Research reveals 'shocking' weakness of lab courses

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With the new emphasis on hands-on, active learning throughout higher education, lab courses would seem to have an advantage - what could be more active than doing experiments? But surprising new research reveals traditional labs fall far short of their pedagogical goals.

In a paper published Jan. 2 in *Physics Today*, "Introductory Physics Labs: We Can Do Better," Natasha Holmes, Cornell assistant professor of physics, and Nobel laureate Carl Wieman of Stanford University report on their analysis of nine introductory physics laboratory courses at three institutions, taught by seven instructors and involving almost 3,000 students. The labs were all designed to support student learning of the associated lecture course content. Because the lab sections were optional, the researchers could compare outcomes with a control group of students who did not take the lab courses.

The results were so consistent, and so abysmal, that the researchers call it "shocking." They write that "with a high degree of precision, there was no statistically measurable lab benefit. ... None of the mean effects was larger than 2 percent statistically; they were all indistinguishable from zero."

Even when the researchers restricted their analysis to exam questions that didn't require quantitative calculations, but only conceptual reasoning that should have been enhanced in a lab course, they got the same results for the lab benefit: zero.

Lab courses are supposed to enable students to see how physics principles work in real life; conducting experiments should help them understand physics better and reinforce classroom instruction. Why is this not happening?

"Although one may think that labs are inherently active, our research shows that in traditional labs students may be active with their hands but they're not really active with their brains," says Holmes. "Following rote procedures to get a proscribed outcome at the end isn't doing a whole lot."

In extensive interviews with students, Holmes and Wieman write that they found, "the only thinking the students said they did in structured and content-focused labs ... was in analyzing data and checking whether it was feasible to finish the lab in time."

In a typical lab activity, "the relevant equations and principles are laid out in the preamble; students are told what value they should get for a particular measurement or given the equation to predict that value; they are told what data to collect and how to collect them; and often they are even told which buttons to press on the equipment to produce the desired output," write the researchers.

Students in traditional labs, therefore, don't need to think about physics content but only how to correctly follow the instructions. But, write Holmes and Wieman, "overcoming obstacles and learning from failure are vital skills for every experimental scientist... Also important [is] having the time both to reflect on those decisions and their outcomes and to fix and improve the experiments iteratively."

The innovative lab design that Holmes and Wieman offer as one alternative in their paper - structured quantitative inquiry labs (SQILabs) - emphasize iterative experimentation, decision-making and developing quantitative critical thinking skills. While SQILab activities give students a limited and realistic goal, the students decide how to conduct the experiment and interpret the data. They have the opportunity to troubleshoot, revise and test models, and try new things.

The researchers found that SQILab activities are more enjoyable for students and decrease their sense of frustration when things don't go as planned. The students were also less likely to manipulate the data for a desired result.

"Rather than being seen by students as pointless and frustrating hoops that have to be jumped through, introductory physics labs can instead offer rewarding intellectual experiences," conclude Holmes and Wieman.

Provided by Cornell University

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