

Virtual Labs in the Online Biology Course: Student Perceptions and Implications for Policy and Practice

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Abstract. The purpose of this exploratory study was to investigate student perceptions of virtual biology labs used in two online introductory biology courses. Students completed an online survey about their experiences using several CD-ROM-based virtual laboratories. The authors present preliminary results of this survey, a brief synthesis of extant literature in this area, and suggestions for future research on examining student learning outcomes and effectiveness of virtual biology laboratories.

Background

The context of this study takes place at an urban multicultural, multi-college community college district in the Midwestern region of the United States that attempted to address the simultaneous challenges of decreased lab availability and the growing demand for online lab science course offerings while keeping the integrity of the course. The aforementioned institution offered a human biology course online for non-science majors that included a series of both on campus labs or “wet labs” and a series of virtual laboratories for a number of years. This online human biology course meets the Illinois Articulation Initiative’s requirements for transferring lab science credit to various 4-year colleges and universities in Illinois (iTransfer/Illinois Articulation Initiative, 2007). However, due to a sudden reduction in the availability of the biology laboratories and the steadily increasing enrollments in the aforementioned online human biology course, this institution was planning to redesign its online human biology course to be 100% online. Thus the human biology course was being redesigned and redeveloped to replace the on campus or “wet labs” with online or virtual labs. Therefore, the plans required reviewing relevant literature regarding online or virtual labs and exploring student perceptions of the existing on campus and virtual labs in this online human biology course.

Review of Relevant Literature

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. Virtual laboratories may be an effective way to provide students with active, engaged learning experiences in absence of a face-to-face laboratory.

Research supports the use of hands-on and active instructional strategies over passive, lecture-based instructional methods for improved student learning outcomes in science education (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 we study these experiences to determine if evidence exists to support the use of virtual labs 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 challenges to learning 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 fight student attrition. Instructional materials 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. "Distance education can be a frontier for new methods of communication giving rise to innovative teaching and learning practices that may not be possible in traditional, place-bound education." (McDonald, 2002, p. 12). The use of virtual laboratories in online science courses is one relatively new instructional practice that may help to create the engaged and active learning experience that is supported in the literature.

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 empirical research that focuses specifically on the effectiveness of the use of virtual biology laboratories in the college classroom. 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.

Study Overview

This exploratory study is the first step in a research agenda that is focused on investigating the effectiveness of virtual laboratories. The purpose of this study 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 F2F and virtual labs. Since students completed both F2F and virtual labs, 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 (i.e., "...characteristics of scientific knowledge that necessarily result from the scientific investigations that scientists conduct to develop knowledge..." Lederman (2005). p. 53)?
- 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?
- What factors are perceived to make either type of laboratory most effective and why?

In this study, survey methods, using both closed- and open-ended survey items, were used 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.

Methods

Participants and Course Content

The participants were 36 students enrolled in two online introductory biology courses (n=23, n=15), at a Midwestern, urban, community college. An invitation to participate in the survey was sent out via email to all 36 students and 63.8% (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 introductory Human Biology courses for non-majors conducted entirely 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

completed 12 lab experiences over the course of these sessions. The remaining 10 labs were CD-ROM-based 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

Survey data was collected via FreeOnlineSurveys.com, an online survey creation and delivery tool. The link to the online survey was presented to students via email and through a link in the Announcement section on the Blackboard 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

Data were analyzed 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 student agreed that the virtual laboratories enhanced understanding of course content). Additionally, answers to the qualitative items were examined 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

Although students found the virtual labs to be both useful and enjoyable, responses demonstrated 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)
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For example, though 60% of students perceived that the virtual labs enhanced their understanding of course content, nearly 90% 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 not created with the other course materials, whereas the F2F labs were designed by one of the Biology department faculty members.

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 that the ability to ask questions in a synchronous environment enhanced understanding of course content and the concepts and skills presented during lab exercises. In fact, the instructor reported that students rarely, if ever, ask questions that pertain to the virtual laboratories. Students reported an appreciation for the feedback offered through the F2F format. Since student interaction and collaboration is created through discussion assignments and group collaboration in the online learning environment, the student comments suggest that perhaps virtual labs that incorporate collaborative assignments and discussion may enhance interaction, community building and learning of course content.

Students' comments also reflect a preference toward the hands-on experiences of the face-to-face lab. 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.

Conclusions and Future Research

The purpose of this study was to investigate student perceptions of their experiences completing several virtual biology laboratories during the online Human 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 from a hybrid delivery to a fully online delivery. If the course is fully online, the virtual laboratories would be the sole laboratory experience for the course—thus emphasizing the need for this and further research. Since this study targeted a particular issue related to the use of virtual labs through exploratory means, 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 fully online.

Another limitation is that only one CD-ROM of virtual laboratories was used, 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 labs would yield much different results.

Yet another limitation is that this study used data based on evaluation research and does not employ a research design that lends itself to the use of inferential statistics—thus we are unable to establish relationships between variables or causal evidence. Another possibility for a future study is to employ a research design that would examine relational or causal links 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 course.

The current work is the beginning of a work in progress. As evidenced by the plethora of research ideas, this area of research is ripe and rich with opportunity for development. Online learning is still new in so many ways and more research is needed if educators expect to be able to fully exploit this delivery medium to enhance teaching and student learning.

Implications for Policy and Practice

Although, the design of this study was meant to be exploratory and non-inferential, it does suggest some potential implications for policy and practice. For example, the College Board, one of the most powerful educational organizations in the United States, is investigating the use of virtual labs in courses designated as Advanced Placement (AP) science courses and the results of their investigation will have an impact on policies regarding labs in AP science courses (Dillon, 2006). Another potential policy implication is whether or not respective policy makers view remote labs (MIT and Microsoft, 2006) asynchronous (i.e. on demand) virtual labs and synchronous (real-time) virtual labs (Center for Technology in Learning and Teaching at Iowa State University, 2005; Sevier, 2005) as the same. An example of implications for practice is the instructional design of virtual labs. In other words will the labs be created as recorded media (e.g. video tapes, DVDs/CDs, podcasts/vodcasts, etc.), home kits (e.g. lab materials sent via mail, labs with materials that are commonly available in homes or typical stores, etc.), clinical/lab sites (e.g. labs located in various geographic locations), remote labs (e.g. labs where remote users are accessing and using actual lab equipment and materials in the same physical site) (Alhalabi, Hamza, Hsu and Romance, 1998) or a combination of any of

these lab options. In addition, a key instructional design and development factor is whether or not the aforementioned lab options will be guided by the instructor(s) asynchronously or synchronously, experienced by the students individually and/or experienced by students in groups. Furthermore, there may be implications regarding whether or not the labs are created from available free/open sources, textbook publishers offerings, in house staff, one or more contracted/outsourced entities, etc. The authors of this paper plan to pursue further research regarding related policy and practice implications of providing authentic labs for online and distance education science courses and learning experiences.

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