Does a virtual networking laboratory result in similar student achievement and satisfaction?

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ABSTRACT
Delivery of content in networking and system administration curricula involves significant hands-on laboratory experience supplementing traditional classroom instruction at the Rochester Institute of Technology. Providing the resources necessary in the traditional physical laboratory setting is challenged by increasing budgetary and space constraints. Delivery of laboratory instruction in a distance virtual format is a potential cost-effective solution to the problem, at the same time it presents technical challenges [3, 5]. The blend of face-to-face and online instruction offers the opportunity not only to solve the resource issue, but also to sustain contact beyond the borders of the classroom and extend the learning environment. This paper presents the results of an action research study conducted to investigate the impact on student achievement and student satisfaction of delivering laboratory instruction in a distance delivered virtual laboratory, and discusses some of the challenges encountered in offering this virtual experience.

Categories and Subject Descriptors
K.3 [Computers and Education]: Computer Uses in Education — Distance Learning

General Terms
Experimentation, Human Factors, Management, Design

Keywords
Virtual Laboratory, Distance Learning, Online Learning, Action Research, Virtual Network

1. INTRODUCTION
Delivery of content in networking and system administration curricula involves significant hands-on experience supplementing traditional classroom instruction at the Rochester Institute of Technology. The equipment for this environment requires multiple computer stations with specialized equipment and software. Students need individual access to this specialized environment and often do not complete the work in the allotted laboratory time slot, and require additional access to the laboratory. Providing the resources necessary in the traditional physical laboratory setting is increasingly challenged by the need for space, funding for costly equipment, and budget for personnel to keep laboratories available for use outside of class. In the face of increased demand and scarce resources, the use of a remotely accessible virtual networking laboratory environment potentially offers a cost-effective solution and can expand the accessibility to students. The blend of face-to-face and online instruction offers the opportunity not only to solve the resource issue, but also to sustain contact beyond the borders of the classroom and extend the learning environment.

Distance delivery is a significantly different learning environment that removes faculty and students from the traditional physical laboratory, resulting in the loss of direct interaction with the student. Many faculty members feel that the loss of interaction results in a substandard learning experience for students compared to the traditional environment [1, 2, 4]. This paper presents the results of an action research study conducted to investigate the impact on student achievement and student satisfaction of delivering laboratory instruction in a distance delivered virtual laboratory, and discusses some of the challenges encountered in offering this virtual experience.

2. RESEARCH METHODOLOGY
2.1 Participants
Participants in this study were junior and senior networking and computing majors enrolled in the Introduction to Network Administration course located in the College of Computing and Information Sciences at the Rochester Institute of Technology, a private co-ed four-year technical university in Rochester, New York. The student population is multicultural coming from countries all over the world, but predominantly from the northeastern United States.

Prior to the start of the academic term, 22 students were randomly selected from a population of approximately 80 junior/senior students enrolled in Introduction to Network Administration and randomly assigned to two groups; one group was designated the experimental laboratory group and the other the control group. Students were informed of the purpose of the study and given the option to decline to participate. Any student who declined to participate was replaced by randomly selecting another student...
from the population. All students self-selected enrollment in one of the two lecture sections for the course.

2.2 Technical Environment
The hardware included ten Pentium4-based workstations, each with 1G of RAM and running Windows XP. The machines were connected to a local subnet masked from the rest of the campus network by a router, similar to the traditional laboratory environment. The router provided security for the hosting machines by implementing Network Address Translation (NAT) and a series of non-standard ports, configured to limit access to the target machines on the private subnet.

Each machine was running Windows XP Professional and had Remote Desktop Protocol (RDP) enabled to allow remote administration. Several user accounts were created on each machine to allow access for the student, the instructor, and other support personnel. Students were granted administrator privileges and required to sign a contract agreeing to a restrictive computer-use policy. VMWare Workstation was selected as the virtualization software based on the instructor’s familiarity with the product and availability of licenses.

2.3 Intervention
There were two lecture sections for the course with a maximum enrollment of 40 students meeting twice a week, and six laboratory sections with a maximum enrollment between 10 to 12 students each meeting once a week.

Students in the experimental laboratory group had remote access to the VMWare server from any location with Internet connectivity to complete laboratory assignments. A FirstClass conference was set up for communication, submission of written assignments, and access to posted information. A special FAQ (frequently asked questions) directory was created for commonly asked questions related to the assignments and any other course-related issue. Each assignment had a separate folder where the instructor posted information, and questions were asynchronously posted by students. Students were encouraged to respond to questions and to use the conference to electronically communicate with each other as well as the professor.

Some of the students had prior experience in the physical lab environment, while others had none. A few of the students had some prior experience using virtualization software, but most of that experience was fairly limited. The instructor held a two-hour session at the end of the first week of classes to introduce the participants to the VMWare Workstation environment.

Both groups were taught from the same syllabus covering the same topics with the same course objectives, number of assignments, and comparable assignment due dates. Materials used in the laboratory assignments varied as necessary in the instructions to accommodate the online interface of the virtual laboratory, which required maintaining two sets of “different but equivalent” laboratory exercises; one for the traditional laboratory and one for the virtual laboratory.

The time allotted to complete each assignment in the traditional laboratory is calculated from the scheduled meeting day of the laboratory. Since the virtual laboratory did not have a scheduled meeting time, assignments were posted online based on a schedule that allocated the same amount of time to complete each assignment. Assignment dates were staggered to allow the instructor adequate time to grade the in-depth reports that were submitted and provide feedback with reasonable response time.

2.4 Data Collection
The instructor was the main participant in the day-to-day instructional process and collaborated with the researcher to collect and interpret data. They met weekly to discuss and reflect on events that had transpired and made modifications deemed appropriate. Based on student feedback, laboratory assignments were modified to provide more detailed instructions for the configuration of the virtual environment. Another modification incorporated direct requests for written student feedback on the laboratory assignments and experience. From verbal interaction with some students it appeared that there were some issues that needed to be addressed, but were not being communicated. Formally requesting written feedback provided a mechanism to close this loop and resolve the issues.

Both qualitative and quantitative data were gathered throughout the term using multiple methods for each research question. The instructor maintained a journal recording observations, personal reflections, and student comments and interactions relevant to the study. Observations were conducted on the interactions in the online conference and the behavior and interactions relevant to the research questions in the lecture component of the course.

Formal group interviews and a Likert scale attitude survey were conducted to ascertain students’ satisfaction with the online laboratory experience. With student consent, the interviews were recorded to supplement the interview notes for completeness. Interviews were open-ended to allow deeper investigation of student responses. At the conclusion of the study, students were asked to complete a questionnaire using a five-point Likert response scale to evaluate student satisfaction. A sample copy of the questionnaire can be found in the Appendix A. Interview notes were reviewed and discussed by the instructor/administrator research team and compared with the quantitative results of the questionnaire. Postings to the laboratory course conference and email correspondence with the instructor were reviewed for any indication of frustration and/or satisfaction. The use of multiple methods was employed to corroborate the findings and increase confidence in the credibility of the resulting claims.

Student performance in the laboratory course was evaluated by successful completion, with instructor sign off, of a designated set of required laboratory assignments and submission of formal reports of exploratory laboratory assignments. Failure to complete any one of the required laboratory assignments results in failure for the course; students usually withdraw to avoid the failing grade increasing attrition. Attrition from the course and student grades on the formal reports was compared between the students in the experimental laboratory group and the control group to assess the impact on student achievement. The control group provided criteria for comparison and reduced the potential bias of the instructor to interpret the data as successful. The instructor’s journal was reviewed for any emerging themes and triangulated with the other data methods to confirm results.
2.5 Procedure
At the end of the first week of class, scheduling conflicts resulted in a final enrollment of 10 in the online laboratory section and 11 in the control group. During the course of the study, two of the ten students in the online laboratory section dropped the course due to lack of performance. Follow up with the students revealed that their reasons for lack of performance were unrelated to the online design of the laboratory. One of the students had taken a job and joined the crew team and lacked the organizational skills to manage the complexity of his schedule. The other student had signed up for more than the usual number of courses and found the workload overwhelming and decided to drop the course. Two students also dropped from the traditional laboratory section; one left for employment to satisfy the internship requirement and the other failed to perform.

Informal review of the qualitative and quantitative data and a statistical analysis of the quantitative grading data were used to evaluate results of the study. The laboratory grades and course grades (see Table C2 in the Appendix C) were analyzed using an Independent Samples T Test to check for the achievement hypothesis. There was one independent variable with two levels (one group received online laboratory instruction, the other received traditional onsite laboratory instruction) and one quantitative dependent variable; therefore, the Independent Samples T Test was chosen. Since it was possible to randomly assign subjects to the groups and there was a control group, the design served to control for most sources of invalidity in the statistical analysis.

To assess student satisfaction, small group interviews were conducted and a Likert scale attitude survey was administered. Group interviews were scheduled for two hour blocks with three to four students, the instructor of the course, and the researcher. The same prepared list of questions was asked of each interview group. A copy of the questions can be found in Appendix B. The attitude survey asked the students to respond to a series of survey questions). These scores indicate student agreement that the difficulties were the result of the experimental setup, but the general consensus was that they were not major issues, but somewhat time consuming. Students shared the opinion that the difficulties were the result of the experimental nature of the project, and they felt their participation was helping to debug the environment for subsequent iterations. This was corroborated by the attitude survey with a score of 3.75 for question 5, and 4.13 for question 9 (see Appendix A for sample survey questions). These scores indicate student agreement that technical difficulties and the support software was not a barrier to learning. Observation of the online discussion area and technical problem chat area confirmed some frustration, primarily at the beginning of the course.

Students from traditional laboratory sections shared war stories of their onsite laboratory experiences in conversations with students from the online section concerning technical difficulties and

having to compete for laboratory access and could leave their station running and come back without fear of someone taking their space and interrupting their work.

The convenience of working any time from any location with Internet access was a significant issue to the students. They could work from home at any time that was convenient and not have to lose precious time walking across campus to access the facilities. The students exhibited increased enthusiasm for the work and reported spending additional time working on the assignments. They felt they had an advantage over the traditional physical laboratory because of the increased accessibility of the laboratory and the opportunity to work with the software supporting the environment, which enhanced their technical skills.

The convenience of being able to work at any time initially had a down side. The students reported increased procrastination in starting the first assignment because of the lack of structure created by the distance format. In a traditional laboratory, the scheduled session is the catalyst that initiates the start of an assignment and imposes a block of time to complete as much as possible in a structured environment. While they may procrastinate completing an assignment in the traditional format, they have a sense of the scope of the assignment from the in-class session to estimate the time needed to complete it. In the absence of this structure, several of the students indicated that extreme efforts were required to complete the first assignment on time.

In the traditional laboratory environment, students must obtain approval from the instructor or laboratory assistant that certain key competencies have been completed during their laboratory exercises. Lacking the physical presence in the virtual laboratory, corroborating completion of these competencies proved to be a challenge and created some confusion. Screen captures of completed portions of the laboratory exercises were submitted by the students to mimic the in-class experience. However, students indicated they were unsure of how many screens to capture and which ones. This resulted in students capturing more rather than less in order to be sure their work was verified, which was tedious and time consuming.

Other issues that created some frustration for the students included minor technical difficulties in hardware performance, and the time required to learn to work with the specialized software that supported the environment. The issues were raised but the general consensus was that they were not major difficulties, but somewhat time consuming. Students shared the opinion that the difficulties were the result of the experimental nature of the project, and they felt their participation was helping to debug the environment for subsequent iterations. This was corroborated by the attitude survey with a score of 3.75 for question 5, and 4.13 for question 9 (see Appendix A for sample survey questions). These scores indicate student agreement that technical difficulties and the support software was not a barrier to learning.

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3. RESULTS
3.1 Student Satisfaction
Several themes emerged consistently in all the interview sessions. All students interviewed agreed that the two major benefits of the distance laboratory were availability and convenience. Physical laboratory space has competing uses (scheduled classes, scheduled practical exams, and general student use outside of class) and is not open 24 hours a day. Students compete for laboratory space during the unscheduled open hours and often must sign up in advance to guarantee accessibility during peak loads around exam periods. The online laboratory eliminated the challenge and anxiety of securing laboratory access in order to complete assignments and offered access 24 hours a day 7 days a week. Students unanimously commented they preferred not
equipment failures in their laboratory sessions. While the online students had some start up technical difficulties with the experimental environment, they reported feeling that the online environment functioned better technologically in comparison to the traditional laboratory.

Use of the online conference resources received mixed reviews from the students both in the interviews and the survey. Furthermore, students made use of the online resources in different ways. An open discussion area was created for the students, however, participation was optional. Two of the students reported that they read the online discussions before starting assignments to avoid some of the problems encountered by the other students, but were reluctant to contribute to the open discussions because they did not want to appear stupid. Students were required to post weekly status reports on their laboratory assignments, which all of them did including the students who passively participate to consume information but fail to actively contribute (lurkers). Observation of the online communication corroborated that the students who were the online lurkers, posted only what was required of them to avoid loss of points from their grade. The other students indicated that they checked the online course conference areas two to three times a day; observation of the discussion area indicated frequent postings by these students.

When asked on the survey if the overall communication and use of the conference to communicate with the instructor was effective (questions 4 and 11), results were 4.25 out of 5 for both questions, placing them between agree and strongly agree. The survey showed that students were in agreement that the use of conference resources was effective for communicating with other students about laboratory-related work, rating it a 4 (question 10). The surprise result was question 8, which asked if students felt the online conference enabled them to communicate more frequently with the instructor than an onsite laboratory. A score of 3.5 indicated students were somewhere between neutral and agree in their responses. While a score of 3.5 does not indicate a problem, it was not consistent with the results of instructor-student communication in question 11, feedback from the interviews, or the observations of the interactions in the conference between students and the instructor. Despite the fact that there was a higher level of interaction with the instructor online about laboratory-related work than in the onsite laboratory, students did not perceive that to be the case. Reflecting on this outcome and the interview notes, this researcher believes that the reaction is tied to the students’ need for some level of face-to-face interaction. Students were unanimous in the interviews that they would not want to see the entire course online, in fact several students formed partnerships offline to work on problems both face-to-face and through email. All students in the study were undergraduates who have spent their entire school life in traditional face-to-face learning environments, and for most this was their first experience with online learning.

The remaining survey questions concerned the instructor’s responsiveness and management of the online experience (see questions 2, 3, 6, and 7 in Appendix A). Students felt the instructor effectively managed the online environment and were satisfied to very satisfied with his responsiveness to questions and providing feedback.

Overall the interviews were positive with an open discussion on minor problems. There was a general attitude and feeling on the part of the students that the online laboratory was a positive experience that was at least equivalent, and in some ways superior, to the traditional laboratory environment. Questions 1 and 12 on the attitude survey directly addressed overall student satisfaction and equivalency of the experience. Both questions had an average score of 4, which indicated students were satisfied with their experience and felt it was equivalent to the learning experience in the traditional laboratory. These scores are in agreement with the interview results.

3.2 Student Achievement

Comparison of the laboratory grades between the online and traditional laboratory groups indicated the average grade for the online laboratory group was 8% higher than the traditional laboratory group. The average laboratory grade for the online population was 83.75 and 77.63 for the traditional group. Comparison of the lecture grades between the online and traditional laboratory groups indicated the average grade for the online laboratory group was 5% higher than the traditional laboratory group. The average lecture grade for the online population was 85.56 while the average grade for the traditional group was 81.42. Since the students were randomly assigned, these results appear to support the conclusion that student achievement is equivalent between the two groups.

Using the SPSS 12.0 statistical analysis software, an Independent-Samples T test was performed on both the laboratory and lecture grades (with a 95% confidence interval), confirming the informal observation that there is no significant difference in achievement between the online and traditional laboratory groups. The analysis was designed to determine if there was a significant difference in achievement between students taking the Introduction to Network Administration laboratory in a distance delivered virtual networking laboratory and students in a traditional physical networking laboratory. The null hypothesis to test for acceptance/rejection was: there will be no significant difference in achievement between students taking the Introduction to Network Administration laboratory in a distance delivered virtual networking laboratory and students in a traditional physical networking laboratory. The groups were randomly formed and the skewness values indicated that the data was within acceptable range of a normal distribution. The Independent Samples T Test performed on the laboratory grades indicated the difference between the two groups was not statistically significant at an alpha level of .05 (Table 1). The p value of .437 was greater than .05 and the computed t value of .798 was less than the critical t value of 2.131, which supports the null hypothesis. This indicated that the difference in the means was not greater than could be expected by chance and the research hypothesis that there will be a significant difference in achievement between students taking the Introduction to Network Administration laboratory in a distance delivered virtual networking laboratory and students in a traditional physical networking laboratory was not supported.
The Independent Samples T Test performed on the lecture grades indicated the difference between the two groups was not statistically significant at an alpha level of .05 (Table 2). The p value of .316 was greater than .05 and the computed t value of 1.038 was less than the critical t value of 2.131, which supports the null hypothesis. This indicated that the difference in the means was not greater than could be expected by chance and the research hypothesis that there will be a significant difference in achievement between students taking the Introduction to Network Administration laboratory in a distance delivered virtual networking laboratory and students in a traditional physical networking laboratory was not supported.

Table 2. Statistical Data for Lecture Grades

<table>
<thead>
<tr>
<th>Independent Samples T-Test</th>
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<tbody>
<tr>
<td>Mean Online Grades</td>
</tr>
<tr>
<td>Mean Traditional Grades</td>
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<tr>
<td>Alpha value</td>
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<td>Degrees of freedom</td>
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<td>Critical t value</td>
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<td>p value</td>
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Informal and statistical analysis of student performance in the lecture and laboratory indicated achievement of the online laboratory students was not significantly different than achievement of the onsite laboratory students. However, any conclusions drawn from this experience must take into account the small sample size.

4. CONCLUSION

Students perceived their online laboratory environment to be equivalent to the onsite laboratory, and were satisfied with their experience both technically and personally. Comparing student performance between the experimental and control group indicated no significant difference in achievement. Student satisfaction with the learning experience in the experimental group was generally equivalent to the control group; and in the case of convenient access to laboratory resources, the experience was perceived as better. Based on these results, a virtual online laboratory offers a viable alternative strategy to deliver instruction. A virtual online environment can be used to expand limited laboratory resources and reduce costs without a negative impact on students’ learning experience. The application of online and virtual technology in laboratory-based courses can extend accessibility of laboratory resources to traditional on-campus students and facilitate access to the curriculum to remote learners previously excluded by geography. This not only benefits students, but makes more effective use of physical resources.

Although the results were positive, students indicated they did not want their entire course experience online and would not want to take all of their laboratory requirements online. In view of these attitudes and recognizing the limited laboratory resources, both online and traditional laboratory environments should be made available and track how student preferences and success develop in the future.

The project was designed to address resource constraints in the local context of the Information Technology Department at the Rochester Institute of Technology. The population available to draw from for the study was limited to students who choose to enroll in Introduction to Network Administration, which was entirely male between the ages of 19-23. This limits the applicability of the results; however, the study can serve as a model for further study at RIT and other institutions.

5. RECOMMENDATIONS

Reflecting on students’ comments during the interviews and in postings online, the student experience can be improved through several changes to the design of the online laboratory. The addition of a tutorial on the installation and use of the VMWare software prior to the start of the laboratory assignments would prepare students for the software environment, and avoid potential frustration at the beginning of the course. A better approach to verifying completion of key competencies is needed. In the short term, a minimal list of strategic screen captures should be developed for each exercise.

Students in the onsite laboratory were paired into two-person teams to work on their laboratory exercises, and had in-class interaction and support from the instructor. To better map the online experience to the traditional laboratory, partners could be assigned and an optional synchronous chat session conducted online once a week. Partners should be allowed to collaborate on homework assignments and non-graded laboratory exercises. The chat sessions would provide synchronous interaction with the instructor, and a forum for immediate feedback to questions that is not always possible in online postings. Questions posted online can take up to 24 hours before a response is received.

The online conference and submission site should be relocated to the online course support environment developed at RIT, known as MyCourses. This study used the FirstClass conference software; however, students use the MyCourses learning management system for all other courses, which meant they had to check two different online environments. Since FirstClass was only used for the online laboratory class, frequent checking for postings was not as convenient.

In addition to the local context of the study design, the sample size was small. Further study is needed to corroborate the results and conclusions drawn from this pilot study. A larger sample size would be preferred and inclusion of other schools so the results of the study will be more significant and can be generalized to a wider audience.

6. SUMMARY

The positive results of the study broadened both the instructor’s and students’ experience with alternative delivery options, and suggest offering the virtual experience on a continuing basis as an
option to the traditional format. As curriculum expands and enrollment increases in networking and systems administration, this will potentially provide a cost-effective solution to resolve budgetary and space constraints.

7. REFERENCES


8. APPENDICES

8.1 Appendix A

8.1.1 Online Laboratory Questionnaire

1. How satisfied were you with the laboratory experience gained in this virtual laboratory?
   ___ very satisfied
   ___ satisfied
   ___ somewhat satisfied
   ___ somewhat unsatisfied
   ___ very unsatisfied

2. How satisfied were you with the promptness that the instructor recognized and answered student questions in the online conference site?
   ___ very satisfied
   ___ satisfied
   ___ somewhat satisfied
   ___ somewhat unsatisfied
   ___ very unsatisfied

3. How satisfied were you with the material exchange (method of sending/receiving materials, promptness) between you and the lab instructor?
   ___ very satisfied
   ___ satisfied
   ___ somewhat satisfied
   ___ somewhat unsatisfied
   ___ very unsatisfied

4. Communication was used effectively throughout the laboratory course.
   ___ strongly agree
   ___ agree
   ___ neutral
   ___ disagree
   ___ strongly disagree

5. Technical problems did not interfere with your learning of the content covered.
   ___ strongly agree
   ___ agree
   ___ neutral
   ___ disagree
   ___ strongly disagree

6. The instructor encouraged interaction among students through online discussions and/or questions.
   ___ strongly agree
   ___ agree
   ___ neutral
   ___ disagree
   ___ strongly disagree

7. The instructor provided feedback on assignments in a timely manner.
   ___ strongly agree
   ___ agree
   ___ neutral
   ___ disagree
   ___ strongly disagree

8. Use of the online conference enabled me to interact more with the professor.
   ___ strongly agree
   ___ agree
   ___ neutral
   ___ disagree
   ___ strongly disagree

9. The virtual laboratory interface was easy to use.
   ___ strongly agree
   ___ agree
   ___ neutral
   ___ disagree
   ___ strongly disagree

10. The FirstClass conference was effective for communicating with other students about laboratory-related work.
    ___ strongly agree
    ___ agree
    ___ neutral
    ___ disagree
    ___ strongly disagree

11. The FirstClass conference was effective for communicating with the professor about laboratory-related work.
    ___ strongly agree
    ___ agree
    ___ neutral
    ___ disagree
    ___ strongly disagree
12. Compared to a conventional in-class laboratory this online learning experience was:

___ better
___ equivalent
___ somewhat equivalent
___ worse
___ ineffective

8.2 Appendix B

8.2.1 Interview Questions

Have you found the virtual laboratory a positive experience? What have been the major benefits?

Have you experienced any difficulties? If so, how have they impacted your learning experience?

Do you use the online class conference to communicate with other students? If not, why not?

Do you feel comfortable communicating online? Why or why not?

Would you communicate online if it was not required?

Would you take another online laboratory course?

Would you change anything?

Would you like to see the entire course online or do you prefer the combination of online and face to face?

8.3 Appendix C

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Table C1. Survey Likert Scale Values

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