Virtual Labs in the Online Biology Course: Student Perceptions of Effectiveness and Usability

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Abstract

The purpose of this study was to investigate student perceptions of virtual biology labs used in two online introductory biology courses. Students completed an online survey, containing Likert-type and open-ended items, about perceptions of the CD-ROM-based virtual biology laboratories and face-to-face (F2F) laboratories they completed during the courses. Findings indicated that though most students (86.9%) perceived the F2F laboratories as more effective than the virtual laboratories across several criteria, many of them (60.8% on one criterion) perceived the virtual laboratories as effective as well. The authors discuss how student-identified issues related to interactivity and feedback could be influenced by the design of the learning experience, virtual laboratory tool, and/or the use of synchronous collaboration tools. Additionally, the authors include suggestions for future research on the use of virtual biology laboratories in the online setting.

Keywords: Virtual experiments, online science instruction, web-based instruction, community college, higher education

Introduction

The areas of online instruction and web-based learning initiatives have grown tremendously over the past two decades, though there are certain areas within which a paucity of research on effectiveness and learning outcomes remains. One of these areas is the use of virtual biology laboratories in the online science classroom. Research findings support the use of virtual laboratories for providing engaged, active learning experiences in physics education (Finkelstein, et al., 2006; Finkelstein, et al., 2005) and use of website-based simulations in the online biology classroom (Gilman, 2006), but there are few studies that examine the use of virtual laboratory simulations in face-to-face (F2F) or online postsecondary biology courses. The current study is an exploratory beginning of a research agenda to address this gap.

Research supports the use of hands-on, minds-on, active instructional strategies over passive, lecture-based instructional methods for improved student learning outcomes in science education (Burrowes, 2003; Lord, 1997; Pheeney, 1997; Bredderman, 1982). One way of creating an active learning

environment is to use multiple modes of instruction. Research has shown that meaningful learning can occur when connections are made between information stored in visual and auditory working memory systems (Moreno & Mayer, 1999). Additionally, reaching today's students can be a challenge when using primarily lecture-based instructional methods. Today's youth are visuo-spatially intelligent and talented (Habraken, 2004) and may need to experience instruction that is visual and that requires active participation. The virtual lab experience combines visual and auditory modalities and requires students to be actively involved.

It is essential that educational researchers study the virtual biology lab experience to determine if evidence exists to support the use of this tool to increase levels of active, engaged learning and overall achievement in science. This issue is especially poignant for the online science classroom due to the inherent learning challenges in the virtual environment, one of which involves developing and maintaining active student engagement in course activities.

There exists a large body of literature on instructional approaches to distance and online learning, with strong support for creating an active, engaged learning environment to enhance student learning (see Lim, 2004; Quitadamo & Brown, 2001). Instructional materials can engage and motivate students when they are user-friendly, interactive, and problem-oriented (McDonald, 2002). McDonald also asserts that the distance education environment is fertile ground for developing new instructional practices, and further, that distance education may be able to extend learning in ways that traditional, face-to-face education cannot. The use of virtual laboratories in online biology courses is one relatively new instructional practice that may help to create the engaged and active learning experience that is supported by the literature. This practice may also extend learning for students when specialized biology materials are not affordable or are deemed undesirable for actual use.

Though the aforementioned studies present a focused effort to inform instructional approaches that facilitate a more active and engaged learning experience, there is a paucity of research that focuses specifically on the effectiveness of the use of virtual biology laboratories in the college setting. A focused research program is needed to determine if these tools are indeed effective in moving students toward a deeper understanding of basic biology concepts and the overall nature of science.

Study Overview

This exploratory study is the first step in a research agenda that is focused on investigating the effectiveness of virtual biology laboratories. The long-term goal of the agenda is to eventually add to the literature in terms of how well virtual biology laboratories, whether used in the online environment or as supplements in F2F setting, could provide a comparable learning experience. Though the literature is growing, there remains a need for more research on virtual laboratories specifically in biology courses.

The purpose of this exploratory work was to investigate student perceptions of their experiences completing several virtual biology laboratories during the online Human Biology courses in which they were enrolled. In an effort to elicit student responses that reflected a more accurate depiction of student perceptions of the virtual laboratories, it was important that students compared their experiences with both face-to-face (F2F) and virtual labs. The students completed both F2F and virtual labs, so they were able to compare their experiences.

Though the ultimate goal of the authors is to eventually examine effectiveness of virtual labs as an instructional tool, the purpose here is to first glean student perceptions of the tool from an evaluative perspective. It is hoped that findings from this research would provide information to use during instructional improvement as well as add to the literature in this area. As such, this study addressed the following research questions:

- How do students perceive virtual laboratories in terms of effectively helping them to understand biology concepts and the general nature of science (Lederman, 2005)?
- How do students perceive face-to-face laboratories in terms of effectively helping them to understand biology concepts and the general nature of science?
- How do students perceive both types of laboratories in terms of enjoyment?

- Which instructional factors are perceived to make either type of laboratory most effective and why?

In this study, the authors used an online survey, with both closed- and open-ended items, to collect data to answer the above questions and explore issues related to perceived effectiveness of the virtual science laboratories used in the human biology courses for non-majors.

Method

Participants and Course Content

The participants were 38 students enrolled in two online introductory biology courses (n=23, n=15), at a Midwestern, urban, community college. The authors sent out an e-mail invitation for survey participation to all 38 students and 60.5% (n=23) replied to the survey. Respondents' ages ranged from 18-55 years. The group was also ethnically diverse; consisting of 47.8% African-American, 34.8% Caucasian, 13% International (European) and 4.3% Asian students. Most participants were not Biology majors (n=22) and were studying in a variety of disciplines (i.e., social science, humanities/languages, business, education, and applied health fields).

The courses were two sections of an introductory Human Biology course for non-majors conducted primarily online except for laboratory experiences. In total, there were 22 laboratory experiences for the semester. Students met face-to-face (F2F) for two 7-hour class sessions and 12 lab experiences over the course of these sessions. The remaining 10 labs were CD-ROM-based (Virtual Physiology Lab, WCB/McGraw-Hill and Cypris Publishing, ISBN 0-697-36286-8) virtual experiences that students completed independently.

The F2F laboratories consisted of primarily reading text and viewing and labeling images that were models of organs and body systems. They were also required to answer questions about the organs and body systems. Some labs required students to collect data from each other and analyze the data. There were also two “wet” labs on chemical digestion of macromolecules (i.e., carbohydrates, fats, and proteins), urinalysis, fetal pig dissection, and microscope use.

The virtual laboratories involved a series of pointing and clicking to manipulate virtual lab equipment. The program produced quantitative data for students to analyze. For the analysis, students answered questions, which were submitted as the laboratory assignment. For example, the virtual lab on osmosis and diffusion contained virtual test tubes filled with virtual blood cells. Students were required to mix a virtual water-based solution of various concentrations with the blood cells to observe its effects. Students then answered questions about their observations. Other virtual lab topics were frog muscle, pulmonary function, and action potential.

Data Collection

The authors collected survey data via FreeOnlineSurveys.com, an online survey creation and delivery tool. The authors presented the link to the online survey to students via email and through a link in the Announcements section on the course website. The survey consisted of seven demographics items (i.e., ethnicity, major, age range, number of online classes taken, and number/type of labs taken), 16 Likert-type items (scaled Strongly Agree, Agree, Somewhat Agree, Somewhat Disagree, Disagree, Strongly Disagree) that focused on student perceptions of effectiveness of the virtual laboratories and the F2F laboratories in terms of increasing their general understanding of the nature of science and the concepts covered in the virtual laboratory. Below are sample items from the survey:

- The virtual biology labs enhanced my understanding of course content.
- The face-to-face biology labs enhanced my understanding of course content.
- The virtual biology labs helped me understand how to analyze data.
- The face-to-face biology labs helped me understand how to analyze data.
- The virtual biology labs enhanced my ability to critically evaluate scientific claims that I hear in the news.

- The face-to-face biology labs enhanced my ability to critically evaluate scientific claims that I hear in the news.

In addition to the demographics and Likert-type items, there were also three open-ended items that allowed for qualitative answers about the effectiveness of the virtual and F2F laboratories. These items are below:

- Which type of lab experience most effectively enhanced your understanding of course content?
- If you feel that one type (virtual or face-to-face) of lab experience was more effective than another, please briefly explain what made it more effective.
- Which type of lab experiences (virtual or face-to-face) did you find to be more enjoyable? Why?

Data Analysis

The authors analyzed data for descriptive trends indicative of student perceptions about the effectiveness of the F2F and virtual biology laboratories. Generally, answers to survey items were tabulated into percentages (e.g., 42.86% of students agreed that the virtual laboratories enhanced understanding of course content). Additionally, the authors examined answers to the qualitative items for salient themes that provided richness to the quantitative findings. In essence, the responses to the open-ended items helped to provide some explanation for student responses to the Likert-type items.

Findings and Discussion

The data from the Likert-type items indicated that the virtual laboratories were generally well-received by students, however, responses indicated that students perceived face-to-face labs as more effective overall. Table 1 shows percentages of students who indicated strong agreement or agreement on each Likert-type item.

Table 1. Percentages of students indicating strong agreement or agreement

Survey Item	Virtual Labs - % agreed/ strongly agreed	F2F - % agreed/ strongly agreed
understand course content	60.8 (n=14)	86.9 (n=20)
understand experimental design	52.2 (n=12)	78.2 (n=18)
understand how to collect data	47.8 (n=11)	73.9 (n=17)
understand how to analyze data	43.4 (n=10)	73.9 (n=17)
understand how science can be used to answer questions	56.5 (n=13)	78.2 (n=18)
understand how scientists are able to explain what they observe	47.8 (n=11)	78.2 (n=18)
understand how scientists use research to create theory	34.8 (n=8)	69.5 (n=16)
ability to critically evaluate scientific claims that I hear in the news	34.8 (n=8)	69.5 (n=16)

For example, in terms of helping them to grasp the nature of science, students perceived the F2F labs as more effective. Specific Likert-type items that addressed elements of the nature of science were:

"…understand how to collect data," "… understand how to analyze data," "…understand how science can be used to answer questions," "…understand how scientists are able to explain what they observe," and "…understand how scientists use research to create theory." (Crowther, Lederman, & Lederman, 2005; Lederman & Lederman, 2005) Percentages of students agreeing or strongly agreeing to these statements ranged from 69.5% to 73.9% while the percentages for the virtual labs ranged from 34.8% to 56.5%.

Additionally, though 60% of students perceived that the virtual labs enhanced their understanding of course content, nearly 87% of them perceived that the F2F labs enhance their understanding of course content. One reason for this finding could be an issue related to instructional alignment of the virtual lab experiences to the course instruction and readings. One issue with the virtual labs is that they were add-on materials, that is, they were not created in conjunction with the other course materials, whereas the F2F labs were designed by one of the Biology department faculty members.

Though the F2F labs were better received overall, student responses indicate that many of them perceived the virtual labs as useful to their learning experiences. For example, over 50% of them indicated that the virtual labs helped them to understand experimental design (52.2%, n=12), how science can be used to answer questions (56.5%, n=13), and course content (60.8%, n=14). The authors interpreted these quantitative findings as an indication that the use of CD-ROM based virtual biology laboratories may have promise for helping students to achieve in biology courses. Further, the open-ended, qualitative responses allowed a deeper look into students' perceptions of the virtual laboratories as compared to the F2F laboratories.

In the open-ended items, students commented that they enjoyed the student/student and student/instructor interactions that the F2F labs allowed. Their comments reflect the perception that the ability to ask questions and receive immediate feedback from the instructor and other students enhanced understanding of course content and the concepts and skills presented during F2F lab exercises. Though the CD-ROM-based labs did offer feedback (e.g., on-screen explanations based on the outcomes of students' decision-making and quiz answers), this feedback was not perceived as feedback by some of students. In fact, the instructor reported that students rarely, if ever, asked questions while completing the virtual laboratories. Further, the instructor did not make any special effort to engage students during the completion of the virtual laboratories. One could speculate that this lack of student-initiated questioning could be due to the design of the CD-ROM based laboratories, the independent, asynchronous nature in which the students completed the CD-ROM based laboratories, or the lack of additional instructor-initiated, interaction-based activities.

Student comments suggested that perhaps virtual labs that incorporate collaborative assignments and discussion may enhance interaction, community building, and learning of course content. An important implication of this finding is that instructors may need to make a concerted effort (e.g., require concurrent participation in discussion boards, chat, or synchronous online conferencing) to engage students during virtual laboratories—especially if students complete them independently. Collaboration tools, such as ElluminateLive! or the live chat function of the Blackboard Course Management System, are some possible features that would be used in conjunction with the virtual laboratories.

Students' responses to the open-ended survey items also reflected a preference toward the "real-world" hands-on experiences of the face-to-face labs. The virtual labs involved decision-making prompts and activities similar to the F2F labs, but without the actual manipulation of real equipment, many students did not perceive the virtual labs as real "hands-on" learning. However, McConnell (2001) suggests that depending upon the course objectives, the development of the psychomotor skills necessary to manipulate laboratory equipment may not be as important as developing higher-ordered thinking, so one may conclude that virtual labs may be a better fit in a course designed for non-Biology majors, such as the course involved in this study. These findings support the conclusion that virtual labs may be promising, not only for the online setting, but also to meet learning outcomes in F2F courses designed for non-majors.

Conclusions, Limitations, and Future Research

The purpose of this study was to investigate student perceptions of their experiences completing several virtual biology laboratories during the online biology courses in which they were enrolled. It is important to note that the impetus for this study was evaluation research conducted due to a department decision to move the Human Biology courses from a hybrid delivery to a fully online delivery. If the courses were fully online, the virtual laboratories would be the sole laboratory experience for the courses—thus emphasizing the need for the current study and further research in this area. This study targeted a particular issue related to the use of virtual labs through exploratory means; consequently, there are many opportunities for future research.

One limitation of this study was the small sample size. Since there were a limited number of participants in this exploratory inquiry, there is a need to continue this line of research with a larger sample. Additionally, this line of research would require an adaptation of methods and instrumentation if undertaken with a sample from this same population because the course used in this study no longer utilizes F2F laboratories. The entire course is now fully online.

Another limitation is that only one, somewhat older, version of CD-ROM virtual laboratories was used, and so all the lab experiences contain similar strengths and weaknesses. This factor provides consistency, but limits the student experiences and the researchers' ability to examine variability across student perceptions that is related to differences in the design of the virtual laboratories. Perhaps a replication of this study with different virtual biology labs would yield much different results.

Additionally, the F2F labs and the virtual labs addressed some different concepts, thus students were not able to provide direct comparisons of virtual and F2F labs that addressed the exact same learning objectives. This particular limitation makes it impossible to truly investigate effectiveness. Further, this study utilized data based on evaluation research and does not employ a research design that lends itself to the generation of causal inferences—thus it is impossible to establish relationships between variables or causal evidence for the effectiveness of virtual laboratories. Another possibility for future study is to employ a research design that would examine relational or causal links, such as between virtual labs and student learning outcomes.

Another possibility for future research is to investigate instructional aspects of the F2F labs that help students develop a depth of understanding about the nature of science. Once those aspects are elucidated and defined, one may be able to build comparable components into the online biology labs. A replication of the current study with this new design would build on the findings of the current study.

Additionally, findings indicated that instructional features preferred by students that were not perceived as present in the virtual labs (e.g., student-instructor interaction and feedback during the labs), may be remedied with design modifications or the addition of synchronous collaboration tools that allow for conferencing via the Internet during completion of the labs. A possible replication of this study would be to include conference tools that allow students to confer in group and with the instructor as they complete the CD-ROM based virtual labs.

The current work represents the commencement of a promising research program. As evidenced by the plethora of research ideas presented here, this area of research is rich with opportunity for development. Online learning, especially in the area of virtual biology laboratories, is still new in so many ways and more research is needed if educators expect to be able to fully exploit this delivery medium and its related tools to enhance teaching and student learning.

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References

Bredderman, T. (1982). What research says: Activity science--the evidence shows it matters. *Science and Children*, *20*(1), 39-41.

Burrows, P. A. (2003). Lord's constructivist model put to a test. *American Biology Teacher, 65*(7), 491-494.

Crowther, D. T., Lederman, N. G., Lederman, J. S. (2005). Understanding the true meaning of nature of science. *Science and Children, 43*(2), 50-52.

Finkelstein, N., Adams, W., Keller, C., Perkins, K., Wieman, C. & the Physics EducationTechnology Project Team (2006). HighTech tools for teaching physics: The Physics Education Technology Project. *Journal of Online Learning and Teaching, 2*(3), 110-121. Available: http://jolt.merlot.org/vol2no3/finkelstein.pdf Accessed: 5/31/07.

Finkelstein, N. D., Adams, W. K., Keller, C. J., Kohl, P. B., Perkins, K. K., & Podolefsky, N. S., et al. (2005). When learning about the real world is better done virtually: A study of substituting computer simulations for laboratory equipment. *Phys. Rev. ST Phys. Educ. Res., 1*, 010103. Available: http://prst-per.aps.org/abstract/PRSTPER/v1/i1/e010103 Accessed: 5/31/07.

Gilman, S. L. (2006). Do Online Labs Work? An Assessment of an Online Lab on Cell Division. *American Biology Teacher*, 68(9), 131-134

Habraken, C. (2004). Integrating into chemistry teaching today's student's visuospatial talents and skills, and the teaching of today's chemistry's graphical language. *Journal of Science Education and Technology*, *13*(1), 89-94.

Lederman, N. G. & Lederman, J. S. (2005). Nature of science is…*Science and Children, 43*(2), 53-54.

Lim, C. P. (2004). Engaging Learners in Online Learning Environments. *TechTrends: Linking Research & Practice to Improve Learning*, 48(4), 16-23

Lord, T. R. (1997). A comparison between traditional and constructivist teaching in college biology. *Innovative Higher Education, 21*(3), 197-216.

McConnell, S. & Schoenfeld-Tachner, R. (2001). Transferring your passion for teaching to the online environment: A five step instructional development model. *E-Journal of Instructional Science and Technology, 4*(1). Retrieved May 15, 2006, from http://www.usq.edu.au/electpub/e-jist/docs/old/vol4no1/2001docs/mconnell.html

McDonald, J. (2002). Is “as good as face-to-face" as good as it gets? *Journal of Asynchronous Learning, 2*(2), 12-23.

Moreno, R. and Mayer, R.E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. *Journal of Educational Psychology*, *91*, 358-368.

Pheeney, P. (1997). Hands on, minds on: Activities to engage our students. *Science Scope, 21*(4), 30-33.

Quitadamo, I. J. & Brown, A. (2001, June). *Effective teaching styles and instructional design for online learning environments*. Paper presented at the National Educational Computing Conference, Chicago, IL. ERIC Document No. ED472228.

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