STEM students who learn by example may miss key concepts, study finds

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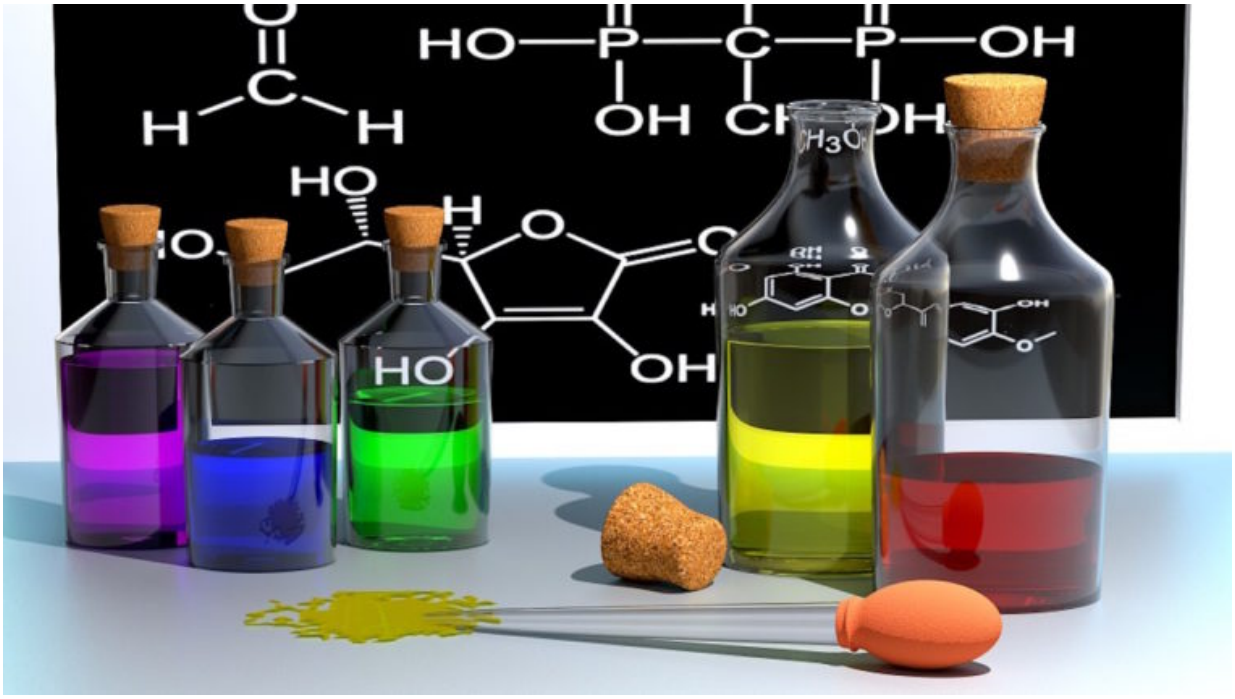

Credit: Washington University in St. Louis

No matter how smart, well-prepared or hard-working, many college students struggle with rigorous introductory science courses because their approach to learning fails to provide a working knowledge of abstract concepts that underlie examples presented in the classroom, suggests new research from Washington University in St. Louis.

"Our results find that individual differences in how learners acquire and represent concepts is a potentially crucial factor in explaining the success or failure of college students learning complex concepts in introductory chemistry courses," said study co-author Regina F. Frey, the Florence E. Moog Professor of STEM Education in Arts & Sciences.

The findings, published online May 12 in the *Journal of Chemical Education*, are important because they may help to explain why so many aspiring students make an early exit from science, technology, engineering and math (STEM) programs after failing to perform well in tough introductory science courses.

In this study, which included more than 800 students taking chemistry courses over three semesters at a highly competitive research university, about 50 percent of those tested were classified as having difficulty making the leap from example to concept. And that was true of students with similar educational backgrounds and equally high marks in advance placement courses and college entrance exams.

"Every instructor nods when you say students seem to do well when tests present concepts the same way they were addressed in class or in homework, but flounder when the test presents these same concepts in a different context ," said study co-author Mark McDaniel, a professor of Psychological and Brain Sciences at Washington University. "If nothing else, this study should provide teachers with a better understanding of why some of their students may be floundering when it comes to applying a studied concept to a novel situation."

Frey and McDaniel are co-directors of the Center for Integrative Research on Cognition, Learning, and Education (CIRCLE) at Washington University, where they explore how new innovations from learning and memory research can be used to improve classroom education.

Much of their current research focuses on improving student performance in introductory science courses where a primary goal is ensuring that students can use basic concepts to explore problems in new and unknown contexts.

This study suggests there are real and identifiable cognitive differences in how individuals go about building a conceptual framework to explain what's happening in complex scientific scenarios. Understanding those differences and finding ways to deal with them early may be critical to success in science because advanced work requires students to be creative problem solvers, they argue.

The study used a computerized learning assessment to gauge how well students are able to grasp abstract concepts presented as part of a fictional NASA science assignment. The task required learning the functional relation between two new elements associated with a new organism discovered on Mars. The students were asked to determine how much of the fictional element Beros the new organism might excrete after absorbing a certain amount of Zebon.

By using a fictional scenario, the researchers eliminated any advantage a particular student might have based on prior education or experience with a real world science problem, ensuring that the ability to build concepts and apply them was a primary driver of performance in the learning assessment.

The assessment, which could be offered online, provides a way for researchers—and potentially teachers and students—to evaluate whether someone has difficulty building a conceptual framework for understanding the interaction between variables in a complex scientific scenario.

Students who are able to make accurate extrapolation predictions based

on the study material were categorized as "abstraction learners." Those who failed to make the leap from the studied examples to the extrapolation test were classified as "exemplar learners."

After the assessment, researchers tracked the performance of all students as they worked their way through one of three semester-long chemistry courses. Abstraction learners consistently outperformed exemplar learners in all three courses. These performance differences grew even more pronounced among students taking the higher level course, Organic Chemistry 2.

"Abstraction learners demonstrated advantages over exemplar learners even after taking into account preparation via ACT scores and prior chemistry performance." Frey said. "Our results suggest that individual differences in how learners acquire and represent concepts persist from laboratory concept learning to learning complex concepts in introductory chemistry courses."

More information: Li Ye et al. Examining the Impact of Chemistry Education Research Articles from 2007 through 2013 by Citation Counts, *Journal of Chemical Education* (2015). DOI: 10.1021/ed5007635

Provided by Washington University in St. Louis

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