An Initial Assessment of Remote Access Computer Laboratories for IS Education: A Multiple Case Study

Christopher L. Huntley
Department of Information Systems and Operations Management
Fairfield University
Fairfield, CT 06430 USA
chuntley@fair1.fairfield.edu

Richard G. Mathieu
Department of Decision Sciences and MIS
Saint Louis University
St. Louis, MO 63108 USA
mathieur@slu.edu

George P. Schell
Department of Information Systems and Operations Management
University of North Carolina at Wilmington
Wilmington, NC 28403 USA
schellg@uncw.edu

ABSTRACT

New technologies are allowing universities and colleges to create remotely accessible, server-based laboratories that support the teaching of server-based software application development. However, the organizational and technical issues associated with implementing these servers often compromise the pedagogical potential of introducing server-based technologies into the classroom. The purpose of this paper is to make an initial assessment of the organizational and technical issues associated with using server-based, remote access computer labs in an academic or IT training environment. Given the investigative nature of this research, a multiple case study method is used including scripted interviews with eighteen leaders in IS education and IT training. An analysis of these cases suggests six categories of issues: (1) organizational issues with lab setup and administration, (2) technical issues with lab setup and administration, (3) cost issues related to faculty, (4) student requirements for the lab, (5) faculty/instructor requirements for the lab, and (6) employer requirements for the lab. We conclude that the major challenge in deploying a remote access computer laboratory is the development of an institutional environment where IT staff and IS faculty work together to design, implement and administer the technologies.

Keywords: Computer Laboratory, Application Development, Multiple Case Study, Remote Access, Virtual Laboratory

1. INTRODUCTION

In response to recent demands for personnel with practical computing skills, information systems faculty and training professionals have begun to rethink, retool, and, in some cases, replace legacy personal computing laboratories. Increasingly, new computer laboratories include remotely accessible servers of various varieties that support the teaching of server-based software application development. However, the organizational and technical issues associated with implementing these servers often compromise the pedagogical potential of introducing server-based technologies into the classroom. Universities, in particular, frequently struggle with balancing student needs for remote access to computer lab resources with the university's need to protect network security and to control overhead support costs.

1.1 Remote Access Computer Labs

The most common form of remote access laboratory is a server (or servers) operating on an intranet or the Internet. Users connect to the lab using personal computers and specialized client software. Connections to the server may be encrypted, but in other cases such security precautions may not be necessary. Ultimately, the function of a remote access computer lab is to allow students to share computing resources over a network without regard for time or place. In many respects the current trend toward networked computing is a return to timesharing models in common use before the rise of desktop computing in the 1980's. This time, however, the architecture is less monolithic than the old mainframe model, with a wide variety of specialized servers of different types playing a role (Press, 1999). A course in web application development, for example, might involve a database server, an application server, a web server, and perhaps a shared version control system. Similarly, a course in database design and administration might expose students to several database servers from competing vendors.

Historically, a laboratory has been defined as a room or building containing specialized equipment. Students, particularly in the U.S., are accustomed to open lab access and to fewer restrictions on use of lab resources (Newby, 2002). In the early 1990's there was a move to replace traditional labs with so-called *collaboratories*, in which "researchers can perform their research without regard to physical location – interacting with colleagues, accessing instrumentation, sharing data and computational resources, and accessing information in digital libraries" (Wulf, 1993). While collaboratories have taken on many forms (Finholt, 2002), perhaps the most famous product of such "virtualized" thinking is the world wide web, which was originally designed as a way to share physics research (W3C, 2003).

While in many ways the remote access labs used by IS departments are functionally equivalent to Wulf's collaboratories, there are subtle differences in scope and purpose. For example, two reasons why the IS instructor may wish to provide remote access to a computer lab are:

- To provide exposure to groupware and other collaborative tools as they are used in medium to large organizations.
- To provide experience with the technologies needed to build server-based software applications.

For the first purpose, exposure to collaborative tools, the specifics of the technology are not important. The focus is instead on collaboration (i.e., collaboratories) within the organization. The tools could be provided in many instances by a third-party vendor (e.g., Groove and SourceForge) without requiring significant additional infrastructure or administrative support. For the second purpose, however, the technology itself is paramount because the intent is for students to apply technology to realistic business problems. The students are given direct access to what would normally be considered "sensitive" and "expensive" resources (e.g., servers and routers) as an integral part of their coursework. Since many organizations lack sufficient capital and IT staff to service these courses, faculty members have often had to resort to "skunk works" tactics in order to acquire and support the required infrastructure. This diverts faculty time and capital from other valuable activities like pedagogical development, research, and service.

We close this discussion of remote access labs by drawing a contrast with the notion of the "virtual" laboratory that has been around for some time in the engineering and computer science communities. In the engineering community, virtual labs allow instructors to simulate 'real' engineering laboratory projects on a computer through experiment-oriented problem sets that can be offered to the students without the overhead incurred when maintaining a full engineering laboratory. Three prominent examples of virtual engineering labs are the Virtual Engineering/Science Lab at Johns Hopkins University (*www.jhu.edu/~virtlab/virtlab.html*), the Resource Center for Engineering Laboratories on the Web at the University of Tennessee at Chattanooga (*chem.engr.utc.edu*), and the Virtual Circuit Laboratory (Hodge et al., 2001). In the computer science community, the term "virtual" is often used in the context of virtual machine technology where multiple operating systems run simultaneously on the same computer. Lutes et al. (2002) describe the use of virtual machine technology to simulate multi-tier software development on a single "client' computer. In the case of the virtual engineering labs the hardware in the laboratory is simulated (through a computer program), while in the case of the virtual machine technology, it is the computer architecture that is simulated. However, in the case of the remote access computer laboratories described in this paper, there is no simulation; students learn and work with real (though perhaps limited) enterprise computing hardware and software.

1.2 Examples

Our definition of the remote access lab permits a number of different implementations. For instance, the lab may be as simple as a small Linux box equipped with an Apache webserver, a MySQL database, a PHP template processor and an OpenSSH shell server. In more elaborate installations, however, the lab may include a server cluster, remotely configurable network, or other more advanced technology. In either case, the same functionality applies. Many of the widely-used labs are implemented using web technologies. Professors at the University of Minnesota and Tulane University developed web applications (located at *WebSql.org* and *Internet-Technology.org*) that give instructors and students web-based access to a cluster of Windows-based servers which run database engines (Oracle and SQL Server) and web servers (Microsoft Internet Information Server) (Allen, G. 2000a; Allen, G. 2000b). Recently O'Reilly & Associates, a major publisher of computer books, partnered with UserInteractive, Inc. and the University of Illinois to develop the O'Reilly Learning Lab (*learninglab.oreilly.com*). This is an interactive learning lab where students practice what they learn using original online course materials and can earn a Certificate for Professional Development in web programming or

Linux/Unix system administration. In an implementation at Marist College, each student in the information technology program is given access to a separate virtual Linux environment located within a single partition of an IBM S/390 and is given shell access to their own virtual Linux environment with its own IP address and domain name (Norton, 2002).

Some universities have turned to off-site application or project hosting to support specific IT courses. The Center for Remote Access Enterprise Hosting at Dakota State University (*cresh.dsu.edu*) hosts PeopleSoft ERP and CRM applications, while the California State University in Chico provides a similar application hosting service that supports SAP. An example of project hosting is the for-profit company CollabNet (*www.collabnet.com*) which hosts commercial software development projects through a web-based software development environment that allows an organization to collaboratively build enterprise-level software. Another similar service is provided by SourceForge (*www.sourceforge.net*), which hosts several thousand open source projects on their server farm. Sometimes the focus of the remote access lab is on hardware instead of software. For example, consider the for-profit virtual router lab (VRL) operated by 'The Network Institute' (*www.tneti.com/vrl.asp*). The VRL is a web-based environment that allows students to connect to and manipulate real networking equipment from anywhere on the Internet. The VRL has a library of over one hundred exercises, ranging from troubleshooting using 'show' commands to configuring complex Border Gateway Protocol (BGP) configurations.

1.3 Computer Labs in the IS Curriculum

The computer laboratory continues to be an essential component of the information systems curriculum. The IS 2002 curriculum (Gorgone et al., 2002) states the importance of having computer labs and describes three types of computer laboratories: (1) structured laboratories, (2) open/public laboratories, and (3) specialized labs for systems development, network infrastructure or other advanced technologies. Within the context of the specialized lab, IS 2002 states that "Contemporary and emerging software development tools should be available to create the most current enterprise solutions". Physical space for computer labs is important. The "physical space requirements for the Information Systems program are more like that of the engineering and the biological and physical sciences than the professional programs in business administration and the social sciences" (Gorgone et al., 2002, pg. 1-2). These same guidelines indicate that there must be facilities to accommodate team development projects and there must be ongoing support for the personnel, maintenance and supplies of computer labs.

Information systems development and system administration are important components of the IS curriculum. The IS 2002 (Gorgone et al., 2002) curriculum includes four courses that require a contemporary development environment to support student projects: (1) programming, data, file and object structures, (2) physical design and implementation with DBMS, (3) physical design and implementation in emerging environments, and (4) project management and practice (capstone project experience). In addition, the IS 2002 Curriculum explicitly identifies both operating system (OS) and database administration as important pieces of the information technology body of knowledge. Yet, it is a challenge to give students access to the administrative software tools necessary to understand the basic principles of network and database administration (Martinez, 2001).

2. THE STUDY

The purpose of this paper is to make an initial assessment of the organizational and technical issues associated with using server-based, remote access computer labs in an academic or IT training environment. Given the investigative nature of this research, a multiple case study method is appropriate (Yin, 1984). This research approach has been successfully used in the business systems disciplines (Dewhurst et al., 2003; Yusuf et al., 2002; Watson et al., 1999; Watson et al., 2000). In our study scripted telephone interviews were conducted with eighteen leaders in IS education and IT training. Important steps in an exploratory multiple case study research strategy include: background research, protocol development, participant selection, data collection, and data analysis (Yin, 1984).

2.1 Background Research

An important starting point in our research was a review of the literature on computer laboratories in computing education. The scope of this review included research papers, 'popular' press articles, and web sites that discussed computer laboratories, virtual labs, virtual classrooms, and collaboratories as they relate to IS/IT education. A summary of this literature review is contained in the 'Introduction' to this paper. It is important to note that no research was found specific to the organizational and technical issues related to remote access computer labs. In addition, nearly all of the research related to computer laboratories in IS/IT education are based on a single case study focusing on the technical architecture of the computer lab. Thus we concluded that the research we undertook in server-based, remote access computer labs is largely exploratory in nature, and a case study methodology is an appropriate research approach. In addition, project goals and objectives were formulated at this point.

2.2 Protocol Development

The structured telephone interview was the prime source of data in this research. In keeping with the principles of case study research, a protocol was developed that included not only the interview questions but also the procedures to be used by the interviewers (Yin, 1984). Each telephone interview session started with a statement about the purpose of the research, a recitation of the definition of "Server-Based Application Development", and an assurance the respondent would receive a transcript of the interview with a chance to change and/or edit any statements in the transcript. This was followed by five interview questions designed to elicit a discussion of relevant organizational and technical issues related to server-based application development. These questions were iteratively developed and tested over the course of three months prior to the actual telephone interviews.

2.3 Participant Selection

Participants were selected based on their expertise and experiences with remotely accessible server-based environments for academic or training purposes. In total eighteen participants were selected. Only one individual who was asked to participate in the study opted to decline. Selected participants had one of three different backgrounds: 1) university faculty, 2) university employee (administrator or IT staff) or external IT (corporate IT administration or training). Ten (56%) were university faculty, with vary levels of administrative responsibilities, each having current teaching responsibilities in an IS/MIS curriculum. Four (22%) were university administrators and/or IT employees with no current teaching duties. Four (22%) were employed external to a university setting but had extensive experience in IT administration and/or training. Following the approach used by (Watson et al., 1999) and (Watson et al., 2000), each person was initially contacted to ask about his or her willingness to participate in the study. An important goal of the participant selection process was to solicit a diversity of well-informed viewpoints.

2.4 Data Collection

Interviews were 20-30 minutes in length, including the introduction, and included the five scripted questions given in Appendix A. These questions were selected based on a review of the literature and background discussions with knowledgeable parties. At the end of the interviews the participants received a transcript of the telephone interview and were asked to review it for accuracy and to add comments where appropriate. In addition, minor modifications were made to the final draft of this paper based on feedback from six of the participants.

2.5 Data Analysis

The goal of our analysis was to treat the evidence fairly and to produce analytic conclusions consistent with an exploratory research project. As a result we used analytical techniques suggested by (Miles & Huberman, 1984) and (Yin, 1984), and incorporated by (Watson et al., 1999) whereby a matrix of categories was created and evidence was placed within each category. See Table 1. This was followed by tabulating the frequency of the different events and examining the complexity of the tabulations. Then the tabulated results were used to develop a more comprehensive analysis of the issue.

3. THE FINDINGS

This section describes the results of our analysis. Following a review of the transcripts, six categories of responses emerged from the two broad topic areas of server-provider issues and computer lab requirements. Service-Provider Issues: 1. organizational issues with lab setup and administration; 2. technical issues with lab setup and administration; 3. cost to faculty, and Lab Requirements: 4. student requirements for lab; 5. faculty/instructor requirements for lab; 6. employer requirements for lab.

Following this step, specific responses from each telephone interview were classified into one of the six categories according to the topic discussed. The results are summarized in Table 1. It is acknowledged that each of the categories deals with issues that are multi-faceted and that contain many sub-issues. While the study participants are our source for raising these issues, the authors were responsible for categorizing and classifying them into the six categories described in this paper.

3.1 Organizational Issues with Lab Setup and Administration

The most frequently mentioned organizational issues relate to lab setup and administration. Twelve of the participants noted that in the past several years, server-based computing has triggered IT staff to carefully reexamine their policies and responsibilities. University information technology services departments experienced a high degree of uncertainty because there was no longer a clear divide between the centralized computing services traditionally run by university IT shops and the decentralized desktop support offered by department-level support staff. As a result, four of the respondents indicated that their university IT departments were struggling with the organizational issues that go with managing distributed computing resources in this new academic environment.

As noted by one of the respondents, the characteristics of a networked server environment have made the centralized administration of a remote access, server-based computer lab a significant challenge. Every computer on the university network can potentially be used as a server with remote access capabilities.

A prominent example is the use and misuse of peer-to-peer networks for sharing music files and other content. While such networks can be temporarily blocked via a firewall, they can easily be reconfigured to get around the firewall. Thus, universities have had to develop policies that address the use of servers by students and other end-users. Participants from the academic community noted four different types of university server-ownership arrangements:

(1) Highly decentralized servers (reported by 2 of the participants) – Servers are physically located in faculty offices, with faculty members providing their own system administration.
(2) Server farms (reported by 2 of the participants) – Servers reside in a central university location and are administered by a centralized IT staff.

Table 1. Participants, their Expertise, and Interview Results

RESPONSES / PARTICIPANTS	EXPERTISE	1) Organizational Issues w/ Lab	2) Technical Issues w/Lab	3) Cost to Faculty	4) Student Lab Requirements	5) Faculty Lab Requirements	6) Employer Lab Requirements
Gove Allen Tulane University	IS faculty and founder of WebSql.org	X	X		X	X	
Denton Arledge New Hanover Health Network	Chief Information Officer	X	X				X
Ray Boykin CSU-Chico	Director of SAP Program at CSU, Chico	X	X	X	X	X	X
Mohan DeSouza IBM, Silicon Valley Labs	NetDB2 Database Teaching Service		X		X		
John Eatman University of North Carolina at Greensboro	Associate Professor of MIS and IT Director of Bryan School of Business	X	X	X	X		X
Kamran Khan Marist College	Vice President/CIO Information Technology	X	X		X	X	
Gary Koehler University of Florida	John B. Higdon Eminent Scholar		X	X		X	
Munir Mandviwalla Temple University	Chair, Department of MIS, Fox School of Business	X	X		X	X	
Anne Martinez Go-Certify.com	CEO and author of the Get Certified and Get Ahead series of books	X			X		X
Arthur C. McAdams People's Bank	Senior Vice President and Director of Information Services						X
Eric Meier University of Virginia	Director of Internetworking Services and MIS Faculty, McIntire School	X	X		X		X
Charles 'Mike' Morrison U. of Wisconsin, Eau Claire	IS Faculty and Co-author of Database Driven Web Sites and A Guide to Oracle	X	X	X	X	X	X
Curt Naser **Fairfield University**	Associate Professor of Philosophy and Chair of the Fairfield University Educational Technology Committee	X			X	X	
Barbara Price Georgia Southern University	Director, School of Information Technology	X		X		X	
Robert Tyndall University of North Carolina at Wilmington	Vice Chancellor for Information Technology Systems	X		X		X	
John Webster Dakota State University	PeopleSoft Programs Director. Remote hosting of PeopleSoft	X	X			X	
Harry Williams Marist College	Director of Technology and Systems	X	X		X	X	
Robert Wurth Saint Louis University	Computer Technician, Information Technology Services	X	X		X		
Number of Responses		**15**	**14**	**6**	**12**	**11**	**7**
Percentage of Total		**83%**	**78%**	**33%**	**67%**	**61%**	**39%**

(3) Departmental (School) level servers (reported by 5 of the participants) – Servers reside in the department or school. The servers are typically highly decentralized servers (reported by 2 of the participants) – Servers are physically located in faculty offices, with faculty members providing their own system administration.

(4) Server farms (reported by 2 of the participants) – Servers reside in a central university location and are administered by a centralized IT staff.

(5) Departmental (School) level servers (reported by 5 of the participants) – Servers reside in the department or school. The servers are typically

administered by department-level or school-level IT staff.

(6) Hybrid server model (reported by 6 of the participants) – Some "standard" servers are administered by IT staff, while others are administered by individual faculty members.

Nearly every participant noted that a highly skilled administrative IT staff is important to the success of a server-based environment. However, eight of the participants acknowledged that faculty in their school had servers located in their offices. Two participants acknowledged that their school did not have the IT staff with the appropriate skill sets to support the servers they required in their classes. One participant stated that their school did have staff to support servers loaded with 'standardized' applications such as Oracle or SAP, but some faculty still required decentralized servers located in faculty offices to support 'cutting edge' technologies (e.g., web services) for developing web applications and eCommerce systems.

Two of the participants have established centers that support application hosting of enterprise applications (SAP and PeopleSoft) that enable remote access by students and faculty at other universities. These centers have full-time IT support staff that install, maintain and upgrade enterprise applications, and participate in curriculum development related to these applications. The centers are financed by a combination of grants from software manufacturers through their higher education initiatives, matching grants from the universities benefiting from the using enterprise software, and grants from third-party organizations that host the enterprise software. One of the institutions indicated that the center was removed from the School of Business and placed under the direction of the Vice President for Academic Affairs. This was done in order to allow the unit to operate as a profit center thus allowing for a more nimble and responsive organizational structure. The other participant from the other hosting center indicated the importance of maintaining good IT support through tough budget times and acquiring adequate facilities for housing computer equipment. Computer hardware and software cost was mentioned as issues by five of the participants. Among these participants there was a consensus that over the past decade universities have done a good job of controlling the costs associated with both open computer labs and structured computer labs that support classroom teaching. Three of the academic participants noted that their universities had successfully established financial policies for operating and updating the technology found in traditional computer labs. One participant indicated an important step taken at his university was the inclusion of server technologies in his university's equipment replacement plan and budget.

Another point that emerged from the interviews is that there is no longer a clear divide between the centralized computing services (e.g., course registration) traditionally run by university IT shops and the decentralized PC support offered by the university's computer help desk. Two participants noted that academic teaching initiatives that require server-based environments using leading-edge technologies are discouraged by the university's centralized IT staff due to security and staffing concerns. One of the participants went so far to say that there were active attempts by the university IT staff to shut down his server. He stated that "I was doing something that they [IT staff] perceived that they should be doing, but couldn't, and it made them look bad." Another faculty member stated that it is not uncommon for university IT staff to put up a firewall that unknowingly blocks access to remote-access servers. There was a general understanding from all faculty participants that both the IT support staff and faculty had to work together to determine the precise requirements for a remote-access, server-based computer lab.

The good news is that software costs for remote access labs are usually quite manageable. This opinion was expressed by eight of the participants. Companies like Oracle, SAP, PeopleSoft, Microsoft, IBM and Computer Associates have created programs that license software to institutions of higher learning used for academic teaching at drastically reduced pricing. In addition, open source software, such as the Linux operating system, the Apache web server, and the MySQL database management system are typically available free of charge. Similarly, in most cases the hardware to support the types of computer servers required to run a remote access lab is also quite manageable. Two of the academic participants noted that the demand for new computer labs with large numbers of desktop PC's seems to have plateaued, while the need for remote student access has increased. Three participants from the academic community noted that while software acquisition costs are reasonably low due to favorable deals with vendors, there are other kinds of costs (e.g. implementation, training, maintenance, testing, upgrades, etc.) that must be considered. One of the participants noted that it often seems that high-level and/or politically powerful employees can mandate application purchases without sufficient deliberations concerning the time, cost, and learning curve required to deploy and use the applications. Such lack of planning can drive up the total cost of ownership considerably.

3.2 Technical Issues with Lab Setup and Administration

Fourteen of the participants in this study cited technical issues with lab setup and administration. Most of these issues were related to server administration, security, and network architecture. The most common issue mentioned about server administration was the setup and administration of user accounts, which was referred to by nine of the participants (all university faculty members). Four of the participants stated that creation of student accounts with the proper permissions is a significant challenge for IT staff to design and administer. Proper account creation allows logins to be authenticated and allows all users to be accountable for their actions while using the remote access lab. Further, some accounts (i.e., for faculty and administrators) require authority to monitor and in some cases deny use of certain systems and services. One participant had created automated scripts for both instructor and student account creation. The other major administration issue is the configuration of the server software. One participant stated that he was a believer in a 'separate server for each application'. This design makes it easier for maintenance and problem solving. Of course, this approach may also require maintaining multiple computers for some courses. Another participant emphatically stated more time should be spent on design because well-designed systems are more robust and need less maintenance. Such design and testing can be quite time-consuming and a bit frustrating, particularly for faculty members without extensive systems administration experience.

All fourteen of the participants who described technical issues during the interviews stated that network security was important in a remote access lab configuration. IT staff must be able to monitor internal security breaches (i.e., students using the server to attack other computers) and external security breaches (i.e., being attacked from outside the university). One of the participants stated that security concerns are a 'hassle' in that different vendors have different schemes for establishing security. One of the participants was actively investigating the use of virtual private network (VPN) technology in order to identify and authenticate each remote user. Five of the participants mentioned the importance of a robust network architecture that permits the flexibility required for advanced applications. Among other things this means that an organization-wide scheme must be in place that agrees on how different networking protocols will be integrated and how 'trusting' relationships will be determined between computers in different local area networks. These relationships can be especially troublesome for applications that use Microsoft Windows networking technologies, where the organization's "domain architecture" (i.e., partitioning of the network into separate Windows domains) can prevent clients in one domain from connecting with lab servers in another domain. Two of the three affected participants decided to locate their remote access lab servers within their university's primary domain while the other participant noted that his servers were placed outside the university's primary domain for security reasons. For the unlucky participant who was placed outside the primary domain, the effect was that his server was shut off from the rest of the university's Windows network. It is noted that such problems are not limited to Windows networks. Such problems can also happen on TCP/IP networks using VLAN technologies to separate dorm rooms and other "uncontrolled" locations from servers and other "sensitive" resources.

Three of the participants stressed the importance of working with the central IT services group on policies and procedures to minimize downtime, computer errors, and breaches of security. One of the participants stated that it is a "challenge for the university to integrate the technical abilities of the IT staff with the teaching and research mission of the school". Two participants noted that they had to implement new procedures for server backup and recovery specific to their lab architecture. One of the participants was in the process of developing a mirror site for their computer lab in order to ensure continuous operation in case of server failure. Fourteen participants noted the importance of having qualified IT staff to support the computer servers used in academic teaching. One participant also noted "it is the job of the IT staff to balance the faculty member's need to have the latest technology with the university's desire for security and availability." Two participants noted that a significant challenge exists for IT staff as traditional personal computing labs become integrated with remote access labs. Instead of supporting a few standard desktop applications on a standard operating system, a remote access lab might require them to support several complex client-server applications on multiple operating systems (even when the clients are all running Microsoft Windows). The learning curve can be quite steep, and the training costs can easily outstrip the typical university IT budget.

3.3 Demands on Faculty

Six of the participants discussed the high demands placed on IS faculty by remote access labs. Three participants noted that while the cost of acquiring software to support remote-access labs is relatively low, the demands on the IS faculty are very high. Academics who respond to these needs often find themselves becoming software developers, system administrators, and help-desk operators at the expense of their research. One participant noted that tremendous effort required to keep current with the technology almost certainly hurts a faculty member's research efforts. This participant further stated that "it can take months to learn the features of a product such as Enterprise Java Beans or COM+ to the depth necessary to teach students. The challenge for IS faculty is to develop research opportunities that may arise of applying the new technology to meet business problems."

There was agreement among six participants that the research demands on IS faculty has increased and that this trend will most certainly continue. One participant noted that this is complicated by the fact that "most IS research does not focus directly on the nuts and bolts of technology. Rather most IS research tends to focus on the organizational issues related to using the technology." Meanwhile, three participants noted that there is increasing accountability for IS teaching. There is recognition that student evaluations are important to faculty members and that meeting students' expectations for a hands-on technology component is important. A challenge for all IS instructors is finding the right mix of theory and hands-on technical skills. For example, one participant said that "a teacher of the database systems course will most likely need to teach the principles of entity-relationship modeling at the same time that he may want to expose his students to hands-on SQL skills in Oracle, DB2 and/or SQL Server. Another example would be teaching the principles of object-based software development at the same time that the students learn to write well-formed Java or C++ code." Thus the lab should be versatile enough to permit exposure to a variety of technologies while still providing the degree of control needed to highlight the theory.

3.4 Student Requirements and Expectations

Twelve of the participants discussed various aspects of the students' requirements for the lab. Each of these participants indicated that providing students the flexibility and convenience associated with remote computer access is important. Four participants noted that many students have jobs, some full-time, and getting to a traditional on-campus lab is inconvenient. Two of these participants went on to say that their graduate-level IS programs would not be practical without the ability to allow remote access to on-campus computers. One participant indicated that the profile of the typical IS student has evolved over the past ten years. He indicated that the typical IS student has little free time, often because they have a part-time job or an internship. In addition, he stated that these students often feel a real pressure to keep up with the latest advancements in IT technology.

From the students' perspective, location of the software required to complete their homework should be transparent to the user. Anecdotal evidence suggests that students are increasingly relying on home computers to do their schoolwork. This is true for all majors, both technical and non-technical. Students want to be able to use any software required for their coursework at home, in the dorm or on the road. It was noted by one of the participants that this view is counter to the philosophy behind the 'locked down' computer labs traditionally offered by universities and corporate training facilities. All four of the corporate participants in the study indicated that there was a need for increased availability and accessibility to IT educational opportunities. In many ways, remote lab access is more important for courses in the corporate sector than for those in university environments. IT professionals are often put in the role of 'student' as they seek to further their education through training courses, vendor certification, university courses, and other educational avenues. There is also an increased need to learn vendor-specific knowledge for the latest tools, and to complement conceptual knowledge with hands-on experience. This only adds to the need for faculty to offer remote access to professional-quality server environments like those used everyday on the job.

3.5 Faculty Requirements and Expectations

Eleven of the eighteen faculty participants discussed their requirements for a remote access computer lab. Professors in the technology-based disciplines are increasingly being asked to introduce their students to "critical information technologies". In today's environment, these critical technologies are almost always server-based. Cases cited in the interviews include:

1. developing web-based eCommerce applications in a multi-tier environment
2. using SQL to query, create, and update relational databases in a multi-user environment
3. using ERP applications populated with "working data" to give students exposure to 'real' business information system problems
4. deploying and administering client-server information systems once they have been acquired and/or developed

The two participants engaged in the remote hosting of ERP applications noted that the administrative costs of implementing and maintaining an ERP system for IS education are substantial. They emphatically stated the importance of having a mature, comprehensive curriculum to complement the ERP software. One of these participants observed that IS faculty typically require a curriculum that is more conceptually oriented than the 'point and click' curriculum often developed by software manufacturers. It was clear from our interviews that the faculty member's ability to use advanced technologies within the context of the IS curriculum is an important issue. One of the participants stated that it was important for the lab to be easy to use, especially for adjunct instructors that may not have time to "get up to speed" on nonstandard lab configurations. At some schools adjunct instructors teach quite a few of the 'hands-on' courses, so creating a flexible, adaptable environment is important. Another participant noted that it is important for the instructor to be able to work from remote locations. For example, the faculty member should be able to read and test student software applications using remote access methods.

3.6 Employer Requirements And Expectations

Businesses that hire and employ IS students are increasingly asking for graduates that have been introduced to the latest "critical information technologies". Presumably, these technical skills would be used for systems development and maintenance. One industrial participant emphasized the importance of teaching students good design and "true systems analysis". He went on to say that "too often employers find new hires that are proficient in a specific technology, but are unable to examine the tradeoffs between competing solutions."

Two participants from the corporate sector indicated a desire to see more IS students with experience working with "real" software applications. They observed that students often learned computing skills by working on small, "baby" systems. Increasingly, in order to demonstrate critical concepts, they recommended that students be exposed to fully developed working models. As an example, one participant stated that "in a database course it is highly desirable for students to be exposed to databases with large numbers of tables with many records so that they will learn and understand the skills associated with performance optimization and database design". Four schools indicated that they are integrating ERP software with "working data" into their curriculums in order to give their students exposure to realistic and complex business information systems. Depending on the software, such systems may have hundreds of even thousands of tables populated with a variety of corporate data. One industry participant emphasized the importance of exposing IS students to computer administration issues. This involves giving students access to the software that allows them to learn how to networked, multi-user systems. She said that in a course on telecommunications it would be preferable for the faculty member to complement telecommunications theory with hands-on experience with software administration tools in multiple networking environments (Unix/Linux, Windows NT/2000/XP, etc.) and multiple database environments (Oracle, SQL Server, DB2, etc). She went on to say that students should be able to work with software tools that test network configurations for reliability and security. Another industry participant indicated the benefit of exposing IS students to collaborative software development environments. Experience with online tools was thought to be increasingly important in a business environment where teamwork is highly valued. Tools can range from simple bulletin boards and newsgroups to collaborative software tools such as source code repositories (e.g., CVS or SourceSafe), bug tracking systems (e.g., Bugzilla), conferencing services (e.g., Jabber or Microsoft's Net Meeting), and network-aware IDEs (e.g., IBM's Eclipse, Sun's NetBeans or Microsoft Visual Studio .NET).

4. CONCLUSION

From this study we postulate that the success of the remote access computer lab is dependent on a system design and implementation process that includes participation on the part of both IS faculty and university IT staff. The immediate challenge in deploying a remote access computer laboratory is developing an institutional environment where IT staff and IS faculty work together to design, implement and administer the technologies. Only through cooperation between university-level IT staff, department/school-level IT staff, and faculty in the academic departments can we develop the type of learning environments that IS students need to be competitive in the modern business world. Our analysis suggests five recommendations for implementing remote access computer laboratories that support the IS curriculum: (1) clearly defined lab objectives, (2) carefully designed lab architectures, (3) clearly defined administrative responsibilities, (4) tested and validated lab exercises, and (5) plans for continued faculty and IT staff development.

The remote access lab is a great opportunity to facilitate teaching software application development and network administration. Pioneering efforts such as the non-profit *Internet-Technology.org* and *WebSQL.org*, as well as for-profit remote labs such as the O-Reilly Learning Lab *(learninglab.oreilly.com)* have demonstrated the viability of the remote access computer lab concept. Centers at California State University – Chico and at Dakota State University are hosting ERP application software for use by students at other universities and are serving as clearinghouses for ERP curriculum appropriate for university students. The remote access lab allows IS faculty to engage students in the learning process. Lab-based student learning permits students to solve projects incorporating the techniques and concepts they were taught in class. Lessons learned by the students that cannot be applied to situations that will be faced in their careers have little value in the education process. An instructor's ability to master advanced information technologies is an important issue for industry professionals as well as academics. The use of advanced technology makes it much more engaging for the students' learning experience.

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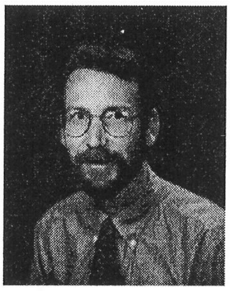
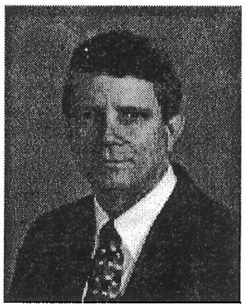
AUTHOR BIOGRAPHIES

Christopher L. Huntley is an Associate Professor of IS&OM in the Department of Information Systems and Operations Management at Fairfield, University in Fairfield, Connecticut. His research and teaching interests include organizational learning, software development processes, and the strategic role of IS and IT. He has published research articles in various journals, including *IEEE Transactions on Engineering Management*, *Interfaces*, *Computers & Operations Research*, and *IEEE Computer*. In addition, he has published teaching cases in the *Annals of Cases in Information Technology* and the *International Journal of Entrepreneurship*. He received his Ph.D., M.S., and B.S. from the University of Virginia.



Richard G. Mathieu is Chair and Professor of MIS in the Department of Decision Sciences and Management Information Systems at Saint Louis University in Saint Louis, Missouri. He has published numerous articles on critical success factors in the development and implementation of information systems and more recently on project management issues related to the distributed enterprise. His articles have appeared in *Communications of the ACM, IEEE Transactions on Engineering Management*, *Computer(IEEE)* and *Computers and Industrial Engineering*. Currently he is an associate editor for *IEEE Transactions on Systems, Man and Cybernetics – Part A* and is the IT Systems column editor for *Computer (IEEE)*. He received his Ph.D. and M.S. from the University of Virginia and his B.S. from the University of Delaware.



George P. Schell is a Professor of MIS in the Department of Information Systems and Operations Management at the University of North Carolina at Wilmington in Wilmington, North Carolina. His articles have appeared in *Communications of the ACM*, *Information & Management*, *Interfaces*, *Computer Personnel*, and others. Dr. Schell received his Ph.D. from Purdue University. His Masters and Bachelors degrees are from the University of Florida

APPENDIX A: SCRIPT FOR TELEPHONE INTERVIEW

Interview with:
Position:
Creator:

Date:

Definition:

'Server-Based Application Development': a computer environment to support n-tier software application development. The architecture includes at least one Relational DBMS, a web-server, a network operating system, and support for an object-oriented programming environment. The system must support 'student accounts', 'instructor accounts', and remote access for both the student and instructor. Optional tools include transaction server software, message queuing software, component/object libraries, data warehousing and OLAP tools, CASE tools, and tools for online collaboration.

1) Describe the computer environment(s) that you have had experiences with that support server-based IS teaching or training?

2) What are some of the positive organizational and technical outcomes that have resulted from this experience?

3) What are some of the challenges/negative organizational and technical outcomes that have resulted from this experience?

4) What changes have you seen from your perspective (industry, student, faculty/trainer, MIS/ITS staff) in the last 10 years in regard to IT teaching or training?

5) What do you see as the greatest challenges facing you in the next 5 years when it comes to teaching and supporting server-based IT teaching or training?