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Houston, We Have a Problem: Effects of Technical Frustration on Student Learning in Physics Laboratories

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Effects of technical frustration on student learning in laboratories

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Abstract

This study investigates the effect of laboratory work's typical technical difficulties on student learning in the physical science classroom. Certainly the educational strategies of text and lecture are sorely lacking. But do laboratories in physical science frustrate students more than they teach them? To investigate this question, the study involved differentiating instruction for three classes of freshmen, sophomore, junior, and senior students enrolled in an introductory physical science course at a local high school. Two classes participated in a physical DC circuits laboratory, while a third class instead participated in a simulation counterpart - that is, an electronic experimental setup that by design cannot have technical difficulties like poor wire connections or faulty bulbs. Results show that the simulation laboratory had a more significant impact on students' posttest responses, though not always for the better. These results are enlightened by observations of student interaction with each laboratory activity.

Method

In order to study the differences in student learning between a physical laboratory setup and a virtual counterpart, two laboratories were written. The concepts and questions posed as a guide in each laboratory were identical. The procedural guidelines were differentiated appropriately for a physical setup versus the simulation, and an effort was made to keep the vocabulary, wording, and conceptual nature of the tasks the same while the actual procedure differed.

The research instrument consisted dually of classroom observations and a portion of The Electric Circuits Concept Evaluation (ECCE) administered to students before and after participation in the laboratory. The ECCE is a multiple choice test, and the questions administered address concepts of current, voltage, and resistance explored in both laboratory setups. Since the study is concerned with student frustration with technical difficulties in the laboratory, the classroom observations were made while students interacted with both laboratories to provide insight.

Results

Classroom Observations of Student Work

Physical	Virtual
Faced with faulty connections between batteries and from wires to bulbs, students first responded by asking the teacher for solutions to the issues. If encouraged to solve the problem themselves, seeing that the final "answers" were simple, students sought solutions from other groups.	Faced with slow computers, students responded by looking to peers whose computers were working quickly to keep from falling behind. No technical difficulties as far as the construction procedure were observed.
All students finished in the allotted time, which is unusual for this group of individuals. Some were finished in half the allotted time.	All students finished in the allotted time, though most utilized the majority of the period.
Step-by-step instructions, which were intended to make the lab as technically fool proof as a typical laboratory, appeared TOO easy – this *decreased* the critical thought required to complete the lab.	Instructions required that students build each circuit piece by piece, which appeared more involved in comparison to clipping a battery to a set of bulbs as in the physical lab.
While a few of the lab questions required critical thought, the laboratory procedure did not. A number of students described the lab as "easy".	In addition to the same thoughtful lab questions, the virtual procedure required more thought in constructing the circuits.

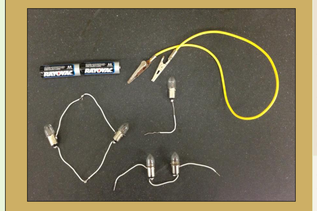


Figure 1. Components of the physical setup, including batteries, alligator clips, and a single bulb in addition to bulbs wired in both parallel and series.

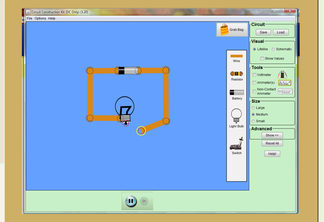


Figure 2. A screenshot of the virtual circuit construction laboratory setup by the PHET group at CU-Boulder. Circuit components such as wires and bulbs are manipulated individually.

Figure 3. (below) Percent of students for both labs answering each item on the ECCE correctly. The red outline indicates items for which the mode of instruction made a significant difference in students' posttest responses.

Pretest and Posttest Assessment Results

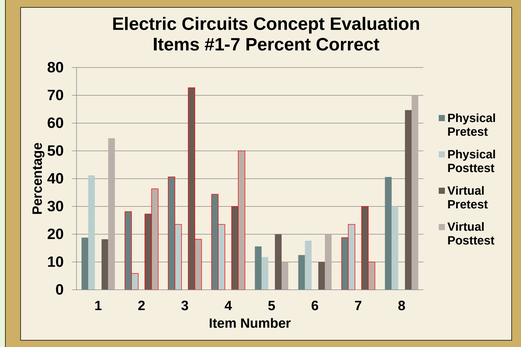
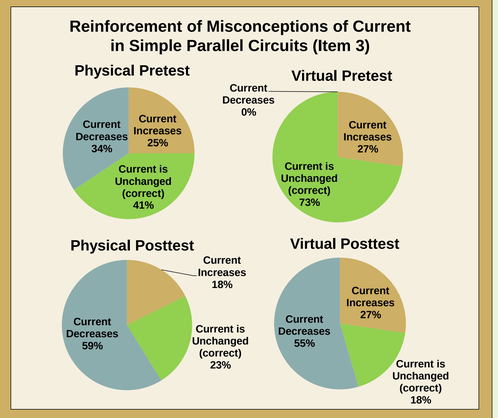
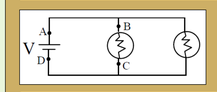
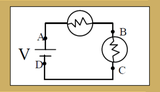


Figure 4. (right) Pretest and posttest responses to item 3, which asks students to characterize the change in the current through a bulb when a second bulb is wired in parallel with it. Both the physical and virtual labs appear to have reinforced the misconception that current decreases in this situation, with a significant number of virtual lab students moving to this from the correct response.





Figures 7 & 8. (left & right) ECCE parallel and series circuit illustrations



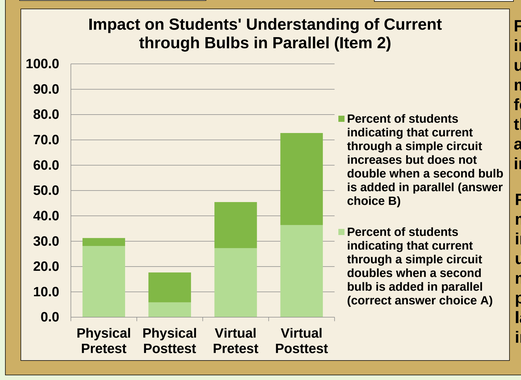
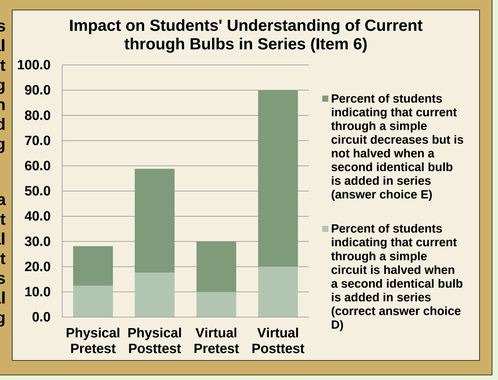


Figure 5. (left) Shows improvement in conceptual understanding though not mathematical understanding for students participating in the virtual lab over and above students participating in the physical lab.

Figure 6. (right) Shows a more significant improvement in conceptual understanding though not mathematical for students participating in the virtual lab than those participating in the physical lab.



Conclusions

- **Students who participated in the simulation showed a more significant difference between pretest and posttest answer choices across all concepts tested.**
- **Though designed to cut out the technical difficulties of actual batteries and bulbs, the simulation ultimately required more thoughtful student input than the physical laboratory setup.**
- **Though subject to some more technical difficulties, the physical setup minimized the student mental effort to a fault. Some students even self-identified it as "the easiest lab ever".**
- **There appears to be a positive correlation between appropriate levels of mental effort on the part of the student and concept attainment as measured by the assessment.**
- **Instead of investigating how too much intellectual frustration may hamper student learning, I believe I have inadvertently investigated how *not enough* intellectual frustration may have the same result.**
- **These conclusions are significant for teachers in that "easy" labs don't mean "easy" learning.**
- **They are also significant for students as they struggle with laboratories, realizing that struggling in a laboratory may provide evidence of critical thought and a foundation for learning.**

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