Self-directed, iterative learning dramatically improves critical thinking in STEM classes

August 17 2015

Larkmead School. Credit: CC-BY-SA-2.5,2.0,1.0

A self-directed, iterative learning framework used in a first-year physics lab dramatically improved students' critical thinking skills, according to new University of British Columbia (UBC) research.

The framework asks students to compare their experimental data to other students' data or to simplified models, think critically, and then rework the science—on their own.

"In a traditional lab, a student conducts an experiment as instructed and writes it up, often chalking up discrepancies or issues to human error or

lousy equipment—then they move on to the next concept," says researcher Natasha Holmes, who oversaw the revamped lab at UBC and is lead author of a *Proceedings of the National Academy of Sciences* study measuring its impact.

"Our framework designs the class more like a research program where scientists have to make decisions about data and uncertainty. It's more about ingraining the iterative scientific process than any single result."

According to the PNAS study, students (N 130) using the iterative approach to experimentation were 12 times more likely to propose or carry out improvements to their data or methods than a control-group in a traditional version of the lab.

They were four times more likely to identify and explain a limitation of an underlying scientific model using their data.

"The exciting thing is that giving the students the guided autonomy to decide how to follow up on a result ingrains critical thinking long term," says UBC physicist Doug Bonn, author on the PNAS paper.

"The improvements persisted when the students were no longer prompted to take the iterative approach, and even as they moved into a more traditional lab course the following year."

The pilot studies testing the impact of this structure, funded by UBC's Carl Wieman Science Education Initiative, were conducted from 2012 to 2014 and further improvements are being tested this September. In January 2016, UBC will roll out the new lab formally to a much larger group of students in a new course, Physics 119.

The pendulum example

As they worked through simple physics experiments, 130 first-year students in the new lab course were asked to do more than 'write up' their results.

They were given explicit instructions to compare data from their experiment to existing models, or to a fellow student's results, and then decide how to act on the comparisons.

For example, when comparing the period of a pendulum swing at various angles, students are given the autonomy and time to conduct more measurements to improve the quality of their data.

Eventually, the higher quality data exposes the limitations and assumptions of an established formula—often surprising the student. This builds confidence in their ability to then explore why the simple model failed.

More information: "Teaching critical thinking," by N.G. Holmes et al. *Proceedings of the National Academy of Sciences* August 18, 2015 ; 112 (33) www.pnas.org/cgi/doi/10.1073/pnas.1505329112

Provided by University of British Columbia