How to Get Real: The Authenticity of Computer-Based Science Labs

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Background

Students often engage in hands-on activities in the science classroom. However, experimental equipment is not always available, whether due to equipment cost or practical constraints. Fortunately, advances in technology have lead to the development of simulations and remote online labs as viable alternatives to hands-on science labs. These technologies are designed to emulate lab experiences and provide students access to equipment they may not normally have in the real world, all through a computer interface. Simulations allow students to use virtual equipment in order to perform an artificial experiment. Remote labs, like genuine hands-on science labs, allow students to use actual equipment to perform an experiment; however, this equipment is accessed over the Internet. But what are the affordances of each modality of doing a lab and what are the implications of these for optimizing the design of the experience for student learning?

The purpose of the current project is to compare perceived authenticity and learning outcomes across simulations and remote labs, as well as to see how the realism of the visualizations used to represent each lab enhances its authenticity.

Findings

In-person labs, remote labs, and simulations differ in ways that may influence the overall learning experience. Previous work has demonstrated differences across lab types in terms of students' perceptions of lab objectives (Lindsay & Good, 2004; 2005), motivations (Scanlon, et al. 2004), and some learning outcomes (Lindsay & Good, 2005; Corter, et al. 2007). For example, Lindsay and Good (2005) presented mechanical engineering students with a standard hands-on lab, a remote lab, or a simulation. In terms of learning outcomes, students in both the remote and hands-on conditions displayed a better grasp of the context of the lab than those who did the simulation, showing an impact of access to the device (whether proximal or remote) on learning. Students also varied in their perceptions of the lab objectives across conditions; students who used the simulation were more likely to believe that the lab emphasized theory and students who used the remote lab were more likely to believe that the lab emphasized hardware. Taken together, these findings suggest that remote labs may more closely recreate the real hands-on experience than do simulations. Although both the simulation and remote lab use the same computer interface, those who use the remote lab concentrate more on the device, just as a student would do in a real, hands-on lab. …

Our investigation was conducted with 122 undergraduate students at Northwestern University, engaged in an activity designed to teach physics content. For both the remote and simulation labs, participants were asked to read descriptions of basic principles of radioactivity (e.g., what is radiation, what is decay, how is it measured). Next, participants were guided through an experience with a tool designed to measure radiation from a sample of Strontium-90. Participants manipulated variables (e.g., distance from Strontium-90 sample; time to record observations) that allowed them to collect readings of radioactive decay (and to potentially learn about the inverse square law). The interfaces for the remote and simulated labs were identical, with the main difference between them being the source of the data.

In the remote lab condition, participants submitted their experimental specifications to a Geiger counter in Australia, which then proceeded to run the experiment in real time. Participants received their data back from that run of the Geiger counter. Participants either viewed a photo of the equipment on the screen or a live webcam of the equipment performing the experiment. In the simulated lab condition, participants used an identical web interface with participants receiving simulated data based on computational models of radioactive decay from a Strontium-90 sample. Participants either viewed a photo of the equipment on the screen or a recording of a live webcam of the equipment. The simulated data included randomized error to emulate the sampling error seen in real data. For both conditions, participants wrote reflective responses throughout the lab in a journal and answered interview questions afterwards. The remote lab elicited a higher degree of authenticity, in that more remote users felt as though they did a real experiment. Students who used a remote lab were more likely to feel as though they did a real experiment than those who did a simulation, $F(1, 115) = 4.277$, $p < .05$. There was not a main effect for the type of visualization $F(1, 115) = 1.344$, p = N.S. However, there was an interaction of lab type by visualization, $F(1, 115) = 4.277$, $p < .05$. Simulation users who saw the video were more likely to feel as though they did a real experiment than simulation users who just saw a photo.

When asked whether the lab felt like an experiment, one remote user replied, "Yeah, even though I wasn't physically working the machine, I'm still running trials, setting up my variables, getting data back that I can interpret so to me that is still conducting an experiment." This response captures two themes of authenticity: the experiment followed the scientific method, and the data source was real. Simulation users also mentioned use of the scientific method as a reason for the lab feeling like an experiment: "I utilized the scientific method to come up with a hypothesis to try to prove or disprove it so I feel like that's what an experiment is." The lack of a real data source was a problem for some simulation users and it made the lab feel less like an experiment: "sort of, it is not like a[n experiment] well I guess it is, but I didn't have a Geiger counter and I wasn't using real equipment." However, the video allowed simulation users to feel better about their experience: "The video was useful... It helps make it seem more realistic if you can see a video of the actual machine. It's a contextualization."

Overall, the majority in both labs would prefer to do the remote lab over simulation, especially those who have already completed the remote lab, $\chi2$ (1, N = 110) = 14.057, $p < .01$. Very few remote lab users would want to do the simulation instead. …

Most students in both conditions demonstrated improved content knowledge after completing the lab. However, there are a few effects of lab type and visualization on learning, especially regarding content questions related to lab use. Students were better able to explain how radioactivity is measured after completing the lab regardless of condition, $F(1, 116) = 105.67$, $p < .001$.

Summary

Our results indicate that improving the realism of a computer-based lab, either by utilizing actual equipment (such as with the remote lab) or incorporating more realistic visualizations, can improve the authenticity of the experience as well as learning outcomes. Students thought that the remote lab experience felt more like a real experiment and would prefer to do a remote lab over a simulation. However, our visualization results show that improving the realism of the visualization can improve the authenticity for simulation users. These results have implications for educators as well as designers, who can implement them to improve virtual learning experiences in the science classroom.

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