Study: Learning Science Facts Doesn't Boost Science Reasoning

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(PhysOrg.com) -- A study of college freshmen in the United States and in China found that Chinese students know more science facts than their American counterparts -- but both groups are nearly identical when it comes to their ability to do scientific reasoning.

Neither group is especially skilled at reasoning, however, and the study suggests that educators must go beyond teaching science facts if they hope to boost students' reasoning ability.

Researchers tested nearly 6,000 students majoring in science and engineering at seven universities -- four in the United States and three in China. Chinese students greatly outperformed American students on factual knowledge of physics -- averaging 90 percent on one test, versus the American students' 50 percent, for example.

But in a test of science reasoning, both groups averaged around 75 percent -- not a very high score, especially for students hoping to major in science or engineering.

The research appears in the January 30, 2009 issue of the journal *Science*.

Lei Bao, associate professor of physics at Ohio State University and lead author of the study, said that the finding defies conventional wisdom, which holds that teaching science facts will improve students' reasoning ability.

"Our study shows that, contrary to what many people would expect, even when students are rigorously taught the facts, they don't necessarily develop the reasoning skills they need to succeed," Bao said. "Because students need both knowledge and reasoning, we need to explore teaching methods that target both."

Bao directs Ohio State's Physics Education Research Group, which is developing new strategies for teaching science, technology, engineering and mathematics (STEM) disciplines. For this study, he and his colleagues across the United States and in China decided to compare students from both countries, because the educational systems are so different.

In the United States, only one-third of students take a year-long physics course before they graduate from high school. The rest only study physics within general science courses. Curricula vary widely from school to school, and students can choose among elective courses.

In China, however, every student in every school follows exactly the same curriculum, which includes five years of continuous physics classes from grades 8 through 12. All students must perform well on a national exam if they hope to enter college, and the exam contains advanced physics problems.

"Each system has its strengths and weaknesses," Bao said. "In China, schools emphasize a very extensive learning of STEM content knowledge, while in the United States, science courses are more flexible, with simpler content but with a high emphasis on scientific methods. We need to think of a new strategy, perhaps one that blends the best of both worlds."

The students who participated in the study were all incoming freshmen who had just enrolled in a calculus-based introductory physics course.

They took three multiple-choice tests: two which tested knowledge of physics concepts, and one which tested scientific reasoning.

The first test, the Force Concept Inventory, measures students' basic knowledge of mechanics -- the action of forces on objects. Most Chinese students scored close to 90 percent, while the American scores varied widely from 25-75 percent, with an average of 50.

The second test, the Brief Electricity and Magnetism Assessment, measures students' understanding of electric forces, circuits, and magnetism, which are often considered to be more abstract concepts and more difficult to learn than mechanics. Here Chinese students averaged close to 70 percent while American students averaged around 25 percent -- a little better than if they had simply picked their multiple-choice answers randomly.

The third test, the Lawson Classroom Test of Scientific Reasoning, measures science skills beyond the facts. Students are asked to evaluate scientific hypotheses, and reason out solutions using skills such as proportional reasoning, control of variables, probability reasoning, correlation reasoning, and hypothetical-deductive reasoning. Both American and Chinese students averaged a 75 percent score.

Bao explained that STEM students need to excel at scientific reasoning in order to handle open-ended real-world tasks in their future careers in science and engineering.

Ohio State graduate student and study co-author Jing Han echoed that sentiment. "To do my own research, I need to be able to plan what I'm going to investigate and how to do it. I can't just ask my professor or look up the answer in a book," she said.

"These skills are especially important today, when we are determined to

build a society with a sustainable edge in science and technology in a fast-evolving global environment," Bao said.

He quickly added that reasoning is a good skill for everyone to possess -- not just scientists and engineers.

"The general public also needs good reasoning skills in order to correctly interpret scientific findings and think rationally," he said.

How to boost scientific reasoning? Bao points to inquiry-based learning, where students work in groups, question teachers and design their own investigations. This teaching technique is growing in popularity worldwide.

Ohio State is exploring inquiry-based learning in its physics classes. Here students use hand-held electronic devices called clickers to answer multiple-choice questions during lectures. They work together to answer questions, and professors use the clicker interaction to guide student learning towards a more investigative style. The department is also adopting an inquiry-based curriculum for undergraduate physics courses.

Provided by Ohio State University