Concrete examples don't help students learn math, study finds

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A new study challenges the common practice in many classrooms of teaching mathematical concepts by using "real-world," concrete examples. Researchers led by Jennifer Kaminski, researcher scientist at Ohio State University's Center for Cognitive Science, found that college students who learned a mathematical concept with concrete examples couldn't apply that knowledge to new situations.

But when students first learned the concept with abstract symbols, they were much more likely to transfer that knowledge, according to the study published in the April 25 issue of the journal *Science*.

"These findings cast doubt on a long-standing belief in education," said Vladimir Sloutsky, co-author of the study and professor of psychology and human development and the director of the Center for Cognitive Science at Ohio State.

"The belief in using concrete examples is very deeply ingrained, and hasn't been questioned or tested."

Kaminski and Sloutsky conducted the study with Andrew Heckler, assistant professor of physics at Ohio State.

Teachers often use real-world examples in math class, the researchers said. In some classrooms, for example, teachers may explain probability by pulling a marble out of a bag of red and blue marbles and determining how likely it will be one color or the other.

But students may learn better if teachers explain the concept as the probability of choosing one of n things from a larger set of m things, Kaminski said.

The issue can also be seen in the story problems that math students are often given, she explained. For example, there is the classic problem of two trains that leave different cities heading toward each other at different speeds. Students are asked to figure out when the two trains will meet.

“The danger with teaching using this example is that many students only learn how to solve the problem with the trains,” Kaminski said.

“If students are later given a problem using the same mathematical principles, but about rising water levels instead of trains, that knowledge just doesn’t seem to transfer,” she said.

“It is very difficult to extract mathematical principles from story problems,” Sloutsky added. “Story problems could be an incredible instrument for testing what was learned. But they are bad instruments for teaching.”

In the research presented in Science, the researchers did several separate experiments that examined how well undergraduate students learned a simple mathematical concept under different conditions. The concept involved basic mathematical properties such as commutativity and associativity – the fact that you can change the order of elements without changing the results. For instance, 3+2 and 2+3 both equal 5.

In the various experiments, some students learned these principles using generic symbols, in which combinations of two or more symbols resulted in a predictable resulting symbol.

Others were presented with one or more concrete examples that involved this same concept. In one concrete example, students viewed three images of measuring cups with varying levels of liquid. Participants were told they needed to determine the remaining amount when different cups of liquid were combined.

Two other concrete examples were used in various experiments – one involving how many slices of pizza in a pizza pie were overcooked, and one involving how many tennis balls were in a container.

After learning this math concept using the concrete examples or abstract, generic symbols, the students took a multiple-choice quiz demonstrating that they learned the principles involved. And in all cases, the study showed that most undergraduate students picked up the knowledge easily.

However, the true test came later when the researchers asked these students to apply the same principles in a totally different setting, which was described to them as a children's game from another country. The rules of this game followed the principles which they had just learned. The researchers calculated how well the participants did on a multiple choice test involving the rules of that children's game.

In the first experiment, involving 80 students, some participants were given one concrete example before testing on the children's game, while some were given two or three examples. One group only learned the generic symbols.

When tested on the children's game, the group that learned the generic symbols got nearly 80 percent of the questions right. Those who learned one, two or even three concrete examples did no better than chance in selecting the right answers.

“They were just guessing,” Kaminski said.

In a second experiment, the researchers gave 20 participants two concrete examples and explained how they were alike. Surprisingly, this still did not help students apply the concept any better and they still did no better than chance when tested later about the game.

In a third experiment, the researchers presented 20 students with two concrete examples and then asked them to compare the two examples and write down any similarities they saw. After this experiment, about 44 percent of the students performed well on the test concerning the children’s game, while the remainder still did not perform better than chance.

This suggests that only some students, not all, benefit from direct comparison of learned concrete examples.

Finally, in a fourth experiment involving 40 students, some learned the concrete example first followed by the generic symbols, while others learned only the generic symbols. The thought here was that the concrete example would engage the students in the learning process while the generic symbols would promote transfer of that knowledge.

But even in this experiment, students who learned only the generic symbols performed better on subsequent testing than those who learned the concept using the concrete example and then the generic symbols.

The authors said that students seem to learn concepts quickly when they are presented with familiar real objects such as marbles or containers of liquid, and so it is easy to see why many advocate this approach. “But it turns out there is no true insight there. They can’t move beyond these real objects to apply that knowledge,” said Sloutsky.

The problem may be that extraneous information about marbles or containers might divert attention from the real mathematics behind it all, according to Kaminski.

“We really need to strip these concepts down to very symbolic representations such as variables and numbers,” she said. “Then students are better prepared to apply those concepts in a variety of situations.

The authors said they doubt this paper will end the debate over approaches to teaching mathematics, but they hope it will generate interest into systematic examination of which ways of teaching mathematics are most effective.

Source: Ohio State University

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