# BIBS: A Lecture Webcasting System[1]

(BMRC Technical Report June 2001)

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## Abstract

The Berkeley Internet Broadcasting System (BIBS) is a lecture webcasting system developed and operated by the Berkeley Multimedia Research Center. The system offers live remote viewing and on-demand replay of course lectures using streaming audio and video over the Internet. During the Fall 2000 semester 14 classes were webcast, including several large lower division classes, with a total enrollment of over 4,000 students. Lectures were played over 15,000 times per month during the semester. The primary use of the webcasts is to study for examinations. Students report they watch BIBS lectures because they did not understand material presented in lecture, because they wanted to review what the instructor said about selected topics, because they missed a lecture, and/or because they had difficulty understanding the speaker (e.g., non-native English speakers). Analysis of various survey data suggests that more than 50% of the students enrolled in some large classes view lectures and that as many as 75% of the lectures are played by members of the Berkeley community. Faculty attitudes vary about the virtues of lecture webcasting. Some question the use of this technology while others believe it is a valuable aid to education. Further study is required to accurately assess the pedagogical impact that lecture webcasts have on student learning.

## 1. Introduction

The Berkeley Internet Broadcasting System (BIBS) offers live webcasts and on-demand replay of class lectures using streaming media (i.e., audio, video, and presentation material) on the Internet. We began Internet webcasting of the weekly Berkeley Multimedia, Interfaces, and Graphics (MIG) Seminar in January 1995. After webcasting this seminar for several years and experimenting with different technologies, lecture webcasting of regularly scheduled classes began in Spring 1999. As more experience was gained with this technology, and in response to student and faculty demand, the system was scaled up each semester. Fourteen and fifteen classes were webcast in the Fall 2000 and Spring 20001 semesters, respectively, including several large introductory courses (e.g., Biology 1B, Chemistry 1A, Classics 28, Computer Science 61A and 61B, IDS 110, Nutrition Sciences 10, and Physics 8A and 8B) and small upper division and graduate engineering courses. Evaluations were conducted in Spring 2000 on student and faculty use of BIBS (e.g., student surveys, focus groups, usage statistics, and instructor interviews). And, a detailed evaluation of BIBS was conducted specifically for Chemistry 1A in Fall 2000. Results from these evaluations, in combination with other feedback received from students and faculty, suggest that lecture webcasting is a valuable service that enriches the UC Berkeley learning experience.

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[1] This work was supported by funding from the National Science Foundation under Academic Research Infrastructure Grant 9512332 and Internet Technologies Grant 9907994, funding from various BMRC industrial sponsors including Fujitsu, FX PAL, NEC, and Philips, and from the Berkeley campus. The evaluation was partially supported by grants from the Hewlett and Mellon Foundations.

This report was written in response to a campus request to assess the costs and logistics of moving BIBS from BMRC to a permanently funded service organization on campus. The report describes the rationale for developing BIBS, the design of the system, including cost estimates for setting up and operating the system, and results from various evaluations of the system. In addition, operational issues and problems, as well as future research and development needs are discussed. Ultimately, we believe BIBS should be expanded to all Berkeley classes that want to provide a lecture webcasting component to the educational process.

The remainder of this introduction discusses the original goals we had in mind when developing BIBS, a brief discussion of user response to the system, and a description of the system from a user's perspective. More details are presented in later sections.

### *Original Goals*

The original goal for BIBS was to use Internet streaming media to allow students to review material from a lecture anytime, anywhere. It was believed that archiving lectures would solve many problems for students, including the difficulty of capturing hand-written or typed notes that accurately represent the lecture material presented, and the issue of making up missed lectures by faculty and students. Other solutions to these problems, such as video taping lectures and using commercial note-taking services, were believed to be inferior to streaming media. For example, finding and locating material on videotape is slow, and most tape libraries are not open 24 hours a day. Note-taking services provide a useful summary about a lecture, but sometimes more details are needed to learn the material.

Internet streaming media offers a better solution because the actual lecture can be viewed at any time on any computer, as long as adequate bandwidth is available. We have also found that lecture webcasting has advantages when instructors want to provide material outside of class meeting times, such as when preparing supplementary lectures for exam review or helping students who are having trouble with particular class topics. Campus surveys of incoming freshman indicate that nearly all students have computers connected to the Internet, and many live in the dorms, so accessing the system appears not to be an issue for most students in lower division courses.

### *Design Principles*

Several principles guided the design of the BIBS system. First, the technology must adapt to the teaching style of the instructor. Second, the lecture webcasts are not intended to replace attendance at live lectures. Third, operating the system must be cost-effective. Fourth, the system must be easy to install and use. If students perceive that lecture webcasts are a valuable learning tool, as we suspect they will, cost will be a major issue in maintaining the system and scaling it up to serve more classes. An important component of cost, and quality for that matter, is the number of people required to produce the lecture webcasts. For this reason, BIBS was designed to run automatically with as few staff as possible.

### *User Response*

The user response to BIBS has been very positive. Analysis of usage data shows that over 10,000, 15,000, and 19,000 videos were played each month during the Spring 2000, Fall 2000, and Spring 2001 semesters, respectively. It appears that students primarily use BIBS for on-demand replay when studying for examinations as shown by weekly usage data that peaks during midterms and before finals. Our best estimate, which is derived from user surveys, is that more than 30% of the students on average watch three or more lectures during the semester. In some classes, the number of students using BIBS exceeds 50%. This number has increased each semester as more people learn about BIBS, and more students get access to computers with broadband access to the Internet.

### *A Snapshot of the BIBS Technology*

BIBS users access the lectures through a web-based electronic program guide developed by BMRC. The screen shot on the left in Figure 1 shows the schedule of classes being webcast during a semester. Clicking on the name of a particular class displays to the user a web page with a link to join the live lecture (if it is currently being webcast) and a list of lectures that can be played on-demand as shown in the screen shot on the right in Figure 1. If the user clicks on the live lecture link or an on-demand lecture icon, a client player is launched and the lecture is replayed as illustrated by the screen shot shown in Figure 2.

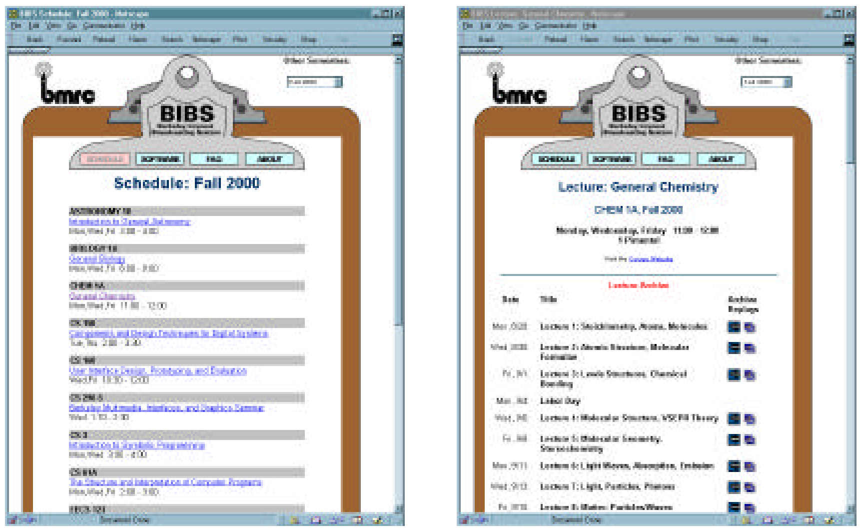


**Figure 1: BIBS Program Guide**

The web page on the left shows the classes being webcast in the Spring 2000 Semester. If the user clicks on a class, a list of lectures is presented for that class as shown in the web page on the right. Clicking on a lecture title launches the player shown in Figure 2.

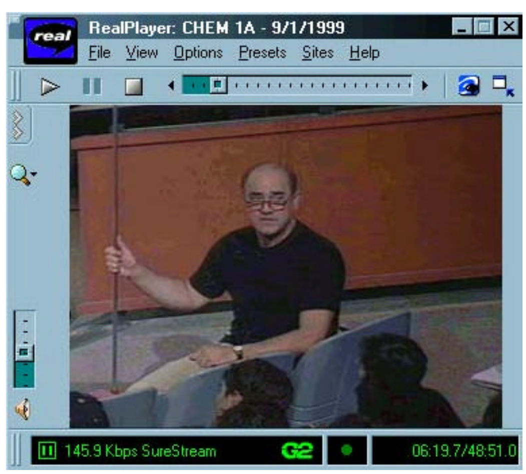


**Figure 2: Example of the Client Player**

This screen shot shows Professor Pines lecturing in Pimentel Hall.

BMRC produced software, based on technology developed at Cornell [Mukhopadhyay99], which allows presentation material (e.g., still images produced by PowerPoint or captured from blackboards) to be synchronized with the lecture audio and video. The *BMRC Lecture Browser*, see example in Figure 3, is a web-based player that presents to the viewer the speaker stream, presentation material, an index to the slide titles, and a keyword search interface. Users can watch a lecture and the slides change automatically as the speaker moves to the next topic. The user can step forward to look at slides that will be used in the future and backwards to re-examine slides already presented. The video continues to play during this time. After examining the slides, the user can either choose to synchronize the slides to the video, or synchronize the video to the currently displayed slide. An index of slide titles can also be used to locate a particular topic and start the video and slides at that topic. Lastly, the keyword search interface allows the user to search for selected words within the current lecture, across all lectures for the class during the current semester, across all lectures for the class during any semester, or across all lectures in the BIBS archive. The word index is constructed from the words used on the slides.

The Lecture Browser technology has been deployed in two classes: General Chemistry (Chem1A) and User Interface Design, Prototyping and Evaluation (CS160). It has also been used for the MIG Seminar and several workshops and special events. Feedback from students in classes that used this technology was positive. They particularly liked the feature that allowed them to search all lectures in a semester to find where the instructor talked about a particular topic.

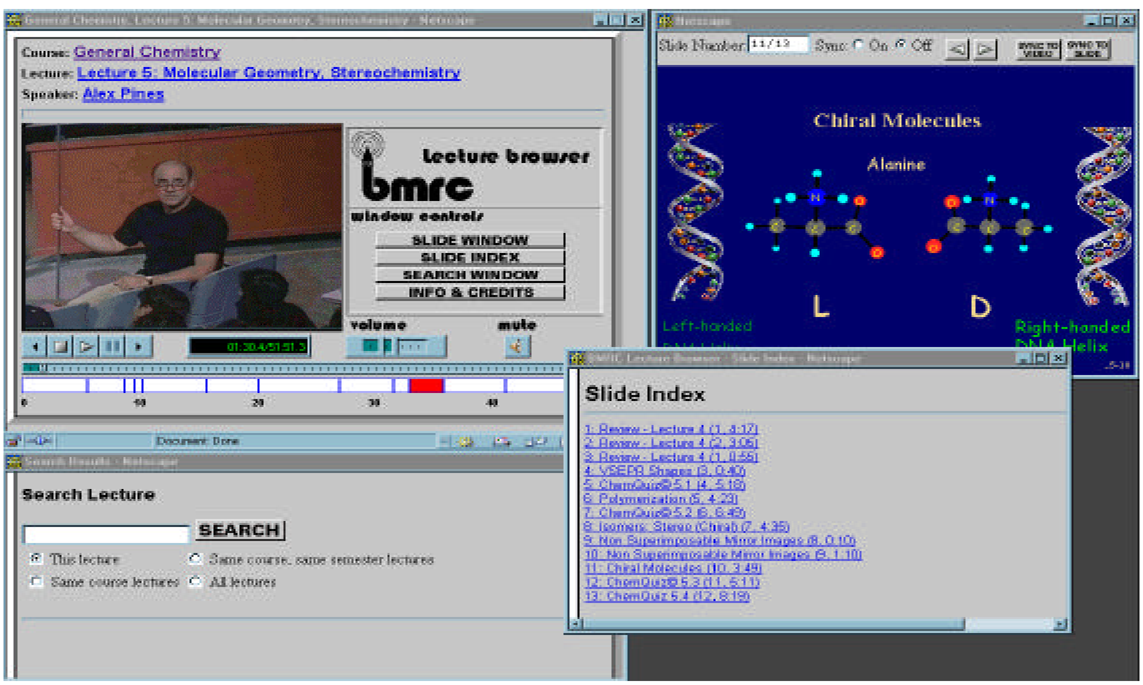


**Figure 3: Berkeley Lecture Browser**

Users can watch the video lecture with synchronized slides. They can look at slides before or after the current slide, reposition the video and slide to the one selected in the slide index or returned by the keyword search command.

The remainder of this report presents further details on BIBS and its evaluation. The paper is organized as follows. Section 2 describes the design and implementation of the system. Section 3 presents results from various analyses and evaluations conducted on the system. Section 4 discusses further development of BIBS and recommendations about deploying the system on the Berkeley campus.

## 2. BIBS Design and Implementation

This section describes the design and implementation of the system and summarizes the costs of setting up and operating a system like BIBS. Material can be captured live if equipment is installed in the classroom; otherwise, it is captured off-line from videotape. Between 5-10% of the classrooms on the Berkeley campus have the equipment required for live capture. The Office of Media Services (OMS) operates most of these classrooms. BMRC installed, and continues to operate, equipment in some classrooms. The presentation in this section describes BIBS from the perspective of a webcast produced in a classroom operated by OMS. BMRC-operated classrooms, primarily located in Soda Hall, use different equipment and operating philosophies than OMS. These differences are discussed below.

### *Design and Implementation*

Figure 4 shows the architecture of the BIBS system. The lecture audio and video is produced in a classroom. This material is transmitted over a conventional video distribution network to the OMS broadcast center, which records the program on videotape. The audio/video signal is also sent to a computer called a *video gateway* that runs software to digitize the lecture and send it to a streaming media server. Users run a program on their computer, called a *client player*, that plays the audio and video webcasts sent to it from the streaming media server. The BIBS system uses commercial software from Real Networks for the video gateways, the streaming media server, and the client player.

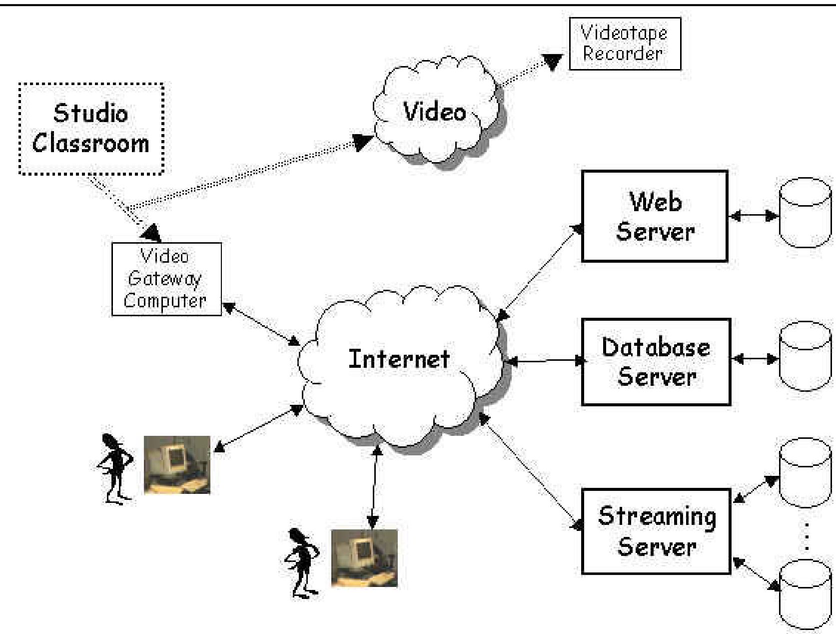


**Figure 4: BIBS System Architecture**

**Managing Video Content.** BMRC developed a database application and web pages for end-users to ~~easily access the video residing on the system. These database applications and web pages also allow~~

staff to manage the system. The database stores information about classes being webcast (e.g., class title, class web page URL, instructor, class meeting dates, times, and location, and lecture titles, start, and end times) and, in the case of seminars, information about individual seminars (e.g., speaker name, affiliation, seminar title and abstract, slides, etc.). Figure 1 showed the archive page for a regular class. Figure 5 shows the archive page for the Berkeley MIG Seminar and an announcement for a specific seminar. Figure 6 shows one of the web pages that BIBS staff uses to edit data about the classes being webcast. This interface allows staff to add, delete or modify information about semesters and classes.

The class meeting days and class start and end times are used to schedule the lecture capture software on the video gateways. The schedule takes into account university holidays to avoid launching a webcast on an empty room. Semesters, classes,[1] and seminar lectures have a *published* attribute that, if not set, causes the semester, class or lecture to be omitted from the BIBS program guide. This feature is used when instructors request that specific material be removed from the system. Information about individual classes and lectures can be modified by clicking buttons next to the specific classes, shown at the bottom of Figure 6.

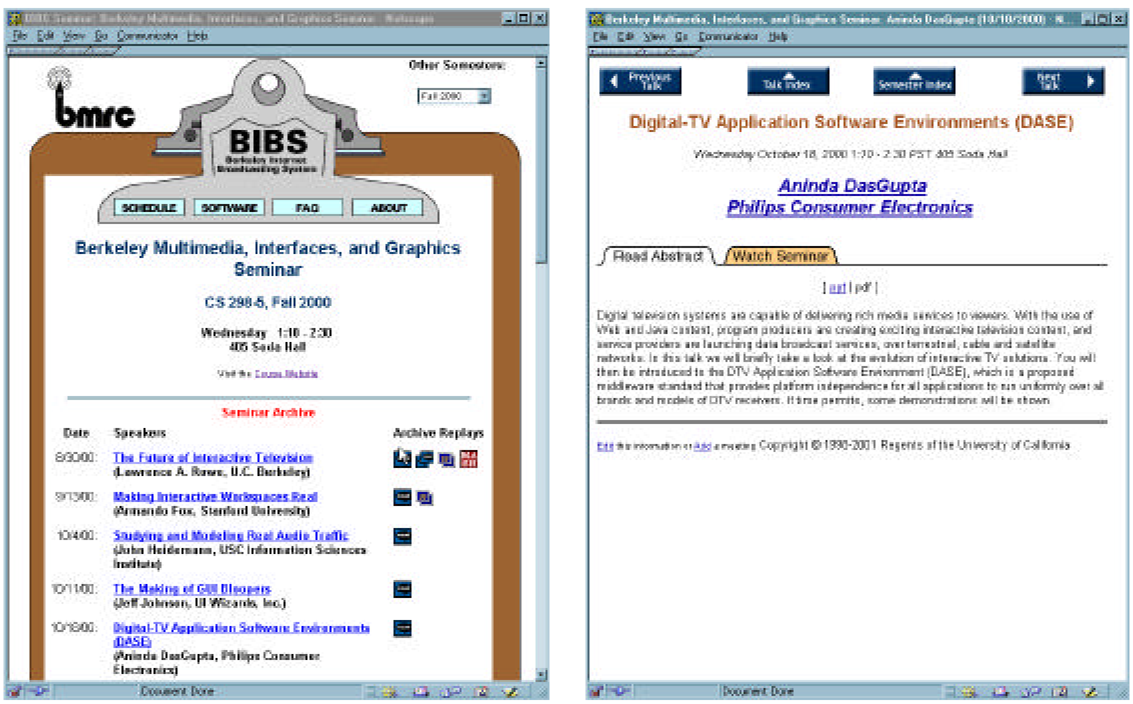


**Figure 5: Sample Seminar Archive and Announcement Pages**

The web page on the left shows the seminars scheduled for a semester, and the page on the right shows the announcement of a specific seminar.

[1] Classes are called *programs* in BIBS because we planned to offer non-class programming using the same system (e.g., cable channels and scheduled event replays). However, we realized that scheduled replays are unnecessary when any content can be played on-demand.

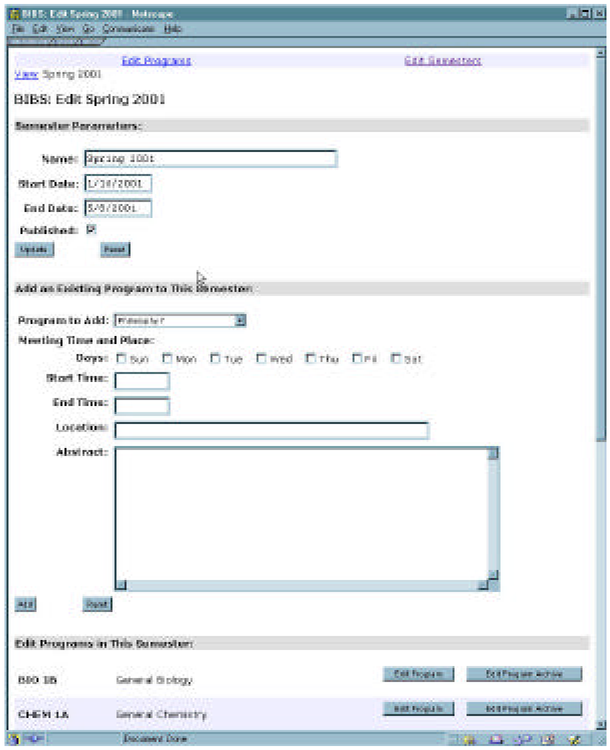


**Figure 6: Example BIBS Database Editing Page**

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BIBS allows a start and end time to be entered for each lecture because the actual time the speaker begins and ends a lecture can vary. The lecture replay starts and ends at the times specified rather than at the beginning and end of the captured material so that when a student asks to watch a lecture, it starts when the speaker begins the class.

Lecture Browser titles are authored off-line (i.e., after the lecture is completed) using tools developed by BMRC. The lecture video, presentation materials (e.g., slide images), and slide time-codes (i.e., start and end times for each slide) are entered into the BIBS database. The Lecture Browser is implemented by a series of JavaScript functions that read the data from the database and implement the interface shown in Figure 3. A plug-in is available to automatically record slide time-codes if the speaker uses a PowerPoint presentation. Otherwise, the author must view the lecture and enter the time-codes manually.

**Servers and Software**. The web server and DBMS system run on a Linux PC. This system serves all BMRC web requests, which averages over 400,000 page requests per month. Approximately 20,000 of these page requests are for BIBS pages. The streaming media server runs on a Windows NT PC. The server has a 300 GB RAID disk storage system and a Real Networks server that is licensed to deliver up to 100 streams concurrently.[2] A *cgi-bin* script reads data from the database and generates the BIBS electronic program guide. The web pages shown in Figures 1 and 4 above are examples. The *cgi-bin* scripts were originally coded in *ColdFusion*, but they are being recoded in *PHP*, which is a server-side scripting language, because it is more flexible, runs on Unix platforms, and eliminates the need for some unreliable software components in the system.

[2] The license was upgraded to serve 200 streams in December 2000 because several times during the semester the server was delivering 100 streams and users were denied access to the system.

The video gateway computers are Linux PC's. The capture software is launched automatically at the appropriate time specified in the BIBS database. The captured material is written to a local disk and simultaneously sent to the Real Networks server, which forwards packets to live viewers. The lecture is also recorded on videotape by OMS. BMRC hires a student, called a *web operator* or *webop* for short, to monitor the webcast, copy the local file to the server at the end of the lecture, and update the BIBS database (e.g., enter the start and end times and lecture title). We use the local copy rather than asking the server to write a copy to the server disk to reduce the load on the server during the live webcast.

Should the audio/video production or capture software fail for some reason, the lecture is re-captured from the videotape off-line. The webop is responsible for re-capturing the lecture. Originally, the webop had to get the physical tape to recapture the lecture. This delayed re-capture and put an extra burden on OMS and BMRC. We recently installed a new capture computer in OMS so now the webop can call OMS and ask them to load and play the tape. The webop runs the software to capture it remotely. This procedural change has reduced the burden on BMRC and OMS staff and improved BIBS service.

The Real Networks streaming media system has a multiple-rate streaming feature, called *SureStream*, which allows several versions of the material to be encoded at different bit rates, stored, and delivered to the user. Users connect to the server asking for the highest bit rate their Internet connection can support. The player and server attempt to play the lecture at that rate. The client player will switch rates during playback if the connection cannot handle the requested bit rate. Dynamic switching also happens if a temporary bottleneck develops in the Internet. The player will switch back to a higher rate if the bottleneck disappears. BIBS material is encoded at three bit rates: 50 Kbs, 128 Kbs, and 200 Kbs. These bit rates were chosen for two reasons. First, they match typical Internet connections. Second, the capture computers installed in 1999-2000 could not encode higher bit rates or more encodings in real-time. Computer performance and encoding algorithms are continually improving so the bit rates chosen should be regularly updated. A three-unit semester class has approximately forty hours of lecture material, which requires 7 GB of storage using the three encodings listed above. Using disk prices quoted below ($85/GB), lectures for one class cost roughly $600 for storage.

**Lecture Capture and Video Gateways.** Our original approach to capturing lectures was to put video gateways in every classroom, but experience suggests a better solution. First, most classrooms do not have an audio/video closet or control booth in which to put the computers. The alternative, which is putting the computers in the classroom, is not a good idea because they are noisy and hot. Second, the video gateways need regular maintenance that requires staff to work in the classroom or bring the computers back to a repair center. Staff working in the room disrupts a class, and lectures cannot be webcast during maintenance periods. Moreover, the Real Networks capture software is unreliable. The connection to the server is dropped periodically which causes the capture software to exit, and the lecture being captured is lost.[3] Given these considerations, we believe a better approach is to transmit the analog audio and video signals to a machine room in the building using either RF transmission on coax or fiber or a baseband signal on unshielded twisted-pair cabling (e.g., CAT5). Computers in the machine room can be shared, and more importantly, two video gateways can redundantly encode the lecture thereby improving the reliability of the webcasting system [Ernie00]. BMRC is installing additional video gateways into the OMS broadcast center in Dwinnelle Hall and building a broadcast center in Soda Hall to implement this strategy.

**Staffing Considerations.** The OMS operating philosophy uses one or more production staff in the classroom to produce the audio/video program. The program, which is composed of a single audio and video stream (i.e., a TV program), is recorded on videotape in the broadcast center in Dwinnelle Hall. BMRC uses a different operating philosophy to produce webcasts. We are experimenting with

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[3] The capture software should continue to capture the lecture into a local file even though the server connection is lost, but the Real Networks software does not operate in that manner.

webcasts that have multiple video streams (e.g., one stream shows the speaker and a second stream shows the presentation material) as shown in Figure 7. The user can view any of the video streams being produced and size them on their computer desktop so the most important material to them is largest.

The use of automatic tracking cameras that follow speakers, webcasting multiple streams with user selection of streams to be displayed, and software automation to control camera switching can reduce production staff. The idea is to replace expensive staff with intelligent software and user control. This approach also deals with chronic staff problems including training, attention to detail during a broadcast, and reliability of personnel. For example, a common student complaint with current televised or webcast lectures is that the camera is not showing what the viewer wants to see. The solution is to produce multiple streams and let the user choose what they want to see. The long-term goal should be to reduce the staff required to one person supervising many webcasts. We believe this goal is achievable, but it will require continuing research and experimentation.

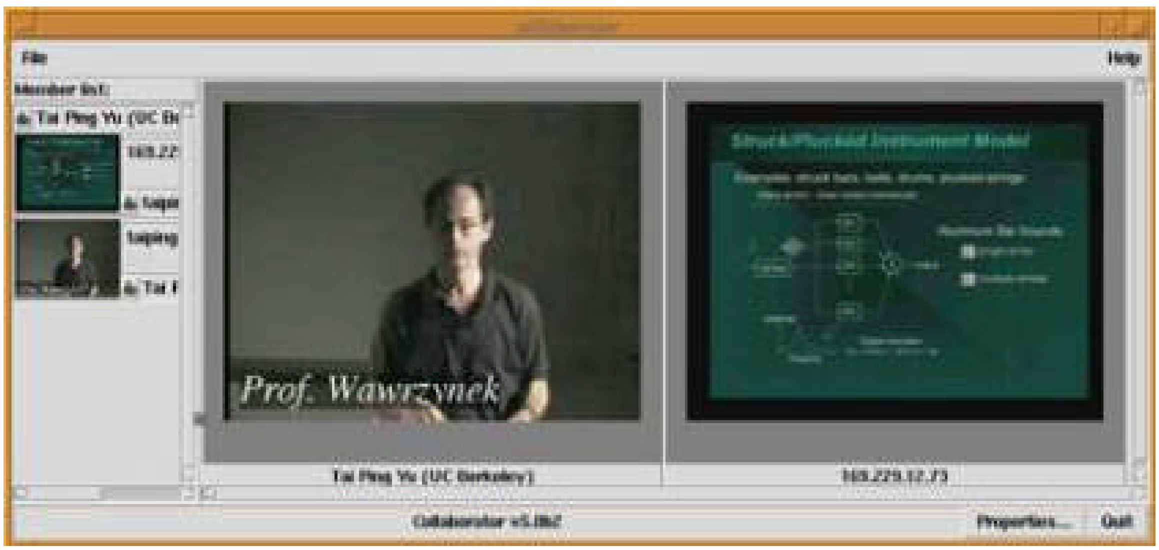


**Figure 7: Two-stream Lecture Webcast**

### *Costs*

The cost of setting up and operating a system like BIBS is complex. The costs can be disaggregated into three components: 1) the streaming media, web, and database servers, 2) the audio/video equipment in classrooms, and 3) staff to maintain and operate the system. Each cost component is discussed in the following paragraphs.

**Streaming Media, Web, and Database Servers.** These three servers are run on different computers, which allows us to balance the workload and to optimize each server (e.g., use the best combination of operating system and server software). These servers handle all BMRC applications, not just BIBS. An *Apache* web server and a public domain relational database system, named *PostSQL*, are run on Unix PC's. The web server handles approximately 400,000 page requests per month. The streaming media server runs on a Microsoft Windows NT PC with 300 GB of disk memory. This server handles more than 50,000 requests to play videos per month, 15,000-20,000 of which are requests to play class lectures.

Rebuilding this system today would cost much less than it cost when the original system was purchased. Moreover, a system built today would be different. A system built to service BIBS can run the web and database servers on one PC that costs approximately $5,000. A streaming media server that can handle at least 25 classes and 200 concurrent streams costs:

| | | |
|---|---|---|
| Computer | $2,500 | Dual processor P3/800MHz with 512MB RAM |
| Disk Storage | $15,000 | 12-disk RAID system with 180GB usable space |
| Streaming Media Software | $15,000 | 200 stream Real Networks Server |
| **TOTAL** | $32,500 | |

The network bandwidth required to serve 200 streams at 200 Kbs per stream is roughly 40 Mbs, but experience indicates that the average bandwidth required is lower, possibly between 10-20 Mbs. A 100 Mbs Ethernet connection is more than adequate to provide this bandwidth. Our current server easily handles 50,000 video plays per month so this server should have room to service many more classes than the current BIBS operation. Additional disk storage is required if you want to add more classes and/or keep lectures from previous semesters on-line. The campus has already purchased the software licenses so they can be shared with BMRC, which reduces the total cost of the hardware and software to build a replacement to $22,500.

The only problem with this PC solution is reliability. The current BIBS system crashes 2-3 times per semester due to software problems. The ColdFusion interface to PostSQL has a memory leak that forces us to reboot the system periodically. And, the Microsoft Windows NT operating system and IIS web server also need to be rebooted every week or two. Sadly, hackers attacking the systems cause some of the problems. Most of these problems will be eliminated when the new electronic program guide scripts are deployed and the streaming media server is run on a Unix system or the streaming media server is upgraded to Windows 2000. However, the system architecture for a permanent BIBS system should use redundant servers and network connections to improve reliability and availability. For example, several streaming media servers can share access to a large disk storage system using a storage area network and a load balancing router with redundant network connections to spread the load across the servers. An alternative approach is to use a large Unix storage server that can be configured to handle the web, database, and streaming media servers. In addition, redundant network connections are needed to improve access reliability in the event that a network interface or router fails. Depending on the approach used, this system might be twice as expensive as the BMRC replacement system described above.

**Classroom Equipment.** Classroom equipment is the second major cost of the lecture webcasting system. Each classroom, called a *studio classroom*, must be equipped with microphones, cameras, presentation devices (e.g., PCs and projectors, overhead or document cameras, VCRs, etc.), room lighting and sound treatment, and other video production equipment. Installing this equipment in a conventional classroom costs between $25,000 and $100,000 for a limited webcasting facility, and between $250,000 and $500,000 for a sophisticated broadcast facility that has a control room with special-effects equipment (e.g., titling, still frame, transitions, etc.) and multiple projection screens for live two-way distance learning (i.e., remote participation by students at a different location). We believe future development of classrooms at UC Berkeley should include a mixture of low-cost studio classrooms that can be used for webcasting and more expensive distance learning classrooms with two-way capabilities. BMRC has seen a significant increase in queries regarding the availability of two-way conferencing facilities for campus classes, seminars, and research projects.

**Staffing**. Operating costs vary depending on the approach used to produce the webcast. The cost of producing and webcasting lectures for a semester is $3,000-$4,000 per class, which includes OMS staff and a BMRC webop. As discussed above, we believe that with the integration of intelligent software, this particular cost can be significantly reduced, possibly below $500 per class. There are additional operating costs as well. A half-time computer systems manager is required to operate and maintain the computer systems, and management personnel are needed to supervise the operation and interact with instructors. Finally, our experience operating BIBS suggests that faculty involvement in the process is important to ensure that instructor questions are answered, their fears about this potentially threatening technology are allayed, and their input is considered in system modifications.

## 3. Evaluation

This section summarizes some of the results from evaluations conducted on BIBS. These results are derived from: 1) analysis of usage logs provided by the streaming media server, 2) analysis of questionnaires and surveys of students and teaching staff, and 3) compilation of self-reported data gathered from a variety of sources, including interviews, focus groups, and unsolicited user comments.

### *Usage Logs*

The Real Networks Server writes a log record every time a video is played that includes the video file played, the date and time it was played, the total time the file was played, and the IP address of the computer on which the client player is running. This section presents results derived from analyzing these logs for the Spring 2000 and Fall 2000 semesters.

A total of 43,569 videos were played in Spring 2000. Eleven classes were webcast, which included nine undergraduate and two graduate classes, with a total enrollment of 2,914, which is 14 videos played per enrolled student. Total plays increased by 55% to 67,642 during Fall 2000. Fourteen classes were webcast, which included 10 undergraduate and 4 graduate classes, with a total enrollment of 4,193, which is 15 videos played per enrolled student. Consequently, most of the increase in plays was caused by the increase in the number of classes webcast.

Figures 8 and 9 show the breakdown of lectures played by class for both semesters. The number of plays per enrolled student is a rough estimate because some students enrolled in a class played zero lectures. We estimate that approximately 50% of the plays are by enrolled students, 25% of the plays are by people at Berkeley not enrolled in the class (e.g., other students, staff, and faculty), and 25% of the plays are by people elsewhere on the Internet. Moreover, some plays are for lectures in classes not being offered in the current semester (e.g., 1,718 plays during Fall 2000). Some of these plays are for classes offered but not webcast during that semester (e.g., CS 61B, CS 61C, CS 152, and EE 105 in Fall 2000). That is, students taking a class watched lecture webcasts from a previous offering of the class, in most cases with a different instructor. And, some plays are for classes, typically graduate classes, not being offered during the semester (e.g., CS 294-1 and ME 221). BMRC is webcasting 15 classes in the Spring 2001 semester, which was the maximum number we could handle given available resources. Several other instructors asked to have their classes webcast, but we could not accommodate their request. All of this data suggests increasing demand for the BIBS service.

The tables in Figures 8 and 9 include both live viewing and on-demand replay of lectures. The table in Figure 10 shows the percentage of live lectures played. The total number of live plays was only 14% and 5% of all plays in the Spring 2000 and Fall 2000 semesters, respectively. Moreover, these results are impacted by the unusually high percentage of live remote viewers in the Spring 2000 offering of CS 61A (29%). Some possible explanations for this large percentage are the specific make-up of the class, the instructor, or the material covered that semester. The percentage declined to 7% in the Fall 2000 semester. Further investigation of this phenomenon is warranted. Notwithstanding this anomaly, most students are not using the webcasts to watch live lectures remotely. This observation is also supported by survey data reported below.

| Class | Spring 2000 Enrolled | Spring 2000 Total Plays | Spring 2000 Plays/ Enrolled Student | Fall 2000 Enrolled | Fall 2000 Total Plays | Fall 2000 Plays/ Enrolled Student | % Increase Plays/Student |
|---|---|---|---|---|---|---|---|
| Art 160 | 20 | 234 | 12 | 0 | 16 | - | |
| Astro 10 | | | | 668 | 12,586 | 19 | |
| Bio 1A | 505 | 13,592 | 27 | 459 | 13,755 | 30 | 11% |
| Chem 1A | 503 | 4,982 | 10 | 1,198 | 17,302 | 14 | 46% |
| CS 3 | | | | 355 | 428 | 1 | |
| CS 61A | 437 | 7,719 | 18 | 477 | 8,577 | 18 | 2% |
| CS 61B | 395 | 5,454 | 14 | 0 | 504 | - | |
| CS 61C | 356 | 1,257 | 4 | 0 | 351 | - | |
| CS 150 | | | | 211 | 684 | 3 | |
| CS 152 | 44 | 1,574 | 36 | 0 | 628 | - | |
| CS 160 | | | | 51 | 755 | 15 | |
| EE 105 | 96 | 728 | 8 | 0 | 43 | - | |
| EE 123 | | | | 33 | 1,648 | 50 | |
| IDS 110 | 510 | 5140 | 10 | 390 | 4,471 | 11 | 14% |
| Phil 7 | | | | 224 | 953 | 4 | |
| **Total** | **2,866** | **40,680** | **14** | **4,066** | **62,701** | **15** | 9% |

**Figure 8: Spring 2000 and Fall 2000 Viewing Statistics for Undergraduate Classes**

| Class | Spring 2000 Enrolled | Spring 2000 Total Plays | Spring 2000 Plays/ Enrolled Student | Fall 2000 Enrolled | Fall 2000 Total Plays | Fall 2000 Plays/ Enrolled Student |
|---|---|---|---|---|---|---|
| CS 294-1 | 0 | 125 | - | 0 | 176 | - |
| CS 298-5 | 13 | 1,246 | 96 | 15 | 1,455 | 97 |
| EE240 | 35 | 1,468 | 42 | | | |
| EE 245 | | | | 64 | 2,281 | 36 |
| Jrnl 298 | | | | 7 | 208 | 30 |
| ME 221 | 0 | 50 | - | 35 | 425 | 12 |
| ME290F | | | | 6 | 396 | 66 |
| **Total** | **48** | **2,889** | **60** | **127** | **4,941** | **39** |

**Figure 9: Spring 2000 and Fall 2000 Viewing Statistics for Graduate Classes**

| Class | Spring 2000 Live Plays | Spring 2000 Total Plays | Spring 2000 Live % | Fall 2000 Live Plays | Fall 2000 Total Plays | Fall 2000 Live % |
|---|---|---|---|---|---|---|
| Astro 10 | | | | 608 | 12,586 | 5% |
| Bio 1A | 398 | 13,592 | 3% | 336 | 13,755 | 2% |
| Chem 1A | 526 | 4,982 | 11% | 1,199 | 17,302 | 7% |
| CS 61A | 2264 | 7,719 | 29% | 639 | 8,577 | 7% |
| CS 61B | 1002 | 5,454 | 18% | | | |
| CS 152 | 192 | 1,574 | 12% | | | |
| CS 160 | | | | 75 | 755 | 10% |
| EE 123 | | | | 34 | 1,648 | 2% |
| IDS 110 | 815 | 5140 | 16% | 293 | 4,471 | 7% |
| **Total** | **5,197** | **38,461** | 14% | **3,184** | **59,094** | 5% |

**Figure 10: Live –vs- On-demand Plays**

Figure 11 shows a graph of the number of plays per week for the two semesters. The dashed line shows the weekly total of on-demand replays for the Spring 2000 semester and the solid line shows the weekly total for the Fall 2000 semester. The sixteenth week corresponds to the two weeks of finals. The peak during the tenth week in the Spring 2000 semester is deceiving because it includes plays over the spring break; in other words, it included plays from two weeks. The peaks during weeks five, eight, and ten correspond to normal times when midterms are given. Lastly, there is a significant increase in usage during the fifteenth and sixteenth weeks as students begin preparation for finals. These data strongly support the observation that students are using the BIBS lectures on-demand to prepare for examinations.

Other findings discovered by analyzing the usage logs include the following:

1. The duration of each play is short. If you divide the typical lecture into five equally spaced time segments (e.g., 0-10 minutes, 11-20 minutes, etc. for a fifty minute class), over 60% of the replays are in the first segment, which means they are shorter than 10 minutes. The remaining 40% of the plays are equally distributed over the other segments so that only 10% of the replays last for the entire lecture. A similar observation is reported by other researchers [He99]
2. Analyzing the IP addresses where the player is running shows that 50% of the plays are from computers directly connected to the campus network. The vast majority of these on-campus requests come from students in the residence halls who are enrolled in large introductory courses.
3. Students access the archive beginning around 10 AM in the morning building to a peak around noon. Usage continues heavy throughout the afternoon and evening with a short drop around dinnertime. Usage continues until 2 AM when it falls off rapidly until it picks up again later that morning. This pattern is likely to be affected by access from people outside North America in different time zones. Further analysis of the logs is required to confirm this hypothesis.
4. The BIBS logs show that the vast majority of users accessing the archive are using PC's with Windows 98. While providing access for other platforms is important, it appears that a Windows PC is the standard computer platform for students.

Taken together, this data supports the claim that students are using the archive primarily for on-demand study rather than replacing attendance during live lectures.

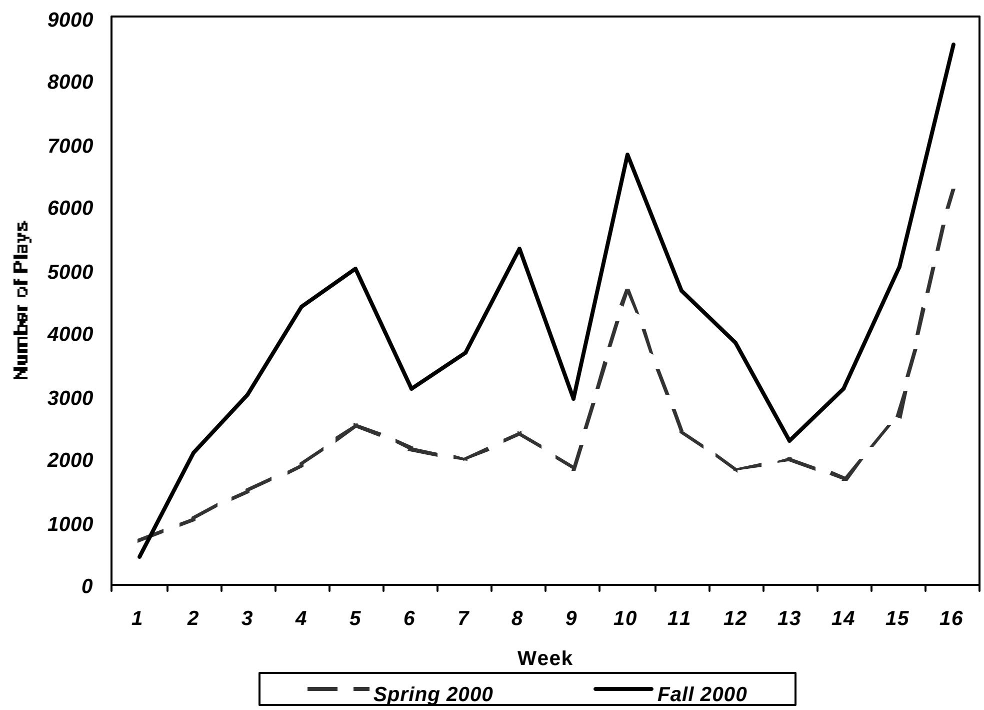


**Figure 11 : Plays Per Week**

This chart shows the number of plays each week during the semester. A class with two midterms typically schedules them during weeks five and ten, and a class with one midterm typically schedule it between weeks eight and eleven. Week sixteen corresponds to the final examination period.

## *Student Surveys, Interviews, and Focus Groups*

We have conducted a number of surveys, focus groups, and interviews regarding student and faculty use of BIBS. A study conducted in Spring 2000 sampled all classes using BIBS. The results of this study lead to improvements in the system. In Fall 2000, we conducted an in-depth evaluation of technology enhancements in Chem 1A, including BIBS and the Lecture Browser. A brief summary of our findings to date from these two studies is presented below.

**Spring 2000 Evaluation**. The Spring 2000 study was conducted by the Center for Studies in Higher Education (CSHE) in conjunction with BMRC. On-line pre- and post-surveys were conducted through the BIBS website to collect opinions of BIBS users. In addition, Chem 1A students were surveyed in class to gauge non-webcast user attitudes. Student focus groups and faculty interviews were conducted to gain further insight into student and faculty opinions. Detailed results from this evaluation made up an internal report that was distributed to campus staff and faculty involved in the implementation of BIBS [Harley00b].

A total of 326 on-line pre-surveys and 156 on-line post-surveys were collected during Spring 2000. An additional 36 paper post-surveys were collected from Chem 1A during the last week of class (of 50 distributed, a 72% response rate). Among the students who completed the on-line post-surveys, most students (45%) viewed between one and ten webcasts. A smaller percentage of respondents watched more than 10 webcasts. Only 9 percent of respondents had not viewed a webcast prior to completing the post-survey.

*Changes in Student Behavior.* Students did not perceive lecture webcasts as a timesaving device as much as they provided students the opportunity to reorganize their schedules. For example, post-survey respondents agreed (42%) or strongly agreed (23%) that lecture webcasts enabled them to learn at their own pace. Moreover, students agreed (43%) or strongly agreed (21%) that webcasts enabled them to better juggle coursework with other work and/or home responsibilities.

Class attendance is a controversial issue in discussions about lecture webcasting. However, when surveyed at the beginning of the semester, students had split opinions about whether or not they would skip class because of the availability of lecture webcasts. Students overwhelmingly felt that lecture webcasts improved their learning experience (90%). Post-survey results indicated that students watched lecture webcasts because it was convenient both as a replacement for missed lectures (51%) and as a study tool (47%).

Students agreed that most large lecture courses would benefit from having BIBS lecture webcasts and suggested specific courses to webcast in math, science, and engineering.

*Faculty Interviews.* A total of six interviews were conducted with faculty during the Spring 2000 semester. Though all course instructors felt that lecture webcasts provided students with a useful tool, faculty perspectives about the webcasts varied. Some instructors fully supported the webcast system and either planned to or did integrate the webcasts as part of their overall curriculum. In doing so, they adopted the webcast technology as essential to the overall teaching process. Others were more removed from the webcasts, though no instructors objected to lecture webcasts as a tool for student learning.

Overall, students and faculty agreed that lecture webcasts were useful in their current state but needed improvement for effective scalability. Webcast users repeatedly suggested basic improvements to foster ease of use including titled lectures and topical indexing with search functions. These improvements were implemented by the development and integration of the Lecture Browser into BIBS.

**Fall 2000 Evaluation**. As part of a large Mellon Foundation evaluation grant, an economic and pedagogical analysis of technology enhancements is being conducted using Chem 1A, the largest lecture course on the UC Berkeley campus [Harley00a]. These enhancements include on-line quizzes, lecture webcasting, and the BMRC Lecture Browser.

Chem 1A has a series of exercises and quizzes incorporated into laboratory experiments. Before each lab, students read material about the lab and answer questions. These *pre-laboratory exercises* are completed before the student goes to a scheduled lab session supervised by a teaching assistant. Students are also required to complete a short *homework quiz* (10 minutes) based on textbook reading and exercises. Lastly, the first hour of the lab is a structured discussion about the lab followed by a *check-in question* based on that material to confirm students are ready to do the lab project.

The Chem 1A study divided the class into two groups. The first group, called *Analog Chem 1A*, used the regular study materials and hand grading of the pre-lab exercises, homework quizzes, and check-in question. The second group, called *Digital Chem 1A*, used computer-based materials for the pre-lab exercises and homework quizzes. The computer-based material is completed before the student goes to the lab. Each student is given one of several exercises or quiz questions that are graded by the computer.[4] The structured discussion and check-in question was the same in both groups.

[4] Questions are multiple-choice, true/false, or short answer that can be easily graded by the computer.

The study investigated the educational effectiveness of the two approaches. A total of 225 individuals, out of 1,237 enrolled in the course (18%), responded to an on-line survey during the later part of the semester. Of the responding individuals, 72% (N=161) were in analog sections and 28% (N=64) were in digital sections, roughly matching the distribution in the pre-survey data. A short paper survey was distributed with the course evaluation forms filled in by students at the end of the semester. 904 students responded to that survey (73%). Preliminary findings from these surveys regarding Chem1A use of BIBS and the Lecture Browser are presented in the following paragraphs. The evaluation of the on-line quizzes will be presented in future reports.

*Watching Lecture Webcasts.* Figure 12 shows the distribution of webcasts watched per week as reported on the paper survey. Although 29% of the students watched one or more webcasts each week, the majority watched few if any webcasts. The paper survey also asked if students would be willing to watch the lecture entirely on-line instead of going to the lecture hall. The vast majority of students (82%) responded that they wanted to attend the live lecture in person.

As these questions were asked on the paper survey at the end of the semester, it includes responses from all students in the class. Note that the lecture webcasts were available to both groups although the on-line quizzes and exercises were only available to the Digital Chem 1A group. The next series of questions were asked in the on-line survey.

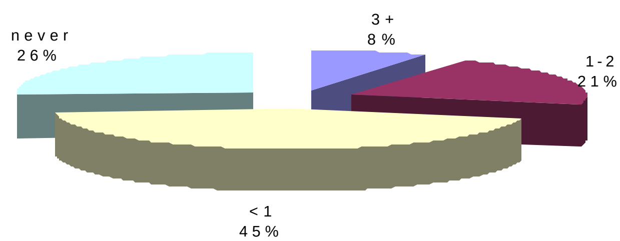


**Figure 12: Distribution of Webcasts Watched Each Week**

*Time and Technology Use Related to Lecture.* Students were asked if the streaming video lectures affected their experience. In general students thought that having webcasts and the Lecture Browser had improved their Chemistry 1A experience.

1. Sixty percent of students (N=131) said they take fewer notes at least some of the time because they know that they can watch the lectures on-line.
2. A slight majority of students (54%, N=121) said they felt that they understood and retained more of the concepts of the course because they had access to the on-line lectures.
3. Most students (68%, N=153) reported that technology problems never inhibited their ability to access and view on-line lectures.
4. Most students (82%, N=184 responding "most of the time" or "always") agreed that they preferred live lectures to on-line lectures.
5. Only a few students (12%, N=26) said they would like to watch the lectures exclusively on-line. A majority (59%, N=130) stated that they would never want that type of a class.

These results confirm the statements made above about the use of the lecture webcasts for on-demand study for examinations. Students in Chem 1A want to attend the live lecture, at least in their current form.

*Willingness to Recommend Internet and Multimedia Technology Using Courses.* Students were asked if they would recommend that other students take courses with Internet and multimedia technology. Students were mostly in favor of courses that use technology. Digital Chem 1A students tended to be more enthusiastic in their recommendations.

1. A majority of students (71%, N=159) felt that the on-line live webcasts were worth recommending to others. Digital section students were once again more positive (77%, N=49) than analog section students (68%, N=110).
2. Most students would recommend a course that used the Lecture Browser (85%, N=192). Significantly ($\chi^2 = 5.0$, $p = 0.02$), the digital section students (94%, N=60) were even more enthusiastic about this recommendation than the analog section students (82%, N=132).

*Access and Use of Technology.* Students were asked where and how they accessed the webcasts and other on-line material. Most students accessed the system from their dorm room via an Ethernet connection. Most students used an Ethernet connection to access the website (82%, N=169), and most did it from "home" (92%, N=190). Usage logs support student self-report data, showing that 78% of website traffic comes from student dorms.

*Non-Native English Speakers.* When English as a Second Language Students (approximately 25% of the enrolled students) were asked about the utility of the on-line lectures, a large number responded that the ability to review difficult sections of the lecture on-line was particularly helpful.

## *Additional Findings*

These surveys show that many students view the lecture webcasts as an important component of their learning environment. We know from miscellaneous e-mails that some students get extremely upset if the lecture archive is down or a specific lecture is unavailable when they are studying for a forthcoming examination. Faculty also reported that they received anxious inquiries from students about delayed or missing lecture webcasts. Surprisingly, more than half the lectures are replayed for less than 10 minutes which suggests that students are using the archive to review specific parts of a lecture rather than watching the entire lecture in one sitting. Students watch lectures from previous semesters in addition to viewing lectures from the current semester when they are available. We also observe people watching lectures for advanced topic courses during semesters when they are not offered.

Many instructors are concerned that students will watch a lecture remotely or watch the replay on-demand rather than attending the live lecture. A few instructors of BIBS classes report lower attendance during live lectures. Analysis of usage logs and student surveys suggest that, except in a few situations (e.g., CS61A in Spring 2000), students do not watch live lectures remotely. Skipping live lectures and watching them later is harder to evaluate. Most large introductory classes with similar enrollment have essentially the same viewing statistics. However, one large class offered at 8:00 AM had nearly three times the usual viewing statistics, and the instructor reported a noticeable decline in attendance at live lectures. Further investigation is needed to determine why students chose not to attend the live lectures. Some possible explanations are:

1) Students want to sleep early in the morning, not attend lecture.
2) The quality of the lectures might need improvement.
3) The amount and complexity of material being presented and the pace of the lectures might have increased the utility of the lecture webcasts for learning the material.

4) Students might not be interested in the class topic.

Anecdotal evidence suggests the problem is the early hour of the lecture.

Lastly, BMRC has received numerous unsolicited messages from students and instructors thanking us for producing the webcasts. One instructor commented that he changed his lecture style after seeing techniques used by other instructors in BIBS webcasts. We have also discussed expansion of the system with other members of the Berkeley community, and many are strongly supportive.

# 4. Discussion: Future Research and Development

This section describes several directions for improving the BIBS system and further exploring the use of Internet technology in teaching and learning. Topics discussed include: searchable text transcripts and support for the hearing impaired, authenticated access, distributed multimedia collaboration, extensions to the BMRC Lecture Browser, and campus commitment to audio/video infrastructure.

## *Searchable Text and Support for the Hearing Impaired*

The success of BIBS in large introductory classes uncovered an issue that we overlooked, namely, support for the hearing impaired. The conventional TV solution to this problem is to use either closed-captioning or an embedded video image of a person signing the words being spoken. Neither solution could be easily incorporated into BIBS. Internet streaming media is represented as digital bits that do not carry the TV signal lines that hold closed-caption text. Although we could produce two webcasts for a class, that is, one with signing and one without signing, a better solution is possible.

The Real Networks streaming media technology used in BIBS has a *Real Text* feature that will stream time-synchronized text with the streaming video. This feature can be used to produce a version of the lecture with scrolling text synchronized with the speaker. It will require producing a time-coded transcript of the lecture audio, but that can be done relatively cheaply off-line. Software and procedures will have to be developed to integrate this feature into BIBS, but it is certainly possible to do.

Another use for this transcript is to improve the keyword search facilities in the Lecture Browser. Several students mentioned that the keyword search feature was particularly valuable when studying for examinations. The current Lecture Browser uses words entered by hand or words taken from PowerPoint slides to construct the index. While constructing the index from these words is useful, particularly the slide titles, an obvious extension is to use a speech-to-text translator and construct the index from words spoken by the instructor. The translation could also be used to construct the scrolling text for hearing impaired. We did a preliminary experiment with three speech-to-text systems (i.e., one research system and two commercial systems), and audio taken from a lecture webcast. The speech-to-text systems performed very poorly. They mis-recognized words (e.g., the word “sodium” in a chemistry lecture was recognized as “Saudi”) and did not provide the appropriate time-code cues required to synchronize the word to where it occurred in the lecture. The mis-recognition is understandable since speech-to-text systems must be trained for particular topics. It is likely that a combination of human editing and topic-specific training and filtering can produce better indexes. Taken together, these extensions require construction of the time-coded transcript.

## *Authenticated Access*

The current BIBS system does not limit access to the lecture archives. Any lecture can be viewed by anyone connected to the Internet anywhere in the world as long as they have adequate bandwidth. A limitation in the existing software and a desire to reduce operating overhead is the reason access is currently not limited. The software does allow us to stop viewers from making copies of the lectures or redistributing them to others. Some faculty members objected to webcasting their classes if we could not limit access to Berkeley students either because they did not want others to see their lectures or because they wanted to protect the lecture material from widespread distribution.[5]

UC is implementing an “authenticated access” system for all campuses. The Real Networks client player has a module for checking authentication before playing a particular video. This feature can be used with the UC system to allow fine-grained access control. BIBS can be modified to allow various levels of access:

> **REGISTERED STUDENTS** – only teaching staff and students registered in the class are allowed to play the videos. This capability might be limited to lectures this semester or it might include lectures from classes in previous semesters.
>
> **BERKELEY COMMUNITY** – any member of the Berkeley community whether students, staff, faculty or alumni can play the videos.
>
> **PUBLIC ACCESS** – anyone on the Internet can play the videos.

Once the authenticated access mechanism is in place, the campus could do experiments with pay-per-view as an additional source of income to support the system. We believe that people will pay a small fee to watch one lecture (e.g., $1 per lecture) or a slightly higher fee to watch any lecture from a class (e.g., $10 for a class). Many outstanding lectures and seminars are held on the Berkeley campus every semester. High-quality capture of these lectures with appropriate marketing might produce an exciting benefit for alumni and content of interest to a wider community. The BIBS system provides the infrastructure required to develop such a system.

On the other hand, public distribution of UC Berkeley lectures has several advantages. First, the knowledge and abilities of Berkeley faculty are shown to students and researchers around the world. In fact, faculty who did offer BIBS courses indicated during interviews that they supported free access to the lecture webcasts and felt that the University was providing an invaluable service to the local, if not worldwide, learning community. Second, a lecture webcast is an excellent way to show prospective students and their parents what classes are like at Berkeley. And third, the lecture webcasts can be used for high school enrichment and outreach. Nevertheless, the campus may want to restrict access to some classes and lectures because they are a potential source of income.

### *Distributed Multimedia Collaboration*

We are strong advocates that a lecture webcast should include multiple video streams (e.g., speaker, presentation material, live experiments, views of other participants, etc.) and rich multimedia content. These streams might be shown simultaneously to each viewer or the user might select the streams he or she wants to view. For example, during a physics experiment, several views of the experiment might be displayed at the same time (e.g., front, side, and top views of the apparatus, a schematic diagram or visual simulation of the effect being demonstrated, and a view of the speaker) and the user can select which one(s) to watch. We have experimented with multiple-stream live webcasts in the MIG Seminar using Internet Mbone technology [Yu01]. The Real Networks system used in BIBS claims to support multiple stream playback. To date, this feature does not work reliably with live streams, and the current implementation requires a separate server license for each stream being played even though they are part of one webcast. Further work on this issue should enable multiple stream webcasts.

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[5] Some faculty even commented that they would think twice about what they said during lectures if they knew someone else might be watching. In one case, lecture material was removed from the archive because an instructor made inappropriate comments during a lecture; the webcast was replaced with an archived lecture from a previous semester. However, other faculty responded positively to the idea that the lectures were freely available.

BIBS, as it currently stands even with multiple video streams, is inappropriate for synchronous distance learning. It does not provide two-way video, which would allow an instructor to see remote students, nor does it provide a floor-control mechanism that allows a remote participant to ask questions. In addition, research on distributed collaboration shows that communication and interaction is significantly improved if the system incorporates shared applications in which both local and remote participants can point to items or edit the material being displayed.

A colleague offered a graduate seminar in 1997 using Internet Mbone technology in a room custom-designed for distributed collaboration that supported many of these capabilities [Landay97]. Figure 13 shows a remote participant's view of the seminar with multiple video streams, mixed audio, and shared application software that supported a pen-based rear-projection screen input/output device in the classroom (see window in lower left corner). The room contained many cameras that remote participants could control so they could look at different people and places in the room. The topic of the class was "Computer-Supported Collaborative Work" so the experiment was a useful example for class discussion. The experiment showed that much research remains to be done to develop the software and tools required for effective, large-scale synchronous distance learning. For example, simple problems like the difficulty of balancing audio levels had a negative impact on the experience for remote and local participants. It also showed the difficulty of operating such software and making the system work seamlessly for all participants.

BIBS can be a foundation for a distributed collaboration system but it will take considerable research and experimentation to produce an acceptable solution. This experimentation will be expensive because numerous technologies and procedures must be tried, some of which will require additional staff to operate. It will also take a willingness on the part of faculty to participate, which requires commitment from both the administration and the research organization doing the experimentation.

We strongly believe an Internet streaming media approach to distance learning as illustrated by the BIBS webcasting system is likely to be more successful than the video conferencing approach typified by the H.32x standards developed by the ITU and the telecommunications providers. The webcasting approach is open, flexible, and most important, scales to large, geographically dispersed audiences.

In the long run, remote participants will likely want university credit and the opportunity to earn degrees or certificates. Important policy issues must be faced if such a program is to be developed at Berkeley including: 1) who is allowed to sign-up for a course, 2) who receives a portion of the marginal income (e.g., campus, college, department, instructor, TA's, etc.), 3) how many remote students (i.e., part-time or extension) are allowed in particular classes, and 3) who owns the intellectual property in a lecture.

### BMRC Lecture Browser

The BMRC Lecture Browser can be enhanced in numerous directions too. First, a research colleague has developed a tool, called *NotePals*, which allows a student to take time-synchronized notes on a pen-based device (e.g., a Palm Pilot or CrossPad) [Davis99]. Together we have done experiments synchronizing student notes with a Lecture Browser title. This extension could be extremely valuable. Students could share notes and comments, and the instructor could add off-line commentary further explaining material in the lectures. Capturing, organizing, and providing access to this material presents many research challenges that should be explored.

Everyone wants a mechanism to reduce the time required to view a lecture. Research in the early 1990's showed that streaming audio/video could be played back faster than real-time, and the viewer could still understand the material. Experiments showed that you could play back the video at up to twice real-time. A commercial company, named Enounce, has produced a plug-in for the Real Player that implements these algorithms. We have used this plug-in with numerous lectures and have found that, for most speakers, the content can be easily understood at 1.5 times real-time, which means that a 50-minute lecture can be viewed in 35-40 minutes; in some cases it can be understood at twice real-time, which would be 25 minutes.  This plug-in should be integrated into the Lecture Browser.

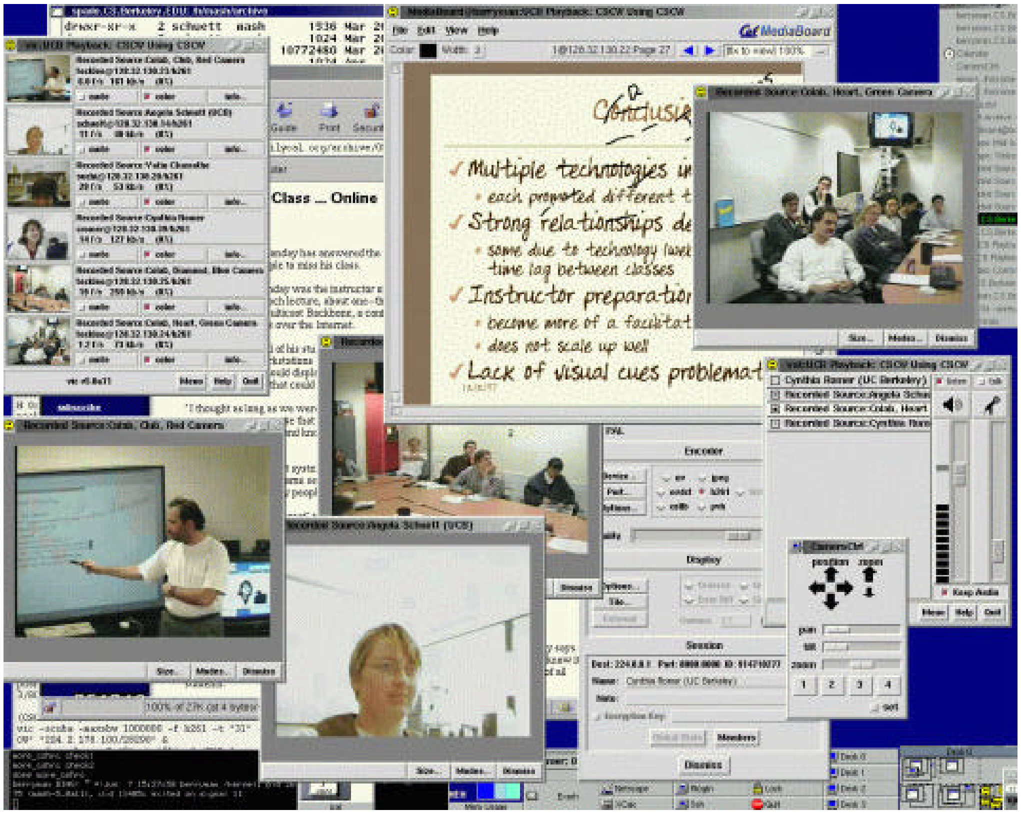


**Figure 13: Distributed Collaboration Example**

This screen shot shows the view a remote participant has to a class held in a collaboratory designed for multiple video streams, shared whiteboards and other group collaboration tools.

More recently, Microsoft researchers explored the idea of creating short summaries of a video presentation [He99].  The idea is to choose a subset of the lecture material that covers the key concepts and ideas presented. Sadly, the automated summary construction techniques did not work as well as a summary produced by the author of the original material. But, this suggests another approach to producing learning material. Perhaps instructors will produce the summaries themselves given adequate support and resources.

### *Campus Commitment to Audio/Video Infrastructure*

Finally, the video infrastructure and support at Berkeley is poor. It is very difficult to conduct experiments of the sort described here, and to build on those experiments, if it requires changing physical classrooms and transporting and manipulating streaming video. The Berkeley campus apparently had reasonable television and radio facilities as well as staff required to maintain and operate it in the 1960's. That infrastructure and organization was allowed to atrophy due to budget pressures and neglect by faculty and administration. Over the last 20 years, the campus computer network has received substantial investment in recognition of the important role it plays in the on-going operation of the campus. We very strongly believe that the campus must raise the level of investment in classroom audio/video infrastructure on the campus. As mentioned above, it should be possible to webcast lectures or bring audio/video of remote experts and experiments into any classroom on the campus just as we expect to be able to project a computer image taken from the Internet in any classroom. Faculty frequently asked BMRC to webcast an event or a class. However, we could not accommodate their requests because the required infrastructure did not exist and the cost of webcasting on an *ad hoc* basis was prohibitive. Just as the campus set an objective to provide a network connection in every classroom several years ago, we need to provide audio/video capability including cameras and microphones in every classroom.

# 5. Conclusion

This report described the design and implementation of the BIBS lecture webcasting system and the results of various evaluations of the system. BMRC developed the system and, in cooperation with other campus researchers and organizations, conducted a series of experiments that attempted to assess the impact and usefulness of this technology. We believe it is time to move the system to a permanently funded service organization on the campus. While the current system has limitations for remote synchronous distance learning, specifically the inability to ask remote questions and the absence of a sense of presence for remote participants (i.e., a reverse video channel), several options exist for providing these capabilities and they should be explored. Continued research and development is required both on BIBS and other teaching and learning technologies.

# 6. Acknowledgements

We want to thank many people on the Berkeley campus without whose support this work could not have been performed. Specifically, we want to thank former Chancellor Chang-Lin Tien and former Vice Chancellor Dan Mote who provided seed funding for BMRC to encourage this type of research and innovation. We want to acknowledge the support and enthusiasm of the faculty and instructors, too numerous to mention, who have participated in these experiments. Special thanks are due to Professor George Chang from Nutrition Sciences, Professor Alex Pines and Dr. Mark Kubinec from Chemistry, Professors Paul Hilfinger and James Landay and Dr. Brian Harvey from EECS, and to Vince Casalaina who were early participants and supporters of lecture webcasting and BIBS. Victor Edmonds and his staff at OMS deserve thanks for working with us to conduct the experiments with large introductory classes. We also want to acknowledge the webops who produced the webcasts, the Digital Chem1A evaluation team, specifically Jonathan Henke, and the BMRC staff and students who helped out when needed and provided invaluable assistance.

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