# Teaching Software Engineering Online Using 21st Century Technology

*Sheryl Duggins[1], Ray Walker[2]*

**Abstract** – This paper will examine the use of 21st century technology to support the delivery of Software Engineering courses online. New technological advances such as high-speed internet connections, virtual classrooms and virtual labs have removed the barriers limiting the kinds of learning opportunities that could be realized in distance education. The students in my online class participate in a semester-long group project and are able to master the same learning outcomes, utilize the same software lab facilities and support, and contribute to the classroom learning environment, with the only caveat being that they are doing this remotely, without face-to-face contact. This paper will also address the need for infrastructure support to be able to successfully provide this type of learning environment. Finally, assessment data as well as student feedback will be analyzed to determine if and in what ways the technology interfered with or facilitated student learning.

*Keywords:* Distance learning, Online learning, e-Learning, Technology, Software Engineering.

## INTRODUCTION

Higher education is fast becoming a very competitive market with the plethora of universities offering online degrees increasing across the country and around the world. Studies indicated that as early as 2001, at least 3 million US students were enrolled in online education [Primary Research Group, 15], and there were 90 million students worldwide studying online at 986 institutions in 107 countries [Debeb, 8]. Today, the e-learning market has a growth rate of 35.6%, which makes online education a very competitive business [Wu, 18]. In 2001, venture capitalists invested one billion dollars in education companies and "entrepreneurs are swarming to the marketplace" [Hedberg, 10]. In Georgia, the 35 institutions in the University System of Georgia have to compete for students with over 30 other private or for-profit universities in the state offering online degrees. To better meet the strategic needs of Georgia, the Board of Regents of the University System of Georgia, like almost all universities today, has a goal of increasing the number of online programs and online degrees offered. Sun et. al [Sun,17] have even suggested that e-learning is emerging as the new paradigm of modern education. To fully comprehend the significance of online education, it is necessary to explore both the history of distance education as well as the impact that technological advances have had upon online education.

Jiang et. al. [Jiang,11] view the evolution of distance education as having three historical phases: the *correspondence phase,* the *analog signal times*, and the *information age*. The *correspondence phase* began before there was radio but continued for many decades, and it was characterized by correspondence courses in which students read books, printed materials, and instructor created lessons, and did assignments which were mailed in to correspondence teachers who monitored and evaluated the students. The next phase was the *analog signal times,* in which one of the earliest programs was Brazil's "University of the Air," which provided educational programs to remote areas of the country [Johnson, 12]. This method of providing distance education to geographically remote sites continued throughout the 20th century. The *information age* began in the 1990s, but will continue well into the

[1] SPSU, Computer Science and Software Engineering, 1100 South Marietta Parkway, Marietta, GA 30060, sduggins@spsu.edu

[2] SPSU, Computer Science and Software Engineering, 1100 South Marietta Parkway, Marietta, GA 30060, rwalker0@spsu.edu

21st century. Distance education in the early and mid-1990s often consisted of telecourses and videotapes. "Telecourses are taped or live television programs provided by broadcast or cable television stations" [Jiang, 11, p. 406]. Videotapes in distance education refer to lectures that were videotaped during a live classroom, which were then mailed to distance students.

The emergence of the Internet and advances made in information and communication technology as well as the technological advances made in multimedia, personal computers and networking has driven the development of distance learning in the *information age* [Sun,17, Jiang,11]. The need for "anytime, anywhere" learning has led to the development of e-learning, otherwise known as web-based or online learning, which uses "telecommunication technology to deliver information for education and training…The great advantages of e-Learning include liberating interactions between learners and instructors, or learners and learners, from limitation of time and space through the asynchronous and synchronous learning network model" [Sun,11, pps.1183-1184]. Maddux et.al. [13] suggested that higher education is on the cusp of a revolution due to several recent changes in technology including:

1. "Recent rapid growth of broadband Internet connections in private homes…
2. Recent widespread availability of free or inexpensive programs that make use of voice over Internet protocol and video over Internet protocol…
3. Transition of the World Wide Web from a space where users search for and read information to an environment for collaboration…
4. Much wider and currently rapidly increasing availability of high quality educational websites."

The existence of this new paradigm of modern education that is transforming higher education "is a point to which virtually everyone agrees" and consequently, the 21st century has also been called the "Age of Learning" [Alt,1]. Blakelock [2, p. 142] reiterated this point stating that one notable change she found in her survey was the "recognition that online learning is not a trend and is certain to be an integral part of higher education for years to come." The need for lifelong learning as well as the changing demographic of non-traditional students who are entering higher education while balancing full-time jobs and families are driving forces behind this educational revolution [Blakelock, 2]. We are at a unique time in history in which the technological advances are occurring at precisely the same time that more people want a different type of educational experience, and universities are taking advantage of this opportunity by using 21st century technology to change the way we educate [Scarafiotti,16, Chickering,4, Conole,6].

This paper will examine the use of 21st century technology to support the delivery of Software Engineering courses online. The students in my online class participate in a semester-long group project and are able to master the same learning outcomes, utilize the same software lab facilities and support, and contribute to the classroom learning environment, with the only caveat being that they are doing this remotely, without face-to-face contact. This paper will also address the need for infrastructure support to be able to successfully provide this type of learning environment. Finally, assessment data as well as student feedback will be analyzed to determine if and in what ways the technology interfered with or facilitated student learning.

## DISTANCE EDUCATION AT SPSU

SPSU has been offering distance education in various forms for over a decade. The first online class I taught was recorded on video and synchronously delivered to several remote sites in the state, allowing distance students to view and interact with on-site students during class time. These videotapes were also mailed to the remote locations to accommodate absenteeism so the distance students could view the videotaped recording of class at a later time. To facilitate the recording and synchronous delivery at that time required extensive technological support. A special classroom was built on campus that was equipped with cameras, microphones suspended from the ceiling, television screens capturing the students at the remote locations, and a special tech room off to the side of the classroom filled with recording and transmitting devices and manned with a technician running the equipment. The remote sites were equipped similarly, so that in effect, all locations were both sending and receiving audio and video feeds.

The course I taught in that format included group work and the groups were comprised of students from various physical locations, and I recall being quite impressed with the quality of student interaction, and with the fact that students seemed to be unaffected by communicating via microphones and TV screens – they were impervious to the technology – and the distance students performed as well as the on-site students. In addition to the communication that occurred during the synchronous delivery, I communicated with the students via email and phone conversations. I recall initially there was talk of the need for professors teaching distance courses to travel to the remote locations for face-to-face meetings with the distance students, but I actually never had to travel; the other types of communication were sufficient.

But there were limits to what we could do at that time. Specifically, the courses we could offer using distance technology of the 1990s were limited due to the nature of our content – computer science and software engineering courses typically have technology requirements that could not be supported at that time. In particular, in a number of our classes we expect the students to use specialized software ranging from Computer Aided Software Engineering (CASE) tools to different programming languages, operating systems, and so forth. The problems had to do with how to provide these tools to our distance students in such a way that was cost effective, did not violate any of the software license agreements that SPSU had with the various vendors, and did not place unreasonable expectations on the student in terms of time, cost, or travel requirements. Our face-to-face students were able to access the required software via our Computing and Software Engineering (CSE) labs. I recall having several conversations with my dean, the lab manager, and the folks in the University's IT division, about how we might provide these tools to our distance students, and the results were always the same. The challenges at that time were limited by the 1990s technology.

## COURSE MANAGEMENT SYSTEMS

One of the biggest changes in distance education was the development of Course Management Systems. In 1999, the University System of Georgia (USG) adopted WebCT as the standard USG online course delivery format [Funk,9]. WebCt is a Course Management System (CMS) that provides a number of features including calendars, threaded discussions, assignment tools, tools for creating and viewing grades, email services within the tool, file management tools for uploading and downloading files, whiteboards, online chat, and a number of other tools. Together these tools provide a complete learning environment for distance classes.

In the early use of these CMSs, the virtual classroom was eerily similar to a traditional face-to-face (F2F) classroom in which the professor "lectured" in the front of the classroom to the passive students who sat quietly at their desks. The differences in an online class at this time consisted of the fact that the students *read* the lecture (in the form of text documents or PowerPoint slides) that were posted in the CMS rather than *hearing* the lecture. Classroom discussions in a F2F classroom happened live, when all the students and the professor were gathered physically in the same location. In the CMS classroom discussions, the students participated asynchronously, whenever and wherever they were when they logged into the CMS. The other students could "hear" (via reading) their classmates' discussion points and contribute to the threaded discussion or ask a question or make a comment by starting a new thread in the discussion topic. It was a nice simulation of or alternative to a traditional classroom. Unfortunately, not all students succeed in this type of learning environment, and a number of online students stop their online learning after their initial experience [Sun,17]. Research has shown that online students who take courses of this type, in which the communication is delayed, asynchronous, and without a personal, human feeling to them feel isolated and dissatisfied with the learning environment [Boulos,3, Davies,7].

The two most frequently used Course Management Systems today, WebCt and Blackboard, which were used by 48.8% and 41.9% respectively of Blakelock's [2] 37 survey respondents, are now being complemented with a number of different tools including video conferencing tools like Horizon Wimba. These video conferencing tools utilize voice over Internet and video over Internet technologies to virtually bring the distance students to the F2F class. I personally utilize Wimba's Live Classroom tool in my Software Engineering class and I believe it has totally changed the nature of online education. WebCt Vista is the CMS we are now using at SPSU, and it comes with Live Classroom as a tool for building your learning environment. With speakers and a microphone, I am able to synchronously deliver my class presentation to my online students. I am teaching a F2F section and an online section of the same course, which makes a great teaching situation. I am able to invite my online students into my live classroom while it is happening. They can login and participate synchronously by either using an inexpensive

microphone on their end or utilizing chat if they don't have a microphone. They hear what is said in the classroom and they see what is displayed on the SmartBoard, effectively participating in the class. Alternatively, if they are unable to log in while the class is being recorded, the Wimba Live Classroom presentations are archived as part of the course content. For professors who are not teaching a F2F section of their online course, you can simply establish a time to hold your "virtual" classroom and invite your students to login, or alternatively, just record your lecture on your own and archive the presentation. [Coghlan,5] did a study on the use of online voice tools in which he described the classroom of the future exactly as I just described using Live Classroom in my course. He went on to state: "This 'classroom of the future' may present a model of teaching that is the perfect blended learning solution. It caters for team teaching arrangements, satisfies various learning style preferences, and affords students opportunity to experience the class synchronously or asynchronously"[5, pps. 9-10]. As Coghlan discussed, my online Software Engineering course included a semester-long team project that the students worked on using the advanced features of Webct Vista. During the term, two teams were affected by one team member traveling; one student traveled extensively to Mexico, and another team had a member who made several trips to Africa. In these extreme situations, the use of advanced features was necessary for successful project completion.

In addition to incorporating audio and video into the virtual learning environment, the improvements in technology have enabled SPSU's School of CSE to solve the software-related problems that were unsolvable a few years ago. Specifically, broadband Internet connections, VPN and Remote Desktop connections, and the increased bandwidth and performance of CSE's network have all laid the groundwork necessary to solve those difficult software problems. But it was only possible with the hard work and dedication of our lab manager, Ray Walker, who researched and developed our virtual lab.

## SETTING UP THE VIRTUAL LAB

This section contains the technical details of setting up the Virtual Lab. This was done within the School of Computing and Software Engineering and was not supported or funded from the university's Information Technology support department. CSE has their own technology support team, headed by the lab manager, Mr. Ray Walker, who oversees the hardware and software needs of CSE. This includes several computer labs, computers and equipment in CSE classrooms, the networking of all computers within CSE, as well as all computers used by the school (professor's and staff's desktops, laptops, and peripherals.) In addition to this already heavy load, Mr. Walker agreed to research and develop specific technology to support our online classes. Other departments on campus have been able to offer online classes and programs without needing additional support other than that provided by the Center for Academic Support, which provides assistance and maintenance for our university's online courses that use WebCt Vista. Without this needed infrastructure support, CSE would not have been able to teach Software Engineering online. This section contains the details of how to set up the Virtual Lab. It is included here for dissemination purposes so that other schools can learn from our efforts. If you are not interested in the technical details, you may want to skip this section.

The Virtual Lab (Vlab) is a small pool of PC's running Windows XP and configured for Remote Desktop connections. The pool is monitored from a server which displays the status of each personal computer (PC) on a web page updated at 15 second intervals. The concept and most of the server software was provided courtesy of the Anderson School of Management at the University of New Mexico (UNM).

The CSE Vlab opened in the fall term of 2008 to support an online Software Engineering class. The hardware consists of 7 desktop PC's (6 Vlab stations and 1 server) with AMD 64 CPUs, 1 GB RAM and 80 GB HDD. No new investment was required as the machines were approximately 4 years old and recently retired from our CSE open lab. The pool stations are running Windows XP and the server runs Windows 2003 with IIS.

Connecting to a Vlab station from off campus is a two step process. Students must first establish a network session to the campus VPN utilizing Juniper Network Connect. The VPN connection is authenticated by a campus server limiting access to currently enrolled SPSU students. A Windows Active Directory domain provides a second tier of authentication when the user logs on to a Remote Desktop session. Screening to limit account access for licensing or other reasons is applied here.

**Server Functionality**

The server monitors the pool of PC's using VB script code provided by UNM. The "rdstatus_ping_error.vbs" script runs in an infinite loop to check the status of each pool machine. The routine pings each machine 5 times and writes the result to a file. If a successful ping occurs, the routine attempts to communicate with the machine using the RPC GetObject call. Responses to the GetObject call are evaluated to assign a status to the machine and the status is written to another file. The CSE Vlab code is essentially identical to the UNM implementation.

A second script, "buildHTML.vbs", reads the status files and updates an html page to reflect each pool machine's status. Machine status is displayed as available, busy, maintenance or error. If a machine is available for a new connection its associated icon is active and users can initiate a new RD connection by opening the associated link. Busy status indicates that a user is currently logged into the machine. Maintenance status indicates that the machine is off line, i.e., not responding to ping. Error status indicates that the machine can be pinged, but is not responding to the GetObject call as expected. The figure below shows the machine status for each of the computers in the Vlab.

These scripts are started as scheduled tasks when the server boots.

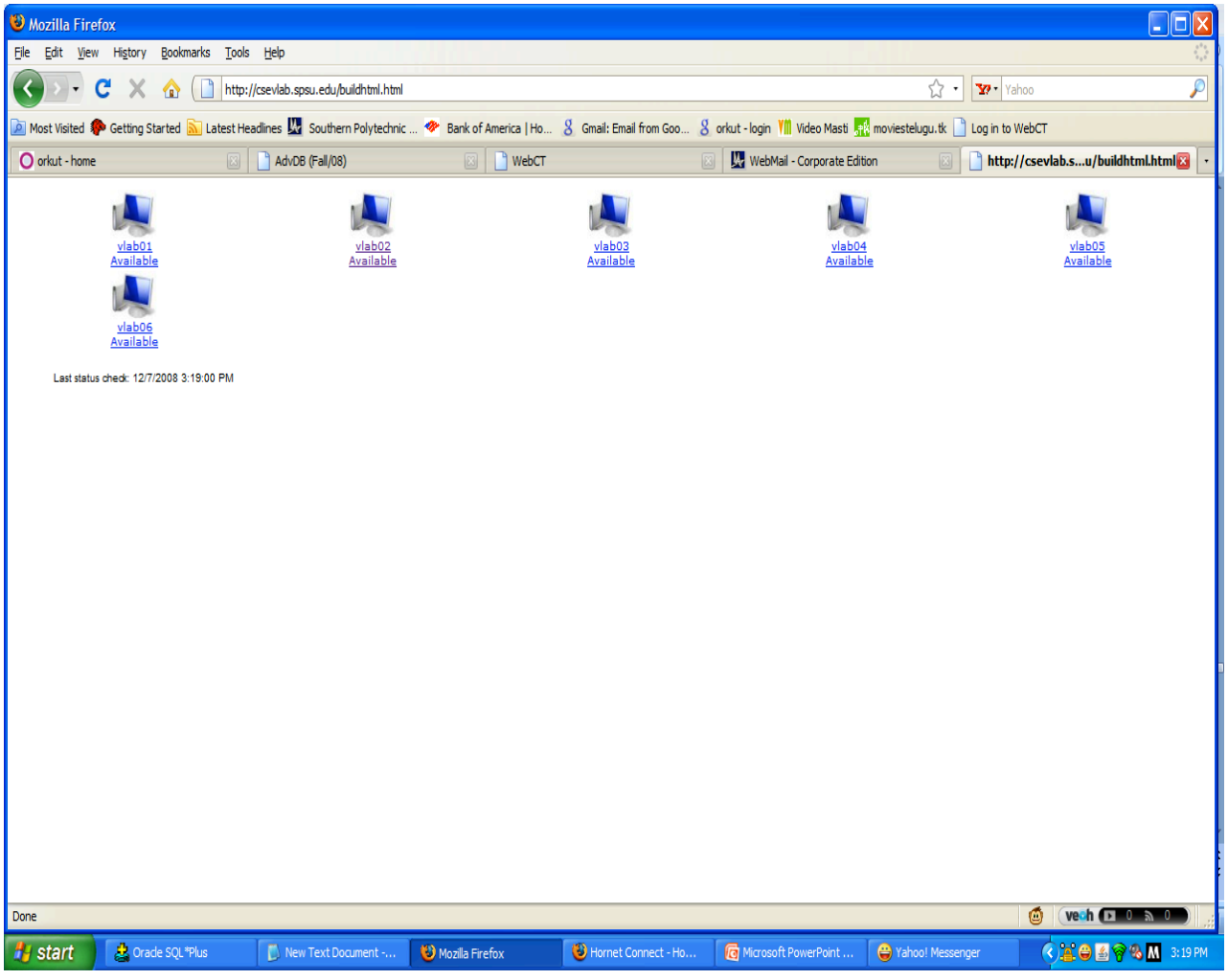


Figure 1: Vlab Pool Machine Status

**Vlab Station Functionality**

Remote Desktop Protocol (RDP) access is enabled on Vlab machines with the local everyone group having permission to make a connection. A logon script adds RDP permissions for the logged on user and removes RDP permissions for the local everyone group to protect the current user from being logged off by a subsequent attempt.

A logoff script reboots the computer when the user logs off. Vlab stations run a utility at reboot to remove files and reset any configuration changes made by users. This places the machine in its default configuration when the next user logs on.

User sessions are time limited and users are automatically logged off after two hours or after 15 minutes of no keyboard or mouse activity. A warning message is displayed 2 minutes before a session is terminated.

Users have access to a home folder on a lab server during their RDP sessions to save files for future use. The campus VPN provides facilities for transferring files to the user's remote computer for printing or email submission to an instructor.

**Support**

Support for access to, and use of, Vlab stations and server functionality is provided by the SPSU School of Computing support staff. Support for VPN issues is provided by the SPSU Department of Information Technology help desk. Application support for fall term 2008 was provided by Dr. Sheryl Duggins and her teaching assistant.

**Experience to date**

The CSE Vlab was implemented at the beginning of fall term 2008 to support an online class requiring access to Rational Software tools.

Two significant service problems occurred. The first involved confusion with use of a tutorial describing the steps users must follow to set up the VPN session. Sections of the tutorial have been rewritten to correct that problem. In the second case, a weekend power failure caused a Vlab server shutdown that was not detected until the following Monday morning. This occurred because of a problem with the server configuration that has also been corrected.

RDP screen refresh response times are constrained by the bandwidth of the connection between remote computer and Vlab station and we have observed noticeable delays with some DSL connections. Our biggest concern at the outset was that some remote users would find RDP performance unacceptable due to limitations of their network end link. A warning about this was prominently displayed on our Vlab web site with suggestions that users encountering this could consider upgrading their connection or asking to use their employer's network after hours, etc. Surprisingly, we have received little negative feed back on this thus far.

Drawing conclusions about the level and quality of technical support to Vlab users is difficult with only 3 months of experience with a very small group of students. Our sense, though, is that problem reports and support requests to CSE lab staff has been less than expected. One reason could be that Vlab students are directing questions that might have gone to lab staff if they had been working in a physical lab to their instructor.

From a cost perspective, the Vlab concept looks promising. Our Vlab was implemented on recently retired lab hardware but it will need upgrading soon. However, as students who would normally use our physical labs migrate to the Vlab and work from home or from their own laptops, we can reduce physical lab stations. Thus, our expectation is that the Vlab will require no net new hardware investment. Total net lab investment could actually decline due to floor space savings from physical lab station reductions.

## SO HOW DID IT GO? A LOOK AT ASSESSMENT DATA

This fall was the first time I have offered the Software Engineering class entirely online. It was developed last spring and offered half-online in the summer. I was able to change some things based on my initial experiences and feedback. As part of this research, I have developed a survey based on the findings of [Sun, 2008] to assess the student satisfaction with their online learning. Additionally, as part of every online course, the Academic Support

Center has created a survey the students take to assess the course as a whole that also addresses their perceptions of the technology.

The survey I created had 13 general questions about student satisfaction with the online course and 18 technology-specific questions: 2 questions determining what technologies the student utilized, 8 questions about the use of the Vlab addressed to only those students who used the Vlab, and another 8 questions about the use of the Wimba Live Classroom tool addressed only to those students who had used it.

One perceived strength of distance learning is that it facilitates learning by allowing the effective use of time. My survey data supported this claim. Ninety-two percent of respondents agreed or strongly agreed that taking the course online allowed them to more effectively arrange their time for the class, and perhaps the same 92% also agreed or strongly agreed that taking the course online allowed them to more effectively arrange their work schedule.

Another area of concern that is frequently mentioned about distance learning is whether the quality of online courses can compare to traditional face-to-face courses. Again my survey results were very positive. Eighty-three percent of respondents agreed or strongly agreed with the statement: "The quality of the course compared favorably to my other courses." However, the remaining 17% felt the quality of the course was affected by conducting it online. This data indicates that while an overwhelming majority found the online experience to be of high quality, distance learning may not be right for everyone.

On three questions about the general use of the information technologies in online learning, 100% of respondents felt the technologies used in online learning had many useful functions, and 92% felt those technologies were very easy to use ,and perhaps the same 92% found those technologies had good flexibility. Regarding the specific technologies used in this class: the use of the Vlab to access specialized software needed for the course and the Wimba Live Classroom tool used to capture the course lectures, the results were not quite as high.

The survey indicated that only 66.6% of the respondents used the Vlab; and those students answered the questions in the related section of the survey. There was a nice distribution of usage in the group with half of them using the Vlab 5 or less times, and the other half using it 9 or more times. Twenty-five percent of the students replied that they tried to use the Vlab but were unable to make it work. There were two additional questions asking if the student sought technical help from either the instructor or lab personnel, or if they asked a friend or classmate for help. The numbers on those two questions don't support the 25% who said they didn't get it working at all, so these results may not be accurate. Subsequent questions in this section also reflect this mismatch of responses. Eighty-eight percent replied that they agreed or strongly agreed to three questions about the use of the Vlab: using it "added more flexibility to the course"; using the Vlab "allowed me to arrange my time for the class more effectively;" and "I found using the Vlab improved my overall experience in this online class since it made it easier to access the required software."

The other technology that the survey addressed specifically was the use of Wimba Live Classroom. Ninety-two percent of the students utilized this tool. Of those students, 36% reported initially having trouble with the technology, but sought technical help and were able to get it working. Three questions were designed to assess the use of Live Classroom to facilitate learning. The results were extremely positive. Ninety-one percent liked using it "because it helped me to understand the course material better than I did from just reading it" and perhaps the same 91% liked using it "because it allowed me to hear and see the course material." Eighty-two percent strongly agreed or agreed that it improved their "overall experience in this online class" while the other 18% were neutral to this statement.

The Academic Support Center developed a course assessment survey that is given to all Distance Learning students. My average for this course was above the university average on every item in the survey. The items were rated on a 5-point scale with 1 being "strongly disagree" and 5 being "strongly agree." On seven items concerning teaching and learning, the median was 5.0 on all the items, and the averages ranged from 4.5 to 4.9. These items asked things like whether the instructor was an effective teacher, whether the instructor gave timely feedback, and if instructor feedback helped the student improve his/her work. Interestingly, there was no difference between this evaluation and the typical evaluations I get in face-to-face classes. For example, an item asking if the instructor explanations of difficult concepts and techniques were clear, had a mean score of 5.0 and an average of 4.6. That is a very high score for a traditional classroom and was far above my expectations for an online class. This data seems to indicate that effective teaching can be as effective in an online class as in a traditional classroom. Also of interest was the

item asking if the course required the student to work hard for a good grade, which also had a median of 5.0, but received the highest average with 4.9. Obviously the students did not feel that taking the course online was any easier than it would have been in a traditional classroom setting.

There were also questions about the use of technology. The one item that stood out was "I had to spend significant time getting the technology to perform properly." The median on this was 4.0 with an average of 3.7, which was lower than the other items, but much higher than the university scores of median 2.0 and average 2.45. This indicated to me that there is a general time factor involved in dealing with the technology in online courses, which still was apparent in my course, but to a lesser degree than average since my students are in a computer-related field. Finally they were asked for any additional comments on the technology. The comments mirrored the results obtained in my survey. Specifically, two students said it was difficult to use the Vlab for Rational software (which was exactly what my survey found); other students mentioned that the technology "was very useful" and "the Live Class concept was very good."

## CONCLUSIONS

This paper explored the technological advances that have changed the nature of distance learning. It gave a brief history of distance learning, and examined the recent developments such as the rapid growth of broadband Internet in homes that have allowed for the increase in online education. The types of distance learning offered at SPSU over the past decade were reviewed and specific problems that Computer Science and Software Engineering programs faced in distance education in the 1990s were elucidated. The widespread use of Course Management Systems and the benefits they provided were discussed and the additional benefits derived from their recent incorporation of video conferencing tools were highlighted. The development of the School of CSE's Virtual Lab to support online Software Engineering courses was described. Finally, the assessment data for the online Software Engineering course surveys was presented and analyzed. The initial data indicated that: students were able to effectively manage their time in online classes; online classes can be of high quality with effective teaching; online students can be as challenged as traditional students; new technologies such as Wimba Live Classroom can improve student learning in online classes by allowing the students to see and hear classroom material; distance learning does have some time costs initially associated with students learning to use the new technology, but most students will be able to master the needed technology; and finally, tailoring the technological needs of your discipline such as setting up the Vlab for software engineering courses, will take effort but ultimately is necessary to provide distance students with an environment comparable to that available to traditional students.

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