Comparing Physical, Virtual, and Hybrid Flipped Labs for General Education Biology

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Abstract

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Itdut n

General education (GE) science requirements are designed to provide students with intellectual tools for growth and a broad base of knowledge about the natural sciences. Part of that mission is fulfilled by the inclusion of laboratory work generally assumed to provide experience with the process and methods of science (National Research Council, 2006). Laboratory work is supposed to simulate scientific inquiry, broadly defined as the way scientists study the natural world, propose ideas, justify assertions, and derive explanations based on evidence. Given the goals of GE science, some have argued that the principal focus of laboratory activities should not be devoted to mastery of particular laboratory techniques (see Hodson, 1993). Instead, the lab component should encourage students to investigate phenomena, solve problems, and pursue inquiry and interests in science. It follows from these assumptions that any investigation regarding laboratory pedagogy should measure students' learning as well as their attitudes towards science. The purpose of this study was to compare learning and attitude outcomes alongside cost considerations in

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experiments can be redesigned with little additional effort. Students can also design and carry out more experiments and gather more information relative to the PL version of the same experiment (Klahr, Triona, & Williams, 2007). These efficiencies tend to emphasize the higher order skills required to plan experiments and to appreciate the scientific method (de Jong, 2006; Wieman, Adams, & Perkins, 2008).

The second advantage of VLs is that reality can be augmented in the service of pedagogy. Especially for novice learners, those that are new to a domain and may be easily influenced by irrelevant information, highlighting important features and stripping out unnecessary details can help direct their learning (Finkelstein et al., 2005; Goldstone & Son, 2005). For instance, novices are more likely to be misled by the noise in PLs, such as the slight displacement of an internal organ in a dissection lab or a worn battery in an electrical circuit. The idealized models present in VLs can help focus their attention on the relevant relationships between variables. Furthermore, virtual simulations can make invisible phenomena visible (e.g., depicting movements of electrons) or link observable phenomena with symbolic representations (e.g., show how variables such as heat or kinetic energy change with a reaction) (Finkelstein et al., 2005; Jacobsen & Wilensky, 2006).

Unfortunately, many of the advantages of VLs have either been theoretically proposed or narrowly tested in an experimental setting. The most rigorous experiments have compared physical and virtual versions of a single laboratory activity with a tight focus on a particular concept. Some of these experiments have shown that there are no significant differences between learning from PL and VL versions (Klahr, Triona, & Williams, 2007; Triona & Klahr, 2003; Zacharia, 2007) although students perceive PLs to be more effective than VLs (Stuckey-Mic3(s)-2.3(s)-2.3(uc)3i e41 Td (6.9(S)1.7(t)-407S9w 11.674 0O6

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Students' attitudes and conceptual learning were assessed online both pre- and post-instruction. We also analyzed student achievement through grades, enrollment, and passing rates. Finally, we also examined the fiscal impact of VL implementation.

Method

Participants

Cal State LA has one of the most diverse student populations in the nation. In 2013, the students were 55.8% Hispanic, 16% Asian American, 9.9% White, and 4.7% African American. Among undergraduates, 59% of the students are female. Many students are older and have families; the average undergraduate is 23.4 years of age. Because the course was a general education course, student enrollment reflected this diversity. Three versions of this course were offered in AY 2013-14: PL model (N = 186, one section), VL-A model (N = 186, one section), and VL-H model (N = 376, two sections).

Procedure and Materials

Course background. The re-designed course was a non-majors GE science course at Cal State LA called *Animal Biology* (BIOL 155). This four-unit, quarter-based course is one of only three courses that satisfy the GE requirement for a life science course with a laboratory component. Most science majors require a non-GE biology course as part of their programs, so this course is usually taken by non-science majors. There are no prerequisites for the course. It is normally taught with two 75-minute lectures and one 150-minute laboratory session per week. The Department of Biological Sciences at Cal State LA usually offers this course 2-3 times per year with 6-8 PL sections of 24 students each in specialized laboratory facilities. The lecture is always offered in a large lecture hall (144-192 students total). The lectures are given by a tenured/tenure track or adjunct faculty member and the PL sections are most often staffed by adjunct faculty or graduate teaching assistants. Tenure/tenure track faculty may occasionally teach a few of the lab sections.

Cal State LA is on the quarter schedule so the PL and VL-A models were offered in Winter quarter (one section each) and the VL-H model (two sections) were offered in the Spring quarter. These sections were taught by experienced faculty members who had previously taught this course. The PL section was taught by an instructor who had previously taught the course with PLs only. The students in the VL-A section and one of the VL-H sections (N = 184) were taught by a different instructor who had taught PL and VL-A versions of the course. The remaining VL-H section (N = 192) was taught by an instructor who had previous experience teaching the course with PL

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given a second attempt to answer the multiple choice questions. The highest grade on the two attempts counted towards their course grade. Additionally, students worked together to formulate hypotheses, design and carry out experiments to test their hypotheses, organize their results, and submit a report in the format of a scientific paper. The lab instructor also introduced the next activity during these meetings. This pattern of individual online activities followed by in-person group work was repeated until the end of the quarter.

VL Assignments Nine virtual labs were employed during the VL-A model (see Table 1). Six were from *Biology Labs OnLine* (BLOL) and the remaining three were from *SmartScience Labs* (SSL). BLOL are simulations of experimental situations such as the genetics of inheritance or evolution. Students can vary several inputs in order to design a large variety of experiments. Tabular and graphical outputs were provided as well as the ability to transfer and export data their experimental data. SSL provides videos of real experiments that the students can view and pause to collect data. Videos of experiments conducted under different conditions are provided. The software has integrated introductory information.

A subset of four labs (all Biology Labs Online) was employed for the VL-H model. These labs were chosen because they offered more flexibility in terms of designing experiments. As part of the in-person activities, students were required to formulate hypotheses and design and carry out experiments to test their hypotheses. Table 1 describes the virtual labs that were employed in the VL-A and VL-H models. Copies of the lab handouts are available at http://tinyurl.com/vlab-eport.

Table 2: *Lab Activities in All Virtual (VL-A), Hybrid Virtual (VL-H), and Physical Labs (PL)*

Activity or Topic	Description	Usage
Biology Labs OnLine		
Cardio lab	Addressed homeostasis using arterial blood pressure as an example. The interaction of variables related to heart rate, vessel radius, blood viscosity, and stroke volume are examined.	VL-A
Demography lab	Investigated differences in population size, age-structure, and age-specific fertility and mortality rates affect human population growth.	VL-A
Evolution lab	Modeled adaptation by natural selection by manipulating various parameters of a bird species and its habitat, such as initial mean beak size, variability, heritability, population size, precipitation and island size.	VL-A, VL-H
Fly l		

Chronobiology Captured student

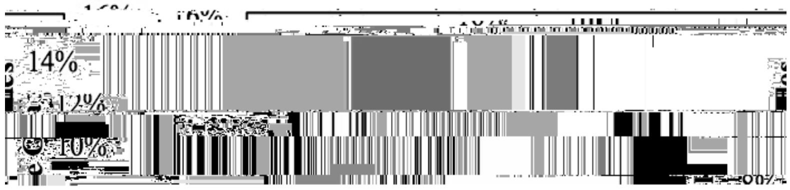

Figure 2. Proportion of repeatable grades for each of the three types of lab experience.

Survey Completion

Because it is difficult to control how seriously students take online assessments, it is important to examine the rates of survey completion across the three types of laboratory formats. In general, pre-instruction survey completion rate (85%) was higher than post-instruction (58%). A chi-square test of homogeneity revealed this ratio did not differ significantly across the three lab types, $\chi^2(2, N = 1075) = 1.72, p = .58$. We then excluded responses where students were unlikely to be reading the prompts (modeled after Semsar, Knight, Birol, & Smith, 2011). Responses were excluded for one of the following reasons: (1) providing the same Likert-scale response (e.g., all "strongly agree") for more than 90% of statements, (2) incorrectly responding to a statement embedded in the survey ("We use this statement to discard the survey of people who are not reading the questions. Please select 'agree' (not 'strongly agree') for this question to preserve your answers."), and (3) for not responding to both pre- and post-instruction surveys. If a student submitted more than one set of acceptable responses, only the first completed response was included in the analysis. There were 343 participants who met all of these criteria and comprised the set of data analyzed for the following survey results.

Student Attitudes toward Biology

The pre-/post- surveys allowed an assessment of the changes in students' attitudes toward biology for the three types of laboratory formats. For each statement, a student's shift in response was designated as favorable (agreeing with the expert consensus—not necessarily agreeing with statement), unfavorable, or neutral as detailed in Semsar, Knight, Birol, and Smith (2011). An ANOVA revealed significant differences among the laboratory groups, $F(2, 340) = 4.2$, $p = .016$. In Fisher's LSD post-hoc analyses, only the VL-H group showed a statistically significant positive increase in the percentage of favorable responses compared to PL, $p = .008$, and VL-A, $p = .003$. The small negative changes for the PL and VL-A groups were not significantly different from zero, $p = .65$. Table 3 shows the changes in student attitudes towards biology overall as well as broken down by sub-category. These results suggest that the VL-H format has the potential for increasing students' attitudes towards problem solving and their enjoyment of biology.

Table 3: *Mean and Standard Errors for the Change in Percent of Favorable Responses*

Category	PL (n=92)	VL-A (n=95)	VL-H (n=156)
Overall	-0.26% ± 1.99%	-1.22% ± 1.55%	+4.57% ± 1.36%*
Problem-solving difficulty	-0.02% ± 2.69%	+0.74% ± 2.97%	+4.28% ± 2.14%*
Problem-solving effort	+0.08% ± 2.38%	+1.32% ± 2.97%	+6.97% ± 2.39%*
Problem-solving strategies	-0.26% ± 2.38%	+4.17% ± 3.59%	+8.39% ± 2.91%*
Conceptual connections	-4.04% ± 2.58%	+1.02% ± 2.74%	+3.21% ± 2.12%
Real world connections	-0.24% ± 2.62%	-2.43% ± 2.82%	+5.25% ± 2.03%*
Reasoning	-6.68% ± 2.80%°	-4.41% ± 3.59%	+2.44% ± 2.29%

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References

Anderson, D.L., Fisher, K.M. & Norman, G. J. (2002). Development and evaluation of the Conceptual Inventory of Natural Selection. *Journal of Research in Science Teaching*, 39, 952–978.

De Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science, 340*, 305-308.

De Jong, T. (2006). Computer simulation—

Triona, L., & Klahr, D. (2003). Point and click or grab and heft: Comparing the influence of physical and virtual instructional materials on elementary school students' ability to design experiments. *Cognition and Instruction*, *21*, 149–173.

Welch, W. W., Klopfer, L. E., Aikenhead, G. S., & Robinson, J. T. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education, 65*, 33-50.

Windschitl, M., & Andre, T. (1998). Using computer simulations to enhance conceptual change: The roles of constructivist instruction and student epistemological beliefs. *Journal of Research in Science Teaching, 35*, 145-160.

Winn, W., Stahr, F., Sarason, C., Fruland, R., Oppenheimer, P., & Lee, Y-L. (2006). Learning oceanography from a computer simulation compared with direct experience at sea. *Journal of Research in Science Teaching*, *43*, 25–42.

Zacharia, Z. C., Olympiou, G., & Papaevripidou, M. (2008). Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. *Journal of Research in Science Teaching*, *45*, 1021-1035.

Zacharia, Z.C. (2007). Comparing and combining real and virtual experimentation: An effort to enhance students' conceptual understanding of electric circuits. *Journal of Computer Assisted Learning, 23,* 120–132.