A Teaching with Technology White Paper

Lecture Webcasting

Ashley Deal | 01.16.2007

The goal of this paper is to provide an overview of lecture webcasting, and to summarize findings from several formal evaluations of the technology. We focus on questions of attendance, learning outcomes, student behavior with regard to access of archived webcasts, and effects on instructor behavior and quality of teaching.

Studies indicate that the use of lecture webcasting for the purposes of archive and review is pedagogically neutral. While lecture webcasts do not affect student performance, there is some evidence that their availability improves the student's educational experience by reducing stress and providing an additional study resource.

To improve learning outcomes, instructors must think creatively about using webcasting technology to free up valuable classroom time for more interactive discussions and activities.

Office of Technology for Education

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Working Definition

There are five general categories of activity and equipment in a lecture webcasting system:

- **Classroom presentation**
- **Classroom recording**
- **Processing and editing**
- **Hosting**
- **Distribution and playback**

Lecture webcasting has been defined as "the attempt to capture new, nonpersistent information (such as speech and the writings on a whiteboard), while integrating it with existing information (such as presentation slides) so that it can be successfully accessed at a later date" (Brotherton and Abowd, 2004, p. 122). There are five general categories of activities and equipment in a lecture webcasting system.

Classroom presentation

Presentation of teaching materials might take place using digital and analog tools, such as whiteboards, chalkboards, overhead projectors, document cameras, microphones, laptops, projectors, and wired or wireless networks. Most large lecture halls are already equipped with some or all of this equipment, and many instructors are well accustomed to their use.

> Webcasting applications compile, synthesize, and synchronize materials from multiple sources into a single interactive format.

Classroom recording

Lecture sessions are recorded using fixed or portable camera systems, and wired networks collect feeds directly from presentation equipment. Fixed camera systems often rely on scheduling software for session start and end times. These systems tend to be more efficient than portable systems as they do not require a camera operator for set-up or recording. However, that efficiency often comes at a loss in quality of the recorded output; these systems tend to focus broadly on the front of the classroom, and do not allow up-close or dynamic views of the instructor.

Most systems currently capture digital slides from a presentation as images (or pixels), not as searchable, selectable text. However, newer systems are designed to capture slides in their native format—allowing students to search webcasts for keywords, and providing a powerful means of indexing webcasts.

Processing and editing

Webcasting applications compile, synthesize, and synchronize materials from multiple sources into a single interactive format. Some systems automate this process, while others require or allow minor editing before publishing webcasts.

For systems reviewed in preparation of this report, the more automated the process, the lower the quality of the output in terms of the overall viewing experience. For example, automated systems often record long periods of inactivity in the classroom as instructors and students come in, get settled, and address course management issues before the lecture begins.

While the sacrifice may seem small in comparison to the savings gained, such quality factors may ultimately influence the duration and frequency with which students access webcasts. Whether and how these sacrifices impact webcast usage is a question that should be considered carefully. To date, we have been unable to find studies comparing the usage of webcast products that differ in this regard.

Hosting

File hosting and system administration are critical and costly components of the lecture webcasting system. The standard issues of security, robustness, reliability, and backups are no less important for lecture webcasting than they are for other academic or administrative systems.

Distribution and playback

Most lecture webcasting systems publish in a format that can be accessed with a standard web-browser or with freely distributed streaming media players. Some systems generate downloadable audio or video files that can be played back on the students' portable music or video devices. More details about the features of webcast output formats are covered in the appendix on software solutions.

There are presumably little or no costs associated with playback equipment, because output from lecture webcasting systems is designed to play back on equipment to which most students already have access. There is some level of cost to the university for providing technical support to students and lecturers in the use of webcasting systems.

Lecture Webcasting: Technical Components and Interactions

Classroom Presentation & Recording

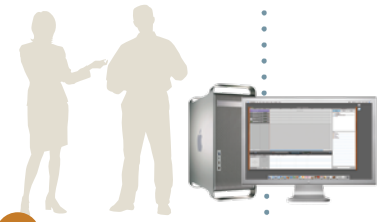
1 Instructor conducts class using a variety of **teaching aids**. Some instructors prefer digital presentation materials, while others rely on more traditional tools.

3 In most lecture webcasting systems, there is at least one **camera**, which follows the instructor throughout the presentation. Additional cameras may be used to capture analog presentation materials, like notes on whiteboards or chalkboards.

Some systems require a **camera operator**, while other systems use fixed cameras and rely on scheduling software for start and end times.

2 In many systems, feeds from digital presentation equipment are routed through **in-class audio-visual equipment**, and also transmitted directly to the webcasting system for output in lecture webcast.

Processing & Editing



4 Feeds from cameras and digital presentation equipment are gathered and synthesized into the **webcast format**. Some systems allow for simple editing before publishing, while others are streamed live and archived automatically.

Editing tasks may be performed by technicians or by instructors themselves.

Hosting

5 Webcast materials are published via the web, requiring web and streaming media **servers**, **authentication**, **backups**, **security**, etc.

Distribution & Playback

6 Once published, students may access lecture webcast archives at any point in the semester.

Most webcasting systems deliver webcasts either through **web browsers** or streaming-**media players**, like Real™ or Windows Media Player™.

Some webcasting systems deliver **downloadable audio or video files** (either primarily or as an alternative format) that can be played back on portable devices.

Learning Outcomes & Student Behavior

In terms of learning outcomes, most studies describe lecture webcasting as "pedagogically neutral," although survey results indicate that the availability of lecture webcasts can have a positive impact on the quality of the student experience. Many students welcome the increased flexibility afforded by webcasts, and report reduced anxiety and increased satisfaction with the course as a result.

Studies show that students access lecture webcasts most frequently before exams. Some reports indicate that the availability of lecture webcasts does have a slight negative impact on attendance; however, most studies concur that this impact can be effectively reduced by attendance policies and other factors.

Case Studies & Assessments

What is the effect of lecture webcasting on student **attendance**?

Does lecture webcasting positively or negatively impact **learning outcomes**?

What is **student usage behavior** with regard to lecture webcasts?

How does webcasting affect **instructor behavior** and the quality of teaching?

How and why are students using lecture webcasts? And what are the outcomes in terms of student performance and impact on the instructor? To answer these questions, we refer to reports from the following institutions: Georgia Institute of Technology (Georgia Tech), University of California at Berkeley (UC Berkeley), University of Texas at Austin (UT Austin), Universität Freiburg and Universität Mannheim, and the National University of Singapore (NUS).

"Costs, Culture, and Complexity" summarizes a UC Berkeley study comparing traditionally-delivered lecture classes to technology-enhanced lecture classes. Technology-enhanced classes use course web sites to deliver online quizzes and assignments, and digital broadcasts of video lectures synchronized to slides. The report focuses heavily on opportunities for the use of technology to help the UC system absorb a 40% increase in enrollment by 2010 (Harley, Henke, Lawrence, McMartin, Maher, Gawlick, and Muller, 2003).

"Lessons Learned From eClass" presents an in-depth analysis of an automated lecture capture and access system developed at Georgia Tech. The paper highlights "lessons learned from our three-year study focusing on the effect of capture and access on grades, attendance, and use of the captured notes and media" (Brotherton and Abowd, 2004, p. 121).

"Class Lecture Webcasting: A Case Study" is a comprehensive program evaluation from UT Austin. It examines five courses using webcasts over two semesters, and involves more than 720 students (Traphagan, 2005).

"Evaluating Web Lectures: A Case Study from HCI" summarizes an alternative approach to lecture webcasting. Instructors at Georgia Tech use webcasting to present information in outside of class, preparing students for more meaningful in-class activities. This report demonstrates that a novel implementation of lecture webcasting can have a higher than average positive impact on learning outcomes (Day and Foley, 2006).

"Lecture Recording and Its Use in a Traditional University Course" is a report on lecture webcasting from faculty at two universities in Germany (Zupancic and Horz, 2002). "NUSCast Survey: Instructor Perspective" (San, 2000) and "NUSCast Survey: Student Perspective" (Acharya, 2000) report survey results from NUS instructors and students after a semester using lecture webcasts.

Attendance

Overall, these studies indicate that the availability of lecture webcasts has only a slight impact, if any, on class attendance rates. However, survey results from several of these sources indicate that students perceive lecture webcasts as a valuable alternative when they do miss class.

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In two out of three sets of comparative attendance counts reported (captured versus noncaptured courses), researchers report a slightly lower attendance rate for captured courses. The third count reported a slightly higher attendance rate, and in all three cases, the results were deemed statistically insignificant (Brotherton and Abowd, 2004, p. 145; Harley et al., 2003, p. 41; Traphagan, 2005, p. 32).

Survey responses provide insight into students' perceptions of the relationship of attendance to lecture webcasting. In the eClass study, 30% of students agreed with the statement "eClass encourages students to skip class." The remaining 70% were divided equally among "disagree" and "no strong feeling" (Brotherton and Abowd, 2004, p. 143). In a related question, 49% of students agreed that eClass made them "feel less worried about missing class if I need to." Thirty percent disagreed, and 21% had no opinion (p. 144).

In the UC Berkeley study, as many as 25% of students reported replacing the lecture with webcasts. More than 60%

of students reported "visiting the [course] Web site rather than attending teaching staff office hours to get answers to questions at least some of the time" (Harley et al., 2003, p. 30–31). This finding is reported as a benefit of technology-enhanced teaching, because it saves valuable instructor time. However, critics might be wary of the diminished face-to-face interaction between instructors and students.

In one of the two semesters evaluated at UT Austin, the absence frequency was significantly lower for those who had never watched webcasts than for those who had. However, UT Austin researchers assert that any negative effect of lecture webcasting on attendance can be "effectively reduced by other factors, such as an instructor's attendance policies and their attitudes about attendance and the use of webcasts" (Traphagan, 2005, p. 6).

In a survey at the National University of Singapore, 61% of students agreed that it is more convenient to watch the webcast as they do not need to be physically present at the lecture hall. However, 75% indicate that they would still attend class in person even if webcast service were available. In a similar paradox, 91% agreed that viewing a lecture's live webcast helped them to acquire the knowledge needed for the subject, but 77% agreed that their knowledge acquisition would be better if they attended lecture in person (Acharya, 2000, p. 4). These findings suggest that students enjoy the convenience of webcasts, but most acknowledge the value added by attending lecture in person.

A 2001 study on college course attendance indicated that among the four most popular reasons for being absent from large classes was this: "The course content is available from another source (e.g., I can get it from the text, the web, a tutor, a classmate's notes)" (Friedman, Rodriguez, and McComb, 2001, p. 132). It stands to reason, then, that the greater access a student has to course content outside of the classroom, the more likely they will be to allow themselves to miss class when other compelling reasons arise. The studies cited indicate that this reason alone is not enough of a factor to cause the large drop in attendance that many fear will come as a byproduct of lecture webcasting.

Learning Outcomes

While none of the three standard-use studies demonstrate that lecture webcasting has a positive impact on learning outcomes, they do seem to indicate that the availability of archived lectures improves the student experience in terms of having a variety of study tools available, and relieving stress and anxiety about missed lectures when necessary. (The HCI study from Georgia Tech demonstrates that lecture webcasts can be used in novel ways to have a more dramatic impact on learning outcomes. Their methodology and findings are discussed at the end of this section.)

> Researchers at UC Berkeley found "no significant difference in the treatment and control groups in grades, retention, or conceptual understanding.

Brotherton and Abowd stated that they were "unable to find any significant difference in exam grades based on availability of captured lecture notes" (2004, p. 147). However, they postulate that students might "achieve the same level of performance with less work. When we asked students (through questionnaires) if this was in fact the case, we found that of 124 GATech students, 54% felt that eClass enabled them to study more efficiently with only 19% disagreeing... [W]hen we asked these same students if they studied more, less, or about the same when using eClass (again, via questionnaires), we found that 74% said they studied the same amount, with 6% reporting an increase and 19% indicating a decrease" (p. 148).

The UT Austin evaluation reports that "exam scores did not differ in a statistically significant way between the webcast and no-webcast sections" (Traphagan, 2005, p. 6). However, survey results indicated

a correlation between students' expectations for grade and the frequency of their webcast access: "Students who expected an A for the course watched more webcasts than those who expected a B" in one of the two semesters evaluated (p. 6). Although this study showed no real impact on learning outcomes, the author reports other benefits to students, "such as a sense of security and a reduction of anxiety" (p. 7).

Researchers from UC Berkeley report that they "found no significant difference between students in the treatment and control groups in grades, retention, or their conceptual understanding" (Harley et al., 2003, p. 39) They also report that "attitudinal data collected over two years suggest that students perceived the suite of [technological] enhancements as a significant contributor to their overall satisfaction" with the course (p. 39).

Although none of the studies show that the availability of archived lectures improves student performance, almost 80% of students surveyed at NUS believed that viewing archived lectures helped them in understanding the subject better (Acharya, 2000, p. 5). While providing archived lectures seems to improve how students feel about their performance in a certain class, there is no evidence that the use of archived lectures has a measurable impact. A potential drawback of lecture webcasting is that students might overestimate the effectiveness of reviewing archived lectures, and devote an inappropriate amount of time to that study activity.

The only outlier with regards to student performance data was the Georgia Tech HCI study, where web lectures were used to present information in advance and outside of class. In this study, students were required to view brief studio-recorded lectures (generally 15 to 25 minutes long) before coming to class. In the experimental section, topics were covered in the same order as in previous traditional semesters, with all but three in-class lectures replaced by web lectures. "Time spent watching web lectures...was deducted from the scheduled amount of in-class time for control reasons" (Day and Foley, 2006, p. 197). Brief lecture homeworks were also assigned to promote synthesis of materials covered in web lectures. (For control reasons, the same lecture homework assignments were also added to the control section curriculum.)

After discussing the web lectures and homework assignments in class, remaining time was devoted to various learning activities, including "project-related presentations, small breakout group discussions and presentations, re-design sessions, design critiques, role-playing activities, and others" (p. 197).

This study showed that "the experimental section clearly outperformed the control section. On all assignments and tests, the experimental section's average grades were higher than in the control session," with the average final course grade differing by nearly eight percentage points. In keeping with other studies, survey data from this report indicate that "students in the experimental section were more positive about the course in general" (p. 199).

The lecture homeworks were most likely a critical component in motivating students to use webcasts regularly. In a study at Universität Freiburg and Universität Mannheim in Germany, students had the opportunity to use archived lecture recordings from the previous year "in order to deal with a subject before the lecture was actually given" (Zupancic and Horz, 2002, p. 25). Their survey results indicate that only 3% of the sessions were used for that purpose.

> Webcasts are viewed most frequently just before exams, with webcast usage increasing gradually over the course of a semester.

Usage Behavior

Each of the standard use studies discussed here reports similar student behavior with regard to access of lecture webcasts. Webcasts are viewed most frequently just before exams, with webcast usage

increasing gradually over the course of a semester. Another common usage of webcasts is for review (or replacement) of recently presented materials.

Brotherton and Abowd report that 43% of all eClass accesses for a course occur within a week of an exam for that course. Nearly a third of all accesses to a lecture occur within a week of the date a lecture was given. (2004, p. 141). Traphagan reports survey data that seem to concur: roughly half of students reported watching webcasts only before exams, with about a third reporting to watch webcasts during the same week of the lecture (2005, p. 41). At NUS, 65% of surveyed students indicated that they accessed archived lectures before exams (2000, p. 5).

Usage statistics from the Zupanic-Horz study in Germany show the same patterns, including peaks in usage before exams and frequent access of lectures within the first two weeks of posting (2002, p. 25). The average recorded lecture in this study was about 70 minutes long, and the average webcast access session was 43 minutes. (However, nearly half of webcast access sessions last less than ten minutes.) The researchers observed that "some of the students who had long sessions copied the notes...on paper or did their homework while listening" to the recordings (p. 26).

The eClass study gives an average access time of less than five minutes (Brotherton and Abowd, 2004, p. 133), while the UT Austin evaluation reports more generally that some students "only watched a specific section, while some watched the whole lecture" (Traphagan, 2005, p. 42).

Instructor Behavior and Perspectives

Lecture webcasting can affect the quality of the educational experience indirectly by influencing instructor behavior and perspectives. The instructor survey from NUS provides some insight into instructors' experiences working with lecture webcasting (San, 2000).

Twelve of fifteen instructors surveyed reported watching their own lectures. They reported their primary reasons for watching as self-evaluation, learning from mistakes, and improving future lectures (p. 4).

> Instructors report watching their own lectures in order to self-evaluate, to learn from mistakes, and to improve future lectures.

Seven of the fifteen felt preparing for the recorded lecture imposed an extra burden (p. 4).

Eleven instructors believed that their subject matter was suitable for live broadcast. Two felt it was not suitable, indicating that they felt the lesson should be more interactive, or that the material was too technical to adapt to presentation-style delivery (p. 4).

Only four instructors reported positive feedback from students on the use of lecture webcasting (p. 5). All but one reported that the use of lecture webcasting did not help them learn about their students level of knowledge or understanding (p. 6).

Conclusion

In order to improve student performance, instructors should think creatively about the use of webcasting technology.

This report is intended to provide answers to some basic (but important) questions about lecture webcasting. Studies to date indicate that the use of lecture webcasting for the purposes of archive and review are pedagogically neutral.

While lecture webcasts do not directly affect student performance, there is some evidence that their availability improves the student's educational experience by reducing stress and providing an additional resource for the student's study toolkit.

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To improve student performance and learning outcomes, instructors must think creatively about using webcasting technology to free up valuable classroom time for more interactive discussions and activities.

Support

If you are an instructor at Carnegie Mellon and are interested in discussing the use of lecture webcasting in your class, please contact the:

Office of Technology for Education
ote@andrew.cmu.edu
412-268-5503

Our consultants will be happy to assist you with any phase of planning, designing, implementing, funding, and evaluating the use of technology tools and strategies for teaching.

References

Acharya C (2000) "NUSCast Survey: Student Perspective." Report from the *The Centre for Development of Teaching and Learning* at the *National University of Singapore*. https://team.nus.edu.sg/cdtl/staff/Research/CDTLMSNo_4.pdf [last access: 01.16.2007]

Brotherton J, Abowd G (2004) "Lessons Learned From eClass: Assessing Automated Capture and Access in the Classroom," *ACM Transactions on Computer-Human Interaction*, 11(2), 122. http://portal.acm.org/citation.cfm?id=1005362 [last access: 01.16.2007]

Day J and Foley J (2006) "Evaluating Web Lectures: A Case Study from HCI," *CHI 2006 Experience Report, User-Centered Design for Learning and Education*. http://portal.acm.org/citation.cfm?id=1125493 [last access: 01.16.2007]

Friedman P, Rodriguez F, McComb J (2001). "Why students do and do not attend classes: Myths and realities," College Teaching, 49(4), 124–133.

Harley D, Henke J, Lawrence S, McMartin F, Maher M, Gawlick M, Muller P (2003) "Costs, Culture, and Complexity: An Analysis of Technology Enhancements in a Large Lecture Course at UC Berkeley." Full report available online at: http://cshe.berkeley.edu/publications/docs/cost_culture_and_complexity.pdf [last access: 01.16.2007] *(Note: Abridged version published in* EDUCAUSE Quarterly*, Vol. 26 No. 3, 26–33.)*

San CY (2000) "NUSCast Survey: Instructor Perspective." Report from the *The Centre for Development of Teaching and Learning* at the *National University of Singapore*. https://team.nus.edu.sg/cdtl/staff/Research/CDTLMSNo_1.pdf [last access: 01.16.2007]

Conclusion continued

References (continued)

Traphagan T (2005) "Class Lecture Webcasting, Fall 2004 and Spring 2005: A Case Study." Report from the *Division of Instructional Innovation and Assessment* at the *University of Texas at Austin*. http://www.utexas.edu/academic/diia/research/reports/ [last access: 01.16.2007]

Zupancic B, Horz H (2002) "Lecture Recording and Its Use in a Traditional University Course," *Annual Joint Conference Integrating Technology into Computer Science Education, Proceedings of the 7th annual conference on Innovation and technology in computer science education*. http://portal.acm.org/citation.cfm?id=544424 [last access: 01.16.2007]

About the Series

The purpose of the *Teaching With Technology White Paper* series is to provide Carnegie Mellon faculty and staff access to high-quality, research-based information with regard to a given classroom technology. These papers offer a general overview of the technology topic, summarize findings from available assessments and evaluations, and give direction toward further reading and online resources.

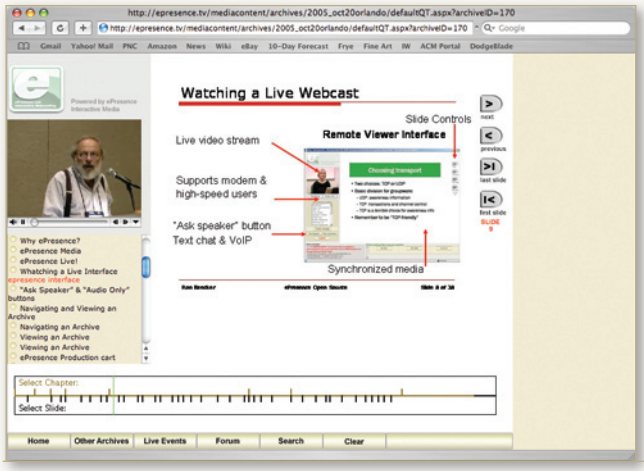
This series does not introduce original research findings from technology assessments or evaluations conducted at the Office of Technology for Education and/or Carnegie Mellon University. The papers serve as literature reviews, intended to provide scholarly integration and synthesis of the most sound and comprehensive studies documented at the time of publication.

Software Solutions

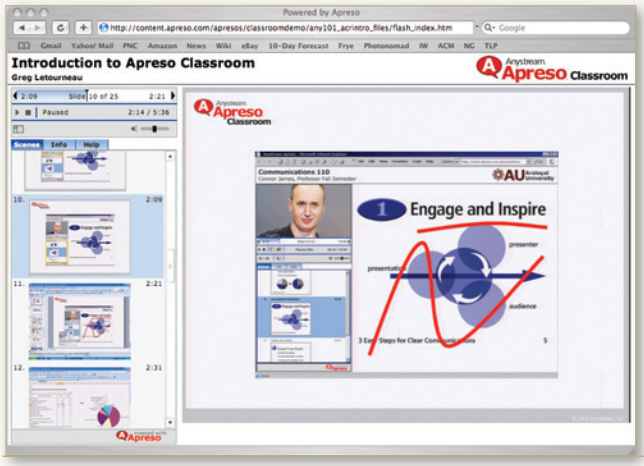
Appendix One

Systems vary widely in the presentation of end products they deliver. However, the typical webcast provides at mini-mum audio capture of the lecturer's voice during presentation. The audio track is often accompanied by either a video recording of the lecturer during presentation, or video of presentation materials, or both.

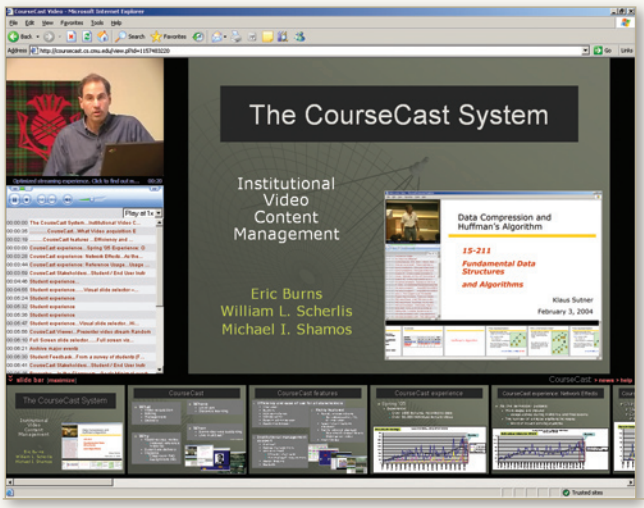
Video of presentation materials can either be recorded by camera, or can be gathered directly from digital presentation tools. The latter method offers obvious benefits with regards to efficiency and image quality. Some webcasting applications can read native presentation files and present slides as searchable and selectable text.



ePresence, an open source system developed by the University of Toronto Knowledge Media Design Institute.

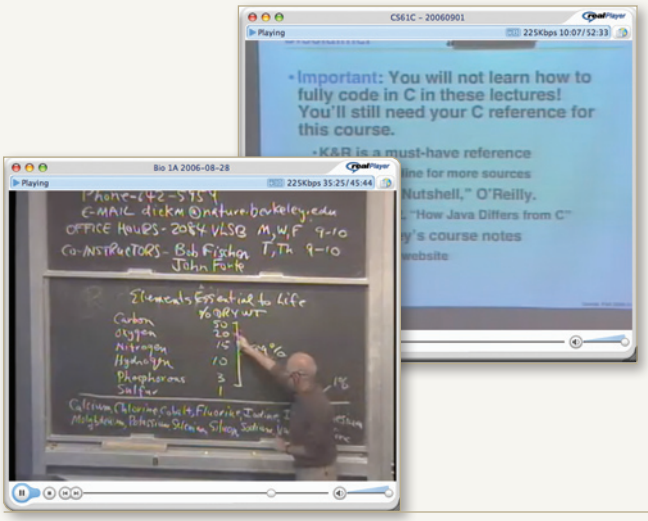


Apreso Classroom, a commercial product developed by Anystream, a company specializing in automated Web publishing systems.

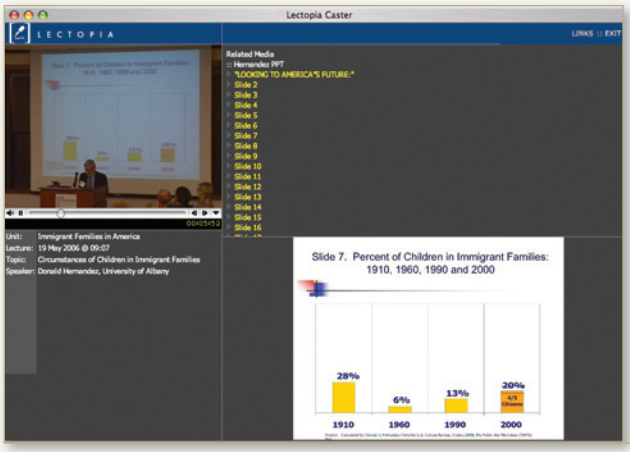


CourseCast, a system developed at Carnegie Mellon by Bill Scherlis and others in Computer Science.

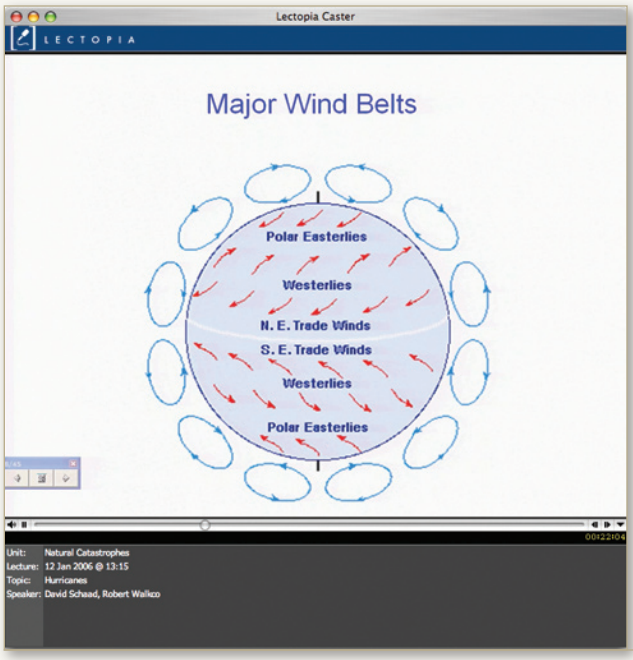
Software Solutions
Appendix One, continued



webcast.berkeley, a lecture-capture system in use at the University of California, Berkeley. This system delivers only audio and video captured by camera. It originated as the Berkeley Internet Broadcast System (BIBS).



Lectopia (also known as iLecture), developed at the University of Western Australia, and used at Duke University under the name DukeCapture. (Audio, video, and slide view shown here.)



Lectopia, shown with audio and slide view only.

Useful Resources
Appendix Two

Assessments, U.S.

"Costs, Culture, and Complexity: An Analysis of Technology Enhancements in a Large Lecture Course at UC Berkeley," by D. Harley, J. Henke, S. Lawrence, F. McMartin, M. Maher, M. Gawlik, and P. Muller. (UC Berkeley, 2003)
http://cshe.berkeley.edu/publications/docs/cost_culture_and_complexity.pdf;
http://www.educause.edu/ir/library/pdf/eqm0335.pdf

"BIBS: A Lecture Webcasting System," by L. Rowe, D. Harley, P. Pletcher, and S. Lawrence. (UC Berkeley, 2001)
http://cshe.berkeley.edu/publications/docs/bibs-report.pdf

"Evaluating Web Lectures: A Case Study from HCI," by J. Day and J. Foley. (Georgia Tech, 2006)
http://portal.acm.org/citation.cfm?id=1125493

"Class Lecture Webcasting, Fall 2004 and Spring 2005: A Case Study," by T. Traphagan. (UT Austin, 2005)
http://www.utexas.edu/academic/diia/research/reports/

"Lessons Learned From eClass: Assessing Automated Capture and Access in the Classroom," by J. Brotherton and G. Abowd. (Georgia Tech, 2004)
http://portal.acm.org/citation.cfm?id=1005362

Assessments, International

"Lecture Recording and Its Use in a Traditional University Course," by B. Zupancic and H. Horz. (Germany, 2002)
http://portal.acm.org/citation.cfm?id=544424

"NUSCast Survey: Instructor Perspective," by C.Y. San; "NUSCast Survey: Student Perspective," by C. Acharya. (Singapore, 2000)
https://team.nus.edu.sg/cdtl/staff/Research/CDTLMSNo_1.pdf;
https://team.nus.edu.sg/cdtl/staff/Research/CDTLMSNo_4.pdf

General

"The Internet-Based Lecture: Converging Teaching and Technology," by J.M. Pullen. (George Mason University, 2000)
http://portal.acm.org/citation.cfm?id=343094

"User Strategies for Handling Information Tasks in Webcasts," by C. Dufour, E. Toms, J. Lewis, and R. Baecker. (Université de Montréal, Dalhousie University, University of Toronto, 2005)
http://portal.acm.org/citation.cfm?id=1056912

"Why students do and do not attend classes: Myths and realities," by P. Friedman, F. Rodriguez, and J. McComb (2001). College Teaching, 49(4), 124–133.

Interaction and Speech Recognition

"Reinventing the Lecture: Webcasting Made Interactive," by R. Baecker, G. Moore, and A. Zijdemans. (University of Toronto, 2003)
http://epresence.tv/downloads_fileSources/reinventingLectureRoom.pdf

"A Principled Design for Scalable Internet Visual Communications with Rich Media, Interactivity, and Structured Archives," by R. Baecker. (University of Toronto, 2003)
http://portal.acm.org/citation.cfm?id=961327

"The Effect of Speech Recognition Accuracy Rates on the Usefulness and Usability of Webcast Archives," by C. Munteanu, R. Baecker, G. Penn, E. Toms, and D. James. (University of Toronto, 2006)
http://portal.acm.org/citation.cfm?id=1124848

"Enhancing Interactivity in Webcasts with VoIP," by R. Baecker, M. Baran, J. Birnholtz, C. Chan, J. Laszlo, K. Rankin, R. Schick, P. Wolf. (University of Toronto, 2006)
http://portal.acm.org/citation.cfm?id=1125501