtually every student would attend those classes.

4.2 Tablet PC based videos

The students were queried about the quality and availability of video lectures recorded on Tablet PCs. As shown in Figure 1(a), virtually all students considered the video quality of lectures to be at least acceptable, while around 40% rated them as very good or excellent. The variation in this subjective perception of quality may be related to the medium on which the lectures were viewed which can vary from an iPod to a high quality monitor. Student responses plotted in Figure 1(b) indicate that students did have difficulty in accessing lecture videos on occasion, but the problems were isolated rather than routine. The infrasructure employed is constantly being upgraded, and while there is certainly room for improvement, we believe it is currently adequate for our educational goals.



(a) Video quality (b) Video availability

Fig. 1. Student responses to the question: *(a) What is your impression of the video quality of the online lectures in the class?* and *(b) How often was it the case that you could not gain access to video lectures because of technological difficulties, such as, the server being down or very slow?*

Students had the choice of watching a class video by direct streaming over the interne or by downloading on their computer and playing locally. Direct streaming has the advantage that video watching can begin almost immediately without waiting for a download to complete. The download time can be significant for a full lecture video, (which is in the range of 50 to 200 MBytes) depending on the internet

connection and the load on the streaming server. However, downloading first and watching has the advantage that the video can be watched independent of the quality or existence of an internet connection, which is particularly important for mobile users. Further, streaming worked only for Windows and Mac users, so downloading was the only option for Linux users. Figure 2 shows that both download and streaming modes were used extensively. Just under a quarter of respondents employed downloading exclusively, a similar number employed streaming exclusively, and the remaining employed both to varying degrees. Streaming without the ability to download offers some protection to the intellectual property contained in a video lecture. However, our results indicate that disallowing downloading would significantly reduce the appeal and convenience of video lectures.

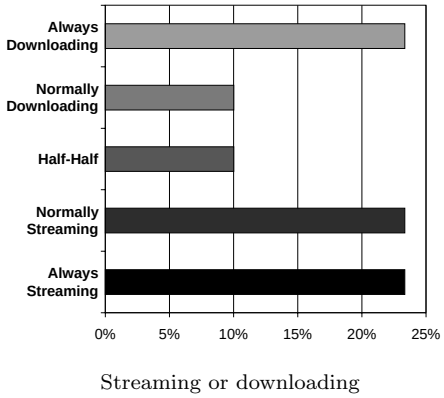


Fig. 2. Student responses to the question: *Did you normally use the video lectures by direct streaming from the server, or by downloading first and watching on your machine?*

4.3 Hybrid format

The students were queried to understand how they were learning and studying with the hybrid option. One of the concerns of any distance learning based approach is that it encourages procrastination. However, almost all the students said that they would view the lecture videos within a week, based on responses tabulated in Figure 3. Perhaps this is not surprising given that all the courses included regular assignments and quizzes that required a knowledge of the lecture material. Further, some of the video lectures had quizzes embedded in them, requiring time bound response from students and provoking discussion on message boards.

The students were also queried on how often they viewed the video lectures over the course of a semester. The results are presented in Figure 4. In the case when the students did not attend a class (Figure 4(a)), a few students did not view the video lectures at all while the remaining students were evenly divided between those who viewed once and those who viewed more than once. We observe from Figure 4(b) that an overwhelming majority of students did view video lectures even if they attended the live class. The point is that the videos serve as a flexible reusable learning resource, not just an alternative to attending a lecture live.

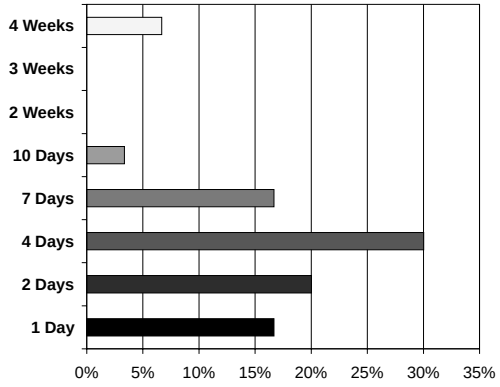
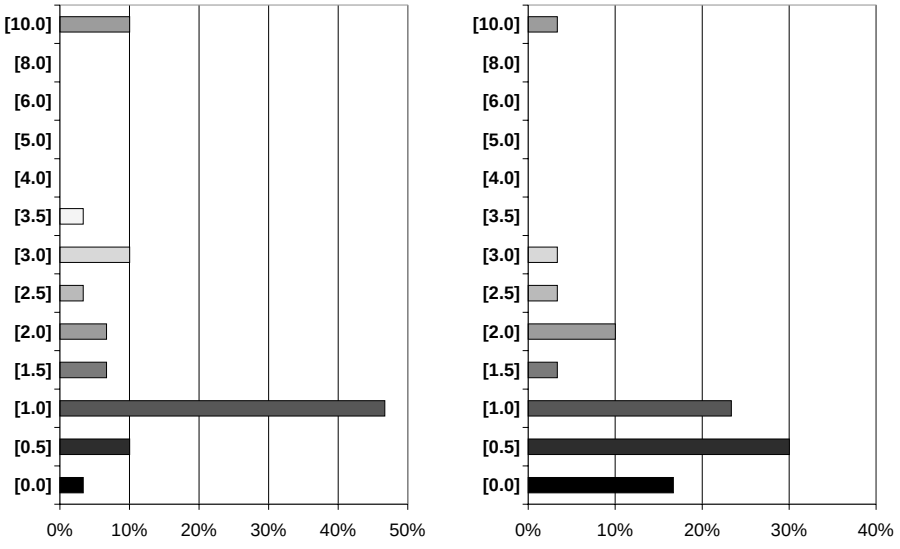


Fig. 3. Student responses to the question: *On average, when would you view the video lecture after the class for the first time if you did not attend the class?*



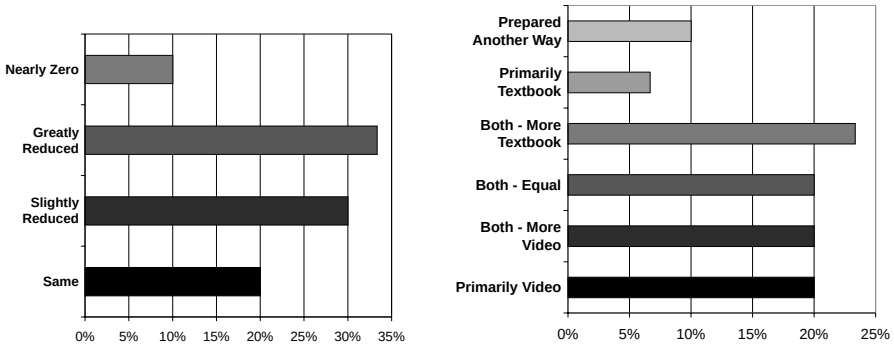
(a) Did not attend live lecture

(b) Did attend live lecture

Fig. 4. Student responses to the questions: *On average, how many time would you view a video lecture over the semester if (a) you DID NOT attend the lecture live and (b) you DID attend the lecture live*

An interesting aspect of making video lectures available to students is the impact on study habits. As noted earlier, almost all students viewed the video lectures as part of preparation even if they attended the corresponding class. Figure 5(a) charts how the student dependence on the textbooks was affected with the availability of video lectures. Approximately 80% of students made less use of the textbooks to

varying degrees since video lectures were available. Figure 5(b) shows the strategies employed for preparing for examinations. Around 65% of the students employed a combination of the textbook and video lectures, while around 20% primarily used video lectures, and only 7% primarily used the textbook. Clearly, the video lectures established themselves as a resource similar to a course textbook.



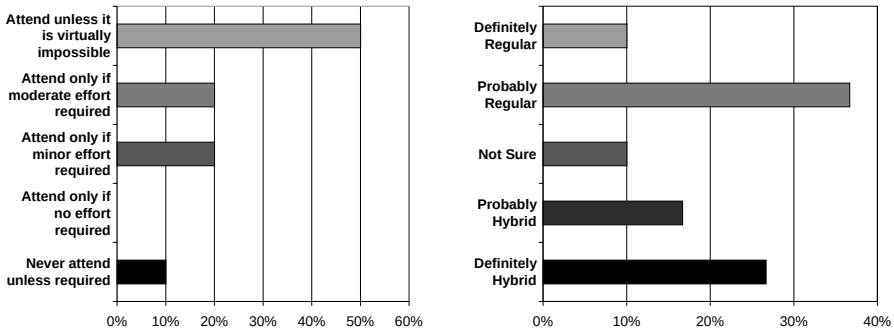
(a) Impact on textbook usage

(b) Examination preparation resources

Fig. 5. Student responses to the following questions: *(a) As compared to the time you would probably spend if video lectures were not available, the time you spent studying the textbook was ? (b) How did you prepare for the mid-term and final exams ?*

In most of our classes, the students were free to attend live classes or view video lectures on their own. While no attendance records were kept, there were significant groups of students in each of the following categories - those who would attend all live lectures, those who would attend only the required live lectures, and those who would attend some live lectures. In order to understand the reasons behind attendace (or lack of it), the students were quizzed on the criteria they would use to decide whether to attend a live lecture or not. The results are plotted in Figure 6(a). Half the students answered that they would attend a lecture if at all it was possible, a small fraction responded that they would not attend a lecture unless it was required, while the remaining would attend contingent on the effort level required. Clearly, the video lectures are not as good as being in a live classroom, but considered a satisfactory substitute by many students when classroom access was not convenient.

In order to further gauge the value the students attached to the video lectures, they were asked if they would prefer to have normal full classroom access but no access to video lectures, or full access to video lectures but no access to the classroom. The results are plotted in Figure 6(b). Students were almost evenly divided in their preference for classroom access only or video lectures only, with a few students with no preference. However, around 27% of the students responded that they would definitely prefer video lectures only, while only 10% of the students responded that they would definitely prefer classroom access only.



(a) Class attendance priority

(b) Online/Live preference

Fig. 6. Student responses to the questios: *(a) Which one statement best represents how you would decide whether to attend a lecture in class versus viewing the video later? (b) Suppose you had to strictly pick one or the other format for this class: If you picked Hybrid, you would not be allowed to attend classes and if you picked Regular, you would not have access to video lectures. What format would you pick ?*

4.4 Future improvements

The framework for hybrid coursework can be improved in a number of ways. We queried the students on the value of the following features if they were made available:

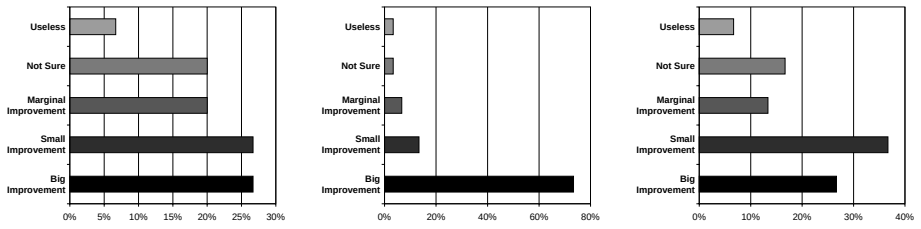
—**Instructor in video:** Currently the videos are based on the screenshots of a Tablet PC. This proposed feature would involve adding a camera and including the instructor in the video, possibly in a separate box.

—**Indexed videos:** The videos would come with index snapshots where a new topic or subtopic was started. The students can skip directly to any index point in the video lecture with a simple click.

—**Live webcast:** This would allow the classes to be webcast live. The students could tune into the class remotely and even type in questions for the instructor in real-time.

The students responses to these proposed features is charted in Figures 7.

The data shows that an overwhelming majority of students believe that adding indexing to videos will be a big improvement, while the level of enthusiasm for webcasting and having the instructor in the videos is not as strong. The chief appeal of the hybrid model is that the students can view the lectures at their own convenience which may explain the rather limited support for live webcast. The presence of instructor in the video primarily has psychological value since relevant speech and actions are captured by the table PC, which may explain the relative uncertainty of the value of this feature. Indexing has the obvious appeal that students can quickly move to the topics they want to learn or with which they are having difficulty. One of the most frustrating aspects of learning from videos is searching for the parts that hold the content that is of interest. Our ongoing research is addressing automatic indexing of lecture videos.



(a) Instructor in video (b) Indexed videos (c) Live webcast

Fig. 7. Student responses to the question: *(a) Suppose the online lectures also included a video of the instructor teaching the class. This would be ? (b) Suppose the online videos came with an index: each index point is a snapshot in the video where a new concept in the lecture is started. This would be ? (c) Suppose the classes were webcast live - you could listen to them and even type in questions for the instructor in real-time. This would be ?*

5. STUDENT COMMENTS

In addition to the multiple choice questions that are the basis of the quantitative results presented in this paper, the student comments were solicited on several topics. We list the major themes that emerged from these comments.

5.1 Technology and logistics:

There were several isolated problems that the students ran into when downloading or streaming lecture videos. Students also had some complaints about the technical quality of some of the lectures. A common problem was that the audio from the students could not be heard in the recorded lectures. (The instructors were aware of this issue and repeated the student questions and comments as much as possible.) Many of these problems have already been resolved as a result of instructor experience and technical improvements, partly driven by the student feedback.

The students were specifically queried if they preferred recordings of live lectures, which was the default mode for these courses, or lectures recorded separately, as was done for one of the classes. The students were nearly unanimous in their preference for live recordings. A representative comment:

"Video lectures should be recorded in regular class. The listeners have the feeling they are in real class and many questions that they want to ask may be asked by the students in the live class".

5.2 Value of lecture videos and hybrid courses:

Most students expressed a distinct preference for live lectures over videos for a variety of reasons. Some representative comments:

"I would like to learn things in class rather than on my own."

"I learn best when I can focus on the instructor and the subject matter exclusively. Setting aside time on my own to listen to the lectures is difficult for me, so having to go to class is helpful."

At the same time, the flexibility offered by the video lectures and the hybrid format was widely appreciated. Some representative comments:

"I work 40 hrs a week. I watched every video lecture, and found it very helpful."

"Flexible schedule - fits my schedule."

"Wanted to avoid bad traffic."

"Interactivity is good, but flexibility is better."

"I'd generally try to attend unless I had pressing work or was exhausted. I prefer flexibility in time commitments, especially since work load in CS classes varies drastically based on what is assigned at any given point - being able to allocate time based on pressure rather than having a fixed commitment makes it much easier to cope with all classes."

Some students pointed out the weakness of video as review material, in general and in comparison with text based material. A representative comment:

"The major weakness of the videos is that they are not flexible enough on delivery of information. The information of several classes can be summarized in written form and reviewed quickly, while the lectures are harder to focus and more time consuming."

Some students suggested that video lectures should be supplemented by an increased use of message boards for communication. Following are representative comments:

" "Online classroom" would do well to take advantage of time flexibility, using something like message forums for communication, rather than just allowing interaction with a class when live."

"There should be some way (some fixed time) we can communicate with instructor after the posting of video."

5.3 Suggestions to students

The students were asked if they had any suggestions for other students that would take hybrid courses in the future. The main thrust of the responses was that students shold videos regularly when not able to attend a class and treat the videos like a regularly scheduled class. Some representative comments:

"Students needs to watch video - not just before the exam but much earlier."

"Make time to watch the recorded lectures - Make yourself sit down and watch them."

"Be sure to spend time on the video lectures every week. Do not get way behind."

"For any class that offers the student flexibility: Know what you need to do to learn the material."

"Take regular class if possible. If not, be strict on your schedule, and treat it as a regular class."

"Taking your own notes forces you to pay closer attention, just as during a live class."

6. CONCLUSIONS

This project is developing hybrid coursework that combines Tablet PC based recorded lectures with limited classroom interaction. The paper reports on student and instructor experience with a total of six course offerings of four different courses at the upper undergraduate level. The key conclusions that can be drawn are the following:

—Tablet PCs offer an excellent way to record and deliver classroom experience for computer science courses. It is important to support video streaming as well as

downloading to provide access to students.

—The students consider video lectures an important resource, and not just an alternate way to "attend" a class. Most students viewed video lectures even when they attended the corresponding class and the video lectures naturally become an important component, along with textbooks and class notes, for learning and preparation for examinations.

—While the students generally consider a live class superior to a watching a video, the two resources are of comparable value when the 'anytime anywhere' flexibility of videos is taken into account. Whether a student attends an optional class or not depends on the individual preferences and logisitics.

—Hybrid coursework requires a higher degree of discipline and is not a good choice for all students or all courses. We hypothesize that it is more suitable for advanced students.

—A hybrid course has to designed carefully to provide for sufficient interaction with limited number of classroom meetings. A key question in the organization of a hybrid course is "What should be the number of mandatory classes in a hybrid course and what should be covered in the mandatory classes?" We provide some insight and guidelines but they remain open questions.

Rapidly improving instructional technologies will almost certainly change the structure of teaching and learning in years to come. However the models in which technology will be employed to facilitate and enhance coursework is far from clear. This project is an attempt to provide "anywhere anytime" learning flexibility to students without losing the benefits of classroom interaction. The goals of this project include reducing time to graduation and increasing enrollments by providing flexibility. We consider the pilot project to be a success and the model has become popular among faculty and students in our institution. A number of other courses will be offered as hybrids in semesters to come. One of the goals of this paper is to help form a community to address the challenges in developing hybrid coursework.

7. ACKNOWLEDGMENTS

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