Testimony to the Commission on the Future of Higher Education

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I am a Professor of Computer Science and Engineering at the University of Washington. About 10 years ago my career took a major shift, away from traditional research in computer science to working with educational technology, where I now spend much of my time developing classroom technology and studying how to design effective pedagogy for novel educational environments. This shift began as I became involved in a series of educational outreach activities in our department. I found the area fascinating, challenging, and rewarding, and have managed to attract a group of strong undergraduate and graduate students to work with. Four years ago, I had the opportunity to spend a sabbatical year with the Learning Sciences and Technology group at Microsoft Research, which has led to a very successful collaborative relationship. The flexibility given by the University of Washington, and by my own department, has been very important in allowing me to pursue this non-traditional path. Today I will be talking about aspects of educational technology. To illustrate some general principles, I will discuss three particular areas I have worked in at the University of Washington.

Key points that I want to get across are that there is tremendous potential for applying new technology to support higher education – as long as instructors define and pursue pedagogical goals that are an appropriate match for the technology. Applying technology to the classroom is neither easy, nor cheap, and there is still substantial work to be done in developing teaching methodologies in concert with the underlying technology.

Tutored Video Instruction is one novel mechanism for taking advantage of archived educational materials in the classroom. The key idea is to facilitate discussion around pre-recorded materials – so students can reach an understanding of classroom content with the help of their peers and a tutor. This method of instruction was developed at Stanford in the 1970's by Jack Gibbons and his colleagues. They demonstrated very impressive results in terms of learning outcomes by students at remote sites. Our tutored video instruction project at the University of Washington was intended to make our introductory computing courses available at community colleges. The specific motivation was to ensure that students who take introductory courses at the community colleges are prepared for follow-on courses when they transfer to a four-year institution. The idea of basing the courses on our pre-recorded materials was to ensure that the coverage of material was the same as at UW, and the Tutored Video model allowed community college instructors to take advantage of the face-to-face interaction. We ran the program for several years and, I will admit, there were serious challenges and missteps, although on balance there were some very positive outcomes. One in particular was the evolving relationship that the Community College instructors would have with the archived materials, integrating the content into their teaching repertoire. The technology for capture, distribution, and replay of course materials has changed radically from the days when Jack Gibbons did his initial work, but the idea has lived; this has enabled Tutored Video Instruction as well as other initiatives to spread the benefits of education in a variety of contexts. Another related project, which is also based on combining facilitated instruction with archived educational materials that I want to draw your attention to is the Digital Study Hall project, being directed by Professor Randy Wang of Princeton University. The Digital Study Hall aims to improve elementary school education in rural India by deploying low-cost digital technology to show pre-recorded educational content, supported by a classroom instructor. One of the brilliant ideas in this project is the model of making it possible for people worldwide to contribute content – such as arithmetic lessons in Hindi – which is then used selectively by the village school teacher. This model of developing a technology around community-based construction of educational resources is powerful, and has broad applications. The reason that I think Tutored Video Instruction has tremendous potential going forward lies in the way it leverages both technology advances and traditional face-to-face interaction.

Another idea that I would like to highlight is *distance learning*. I have worked with distance learning through my department's Professional Master's Program. Some of our courses are offered through site-to-site video conferencing. Over the ten-year history of the program at our department, we have used a number of technologies to support that model. Currently, we are using Microsoft's ConferenceXP. There are tradeoffs between distance and face-to-face interactions, and I don't want to downplay the technical and pedagogical expertise necessary to foster high quality real time interaction. However, digital technology enables some very significant improvements that deserve mentioning. In order to be successful, it is necessary that the value to the participants outweighs the costs associated with the distance delivery. (Our base line is the benefit of professionals not having to commute to UW across Lake Washington during rush hour.) Our most interesting successes have been in delivering recent four-way courses taught between the University of Washington, UC Berkeley, UC San Diego, and Microsoft. These were interdisciplinary courses in Public Policy for Computing, and in Cyber Security, that brought together expertise not available on any single campus. The instructors included a computer scientist from the University of Washington and an economist from UC Berkeley. The technology enabled real time interaction between sites – going a step further than just sharing of lecture content. One of the exciting opportunities of distance education is the possibility of creating experiences that wouldn't otherwise be possible.

Finally, the project I am currently directing most of my attention to aims to enhance traditional classroom instruction through the use of student devices. The vision is a classroom where students have networked devices – laptops, PDA's, tablets, or even cell phones, which interact with the instructor's device to create a learning environment rich in both spoken and electronic interaction. The underlying technology is rapidly approaching a point at which it will become widely available and there are a variety of approaches to getting computational devices into the hands of students. The motivation behind augmenting the classroom with student devices is to achieve specific educational goals. These can include active learning, classroom assessment, and integration of student work into the classroom discussion. There are many educators and researchers pursuing projects based on such networked classroom infrastructures. One major approach falls under the areas of classroom networks and classroom response systems. This is a domain where there is a growing record of documented success in terms of learning outcomes. Notable uses of classroom response systems have been in physics and astronomy, where a pedagogy of *peer instruction* has been developed around students working cooperatively and using a response system so that group responses can be compared and evaluated.

The project at the University of Washington that I am running is the Classroom Presenter project. Classroom Presenter is a Tablet PC based classroom interaction system, where the instructor writes on electronic slides with digital ink and the slides are shared with the student devices. The basic structure of a class session includes activities, where students write their answers on slides, and send them back to the instructor. The instructor then selectively shows some of the student work anonymously on a public display. This turns out to be very powerful in class. It greatly increases contributions by students – especially from quieter students who have difficulty participating otherwise. We have observed many different instructor-specific and subject-specific instructional strategies being implemented with the help of the technology – such as displaying answers from all students to demonstrate that they all have valid contributions, or analyzing particular contributions to be able to address specific key points and misconceptions. I have found it far more powerful to use slide contributions by students in order to make individual points than to rely on prepared examples. Designing a class for student interaction causes a fundamental shift in how the class preparation is thought about – a shift from the traditional model resembling the writing of a speech to a model that starts with identifying the learning goals and desired outcomes, then thinking about how to assess such outcomes, and finally connecting those with the course content.

To summarize, there is an increasing number of opportunities to deploy technology to improve higher education. This includes capturing and reusing educational content to broaden access, connecting people across distances to create opportunities that don't exist locally, and using technology in the classroom to implement strategies that improve student learning. Technology and pedagogy for all of these is still under development – and we are in a period where we have the opportunity for experimentation and discovery. From a personal point of view, the most rewarding part of working in this area has being seeing how colleagues at the University of Washington and at other institutions have used the technology in novel and unexpected ways to enhance student learning.

I thank you all for this opportunity to express my views to the Commission on the Future of Higher Education.

Background

This testimony comes from my experience with a range of educational technology projects. To provide additional context, I am providing short summaries, along with web links for the various projects.

Tutored Video Instruction

Gibbons, J.F., Kincheloe, W.R., and Down, K.S. "*Tutored videotape instruction: A new use of electronics media in education*." In Science 195, 3 (1977), 1139-1146.

In the 1970's Jack Gibbons and colleagues at Stanford pioneered Tutored Video Instruction (TVI). This was done in a program that was offering Stanford masters level engineering courses to non-local industrial sites. The basic assumption – which holds today as well – was that students learn much better from video if in a group with a facilitator who engages students in discussion about the material. Early experimental results have shown TVI instruction to be not only better than watching video (of lectures) alone, but it also compared favorably to in-class instruction. The tutor for a TVI course need not be an instructor who is fully qualified to teach the course, but someone who can lead discussions, and help students resolve questions about the material. In the original TVI model, the students should be in small groups, and the tutor should not perform a grading role in the course.

UW TVI Project

http://www.cs.washington.edu/education/dl/presenter/papers/2001/SIGCSE_TVI.pdf

More recently, TVI has been adopted in computing courses at the University of Washington. The motivation behind this decision is that the State of Washington has a large community college system with many students wishing to transfer courses to 4-year institutions. The goal therefore was to make it possible for community colleges to offer a course which students could then transfer to UW. This is an issue both of course credit, as well as needed preparation for follow-on work. Many community colleges have substantial difficulty in attracting and retraining qualified instructors. The appeal of the TVI model for such community colleges is that it allows them to offer materials (archives lectures, homework, and exams) created at UW, while using instructors with less experience in computing, but also retaining the interaction with students in small classes.

The UW lecture materials were made available online in a popular media player format showing the lecture slides in addition to a small video image of the instructor. A single camera was used for filming the live lecture. We consciously limited the impact of the filming on the instructor so that it would not compromise his or her teaching style. This meant that the instructor's writing on actual transparencies in class was not recorded. Instructors were requested to repeat student questions so that they would be audible in the archived version. The community college instructors would show the lecture in class after downloading it to a PC. These local instructors would periodically stop the lecture video for questions and discussions.

Our expectation was that three hours of lecture would take about four and a half hours to cover in the TVI in-class discussion mode. In reality, this prediction turned out to be near the low end, though it was certainly within the correct range. By deploying TVI to as many as 7 institutions over multiple quarters, and by systematically gathering student feedback, over time we were able to compile valuable ideas on what works and what does not when the classroom dynamics are altered to the point of not having a live lecture. Naturally, flaws were discovered in the concrete implementations and addressed as soon as practical; most had to do with communication to and from instructors, as well as with student perceptions of various aspects of the course mechanics. However, it was encouraging that few of the shortcomings were inherent in the TVI concept.

The Digital StudyHall

http://www.cs.princeton.edu/~rywang/distance/

Digital StudyHall is a project being run by Professor Randy Wang of Princeton University to develop an E-Learning system for improving basic education in third world countries. Good primary education is one of the most crucial factors in combating extreme poverty. In this project, computer scientists and education experts collaborate to build a distance learning system that seeks to offer resource-starved village schools in rural India human and content resources comparable to the urban environments. To avoid retracing the missteps of earlier "wire-the-schools" projects, the projects rests on two important principles: (1) cost realism, essential to scale the system up to a significant number of villages, schools, and students; and (2) building systems that solve end-to-end education problems, beyond just providing connectivity.

The Digital StudyHall system is based on a unique approach leveraging the postal system, DVDs, robotically operated DVD publishers, long-distance ham radio transceivers, and short-range TV transmitters with radio controllers. These components are combined into a general-purpose and transparent communication system, providing pervasive, high-bandwidth, and low-cost connectivity. On top of this, a web repository, called the "learning eBay" is included to enable a wide variety of digital education "workflows," such as lecture capture and replay, homework collection and feedback, and question-answer sessions, connecting learners and teaching staff across time and space, including volunteers from overseas. An important goal of the system is to enable customized any-to-any communication and effective group learning, which may provide an ultimate solution to the scalability problem of the education system.

An initial deployment of the system is taking place in two village schools in north India. One of the current key research topics is mediation-based pedagogy and training models that can simultaneously engage students and improve teachers' teaching skills. The system also plays an effective but subtle role of blurring class differences in a highly stratified society. The hope is to eventually scale up the system to cover a far greater number of villages and children, contributing toward the Millennium Development Goal of universal primary education.

ConferenceXP

http://www.conferencexp.net/community/default.aspx

ConferenceXP is an initiative by Microsoft Research to provide a shared source platform to allow researchers and educators to develop innovative educational applications. The ConferenceXP research platform enables researchers and developers to create distributed applications that take advantage of ConferenceXP technology as well as Tablet PCs and wireless networks. It also enables them to develop the collaborative tools and applications they need without having to build them from the ground up. By partnering with research organizations and universities, the ConferenceXP project combines the academic community's expertise in the learning sciences with Microsoft's expertise in technology.

By supporting real-time audio and video, as well as the development of real-time collaborative applications, ConferenceXP provides an environment that can enrich and even transform distributed learning. Currently, ConferenceXP is being successfully used to support a four-way graduate computer science course shared by the University of Washington, the University of California at Berkeley, the University of California at San Diego, and Microsoft Research. In addition to support for high-quality, low-latency audio and video, ConferenceXP provides efficient peer-to-peer, multicast network capability optimized to scale well in environments where you may find a large number of wireless notebooks or Tablet PCs, such as in a large lecture classroom.

UW Professional Masters Program

http://www.cs.washington.edu/education/courses/csep590/05au/

One application of Internet learning technology is to distribute/extend the classroom, creating a multi-site learning environment. Among the possible benefits are bringing courses to sites that otherwise would not be able to offer them, establishing critical mass to allows course to be offered, or creating a richer learning environment by bringing together students and faculty from diverse backgrounds.

In 2004 and 2005, the University of Washington, the University of California, Berkeley, and the University of California, San Diego offered joint graduate courses using Microsoft's ConferenceXP technology, with the third benefit in mind. The 2004 offering, "Information Technology and Public Policy," was taught by Computer Science & Engineering professor Ed Lazowska at the University of Washington, and Goldman School of Public Policy professor Steve Maurer at UC Berkeley, to roughly 80 graduate students at UW, Berkeley, and UCSD from computer science, public policy, and other fields. For the 2005 course, "Homeland Security," Lazowska and Maurer were joined by Computer Science & Engineering professor Geoff Voelker from UC San Diego and Christine Hartmann-Siantar from Lawrence Livermore National Laboratory; once again, roughly 80 graduate students participated.

The approach offered enormous advantages over a traditional one-campus format. The courses -- inherently interdisciplinary -- were far richer than any one of the participating faculty members would have been able to provide working alone. Students and faculty from diverse backgrounds were able to interact. Course projects involving students from multiple campuses and multiple educational backgrounds were the norm. Phenomenal guest lecturers were willing to participate because of the ability to reach students and faculty on three top-tier campuses with a single stop. ConferenceXP provided a complete archive of all class sessions. A wiki was used for student discussion outside of class; this provided a record of all discussions so that students could benefit even after the fact, and so that student contributions could be evaluated in a way that, while necessarily subjective, was more analytical than usual.

Classroom Presenter

http://www.cs.washington.edu/education/dl/presenter/

Classroom Presenter is a distributed Tablet PC-based classroom interaction system. The system supports sharing of digital ink written on electronic slides. Using a digital pen, the instructor writes on top of a slide on a Tablet PC and the ink appears simultaneously on a public display. This allows the system to be used as a presentation tool that provides dynamicity to traditional PowerPoint-style lectures by enabling ink augmentation of slides. Classroom Presenter also supports sharing of information with student devices: the students' slides can be synchronized with the instructor's slides and receive the instructor's ink in real time. Students can also write on slides and send the result back to the instructor anonymously. The instructor can then choose to show some of the submissions on a public display. Student submissions are central to the pedagogy using interacting devices; they allow the instructor to bring in a diversity of ideas, show novel solutions, and discuss misconceptions arising from student answers. The use of a public display creates a focus of attention and provides a mechanism whereby student work can be integrated into the lecture discussion – one of the most powerful aspects of the student submission process.

Classroom Presenter was developed at University of Washington as part of an ongoing collaboration with Microsoft Research, building on top of the ConferenceXP Research Platform. The system is freely distributed for academic use, and it is being used at MIT, UCSD, UMass, UCSC and other institutions in addition to University of Washington. A main emphasis of the Classroom Presenter project is to understand different pedagogies supported by the technology, including the differences that arise across disciplines, deployment scenarios, and institutions.

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