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Is memorisation a good strategy for learning mathematics?

- Fewer 15-year-olds in East Asian countries reported that they use memorisation than did 15-year-olds in some of the English-speaking countries to whom they are often compared.
- In no PISA-participating education system did boys report more intensive use of memorisation than girls when learning mathematics.
- Memorisation as a learning strategy may work with easy problems, but it is unlikely to be effective if it is the only strategy used when confronted with complex mathematics problems.

The area of a circle is pi *times radius squared. The square of the hypotenuse is equal to the sum of the squares of the other two sides.* Do you remember how you learned those formulae? By understanding what they mean and applying them to a lot of different maths problems set in a lot of different contexts? Or by learning them by heart and applying them to a lot of similar maths problems? Sooner or later, the method matters. Students who avoid making an effort to understand mathematics concepts may succeed in some school environments; but a lack of deep, critical and creative thinking may seriously penalise these students later in life when confronted with real, non-routine problems. No surprise, then, that many education systems around the world are discussing what role memorisation strategies, such as learning by heart, rehearsing and drilling, should play in the learning process. Take, for example, the ongoing debate in England over multiplication tables. Some there argue that having children memorise multiplication tables by the age of 9, as the National Curriculum prescribes, is a move in the wrong direction, while others maintain it will help children get the basics right.

Which students use memorisation the most? The answer might surprise you.

PISA wanted to find out how students learn mathematics. A questionnaire distributed among participating students asked which learning strategy, out of a possible three options, best described their approach to mathematics. One of these statements always corresponded to a memorisation strategy, such as "learning by heart", "recalling work already done" or "going through examples again and again". An index of memorisation was constructed by adding the number of times a student chose a memorisation strategy. The index ranges from zero, when the student always selected another learning strategy, such as "connecting ideas" or "working out exactly what is important to learn", to four, when the student always agreed with the memorisation-related statement.

PISA finds that 15-year-olds commonly use memorisation to learn mathematics. But if you think memorisation is most widely used in the East Asian countries that share a Confucian heritage and are "known" for rote learning, think again. Fewer 15-year-olds in Hong Kong-China, Japan, Korea, Macao-China, Shanghai-China, Chinese Taipei and Viet Nam reported that they use memorisation as a learning strategy than did 15-year-olds in some of the English-speaking countries to whom they are often compared. For instance, 5% of students in Viet Nam, 12% of students in Japan and 17% of students in Korea reported that they learn as much as they can by heart when they study for a mathematics test.

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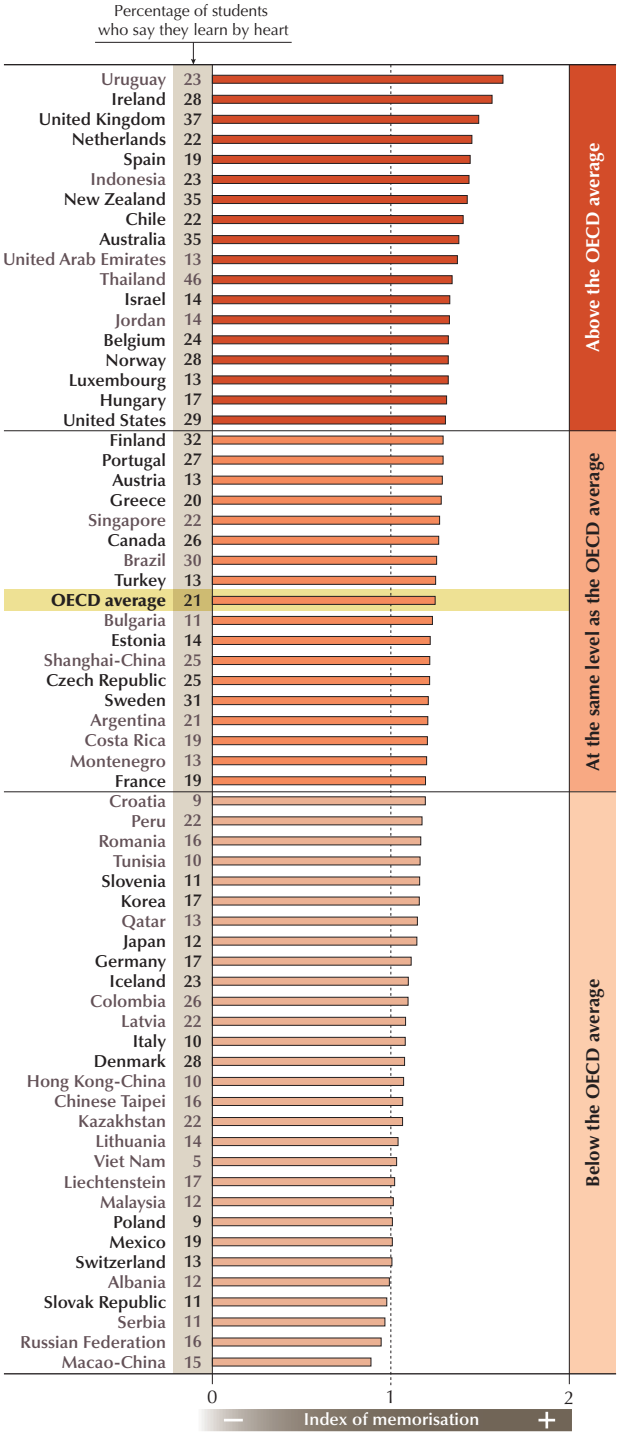
Students' self-reported use of memorisation strategies



Note: The index of memorisation is based on the four questions about learning strategies in the student questionnaire. In each question, students were asked to choose among three mutually exclusive statements corresponding to the following approaches to learning mathematics: memorisation, elaboration and control. A value of four on the index of memorisation means that students always chose a memorisation strategy, such as "learning by heart", "recalling work already done" or "going through examples again and again".

Countries and economies are ranked in descending order of the index of memorisation.

Source: OECD, PISA 2012 Database.

By contrast, 26% of students in Canada, 28% in Ireland, 29% in the United States, 35% in Australia and New Zealand, and 37% in the United Kingdom reported that they mostly memorise to prepare for a mathematics test. Students in Ireland, the Netherlands, Spain, the United Kingdom and Uruguay reported the most frequent use of memorisation strategies, while those in Macao-China, the Russian Federation, Serbia and the Slovak Republic reported the least frequent use.

There are many reasons why students rely on their memory when learning mathematics. Some students who learn by heart, repeat formulae and try to solve only routine problems may avoid intense mental effort, particularly if they are not naturally drawn to mathematics. Others may find it pointless to try to understand mathematics concepts if they have been exposed only to rudimentary and routine problems. Still others might simply believe they are not gifted enough to venture into the realm of conceptual mathematics.

PISA results show that, across OECD countries, perseverant students, students with positive attitudes towards problem solving and mathematics, including high instrumental motivation to learn mathematics, interest in mathematics, high self-efficacy and self-concept, and low mathematics anxiety are less likely to use memorisation strategies. Boys, too, are less likely than girls to use these strategies; in fact, in no education system did boys report more intensive use of memorisation when learning mathematics than girls.

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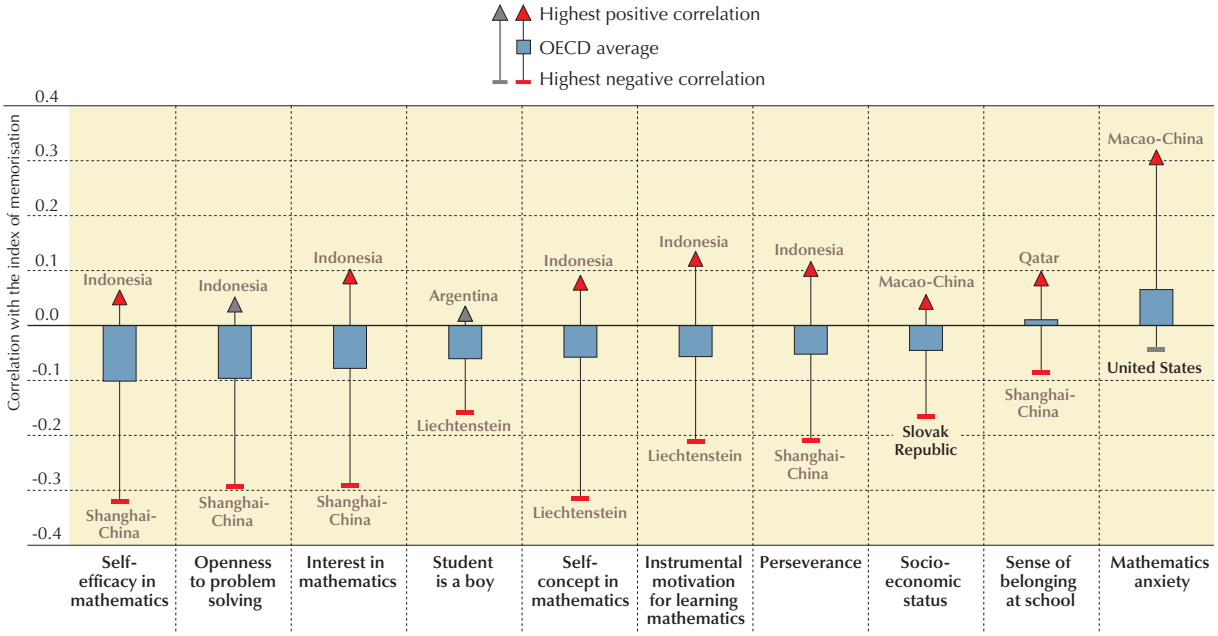
Student characteristics and teacher practices associated with students' use of memorisation strategies



Note: Statistically significant correlation coefficients are indicated in red. All correlation coefficients for the OECD average are statistically significant.
Source: OECD, PISA 2012 Database.

Students who mainly use memorisation strategies can do well on easy questions…

Memorisation is often considered an elementary strategy that is better suited to solving routine mathematics problems that require only a shallow understanding of mathematics concepts. "CHARTS, Question 1", an item from the PISA 2012 assessment that was made public, is one such problem. It asks for a multiple-choice response to a question referring to a simple bar chart.

Some 87% of students across the 48 education systems whose students solved this problem answered this question correctly. It is the easiest of the items that were made public. Students who reported that they use memorisation strategies to learn mathematics had about the same success rate on this easy item as students who reported using other learning strategies. In some school systems, like those in Albania, Lithuania and Slovenia, students who reported using memorisation strategies were even more likely to answer the problem correctly.

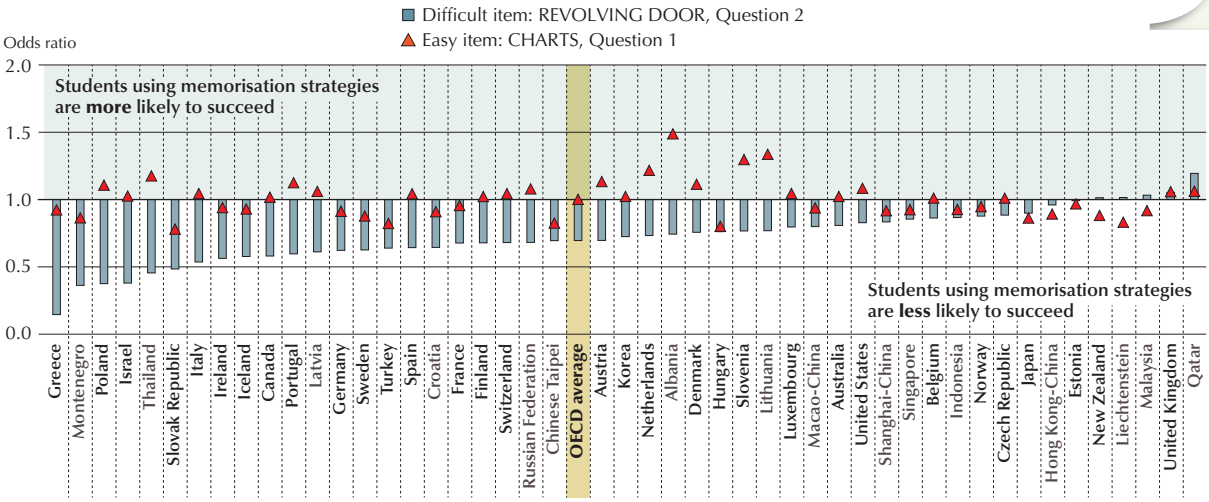
…but complex problems require more than a good memory.

Results look very different for "REVOLVING DOOR, Question 2", the most challenging question from the PISA 2012 mathematics test. "REVOLVING DOOR, Question 2" asks for a constructed, or open-ended, response to a problem that requires substantial geometric reasoning and creativity, involves multiple steps, and draws heavily on students' ability to translate a real situation into a mathematical problem. Only 3% of participants answered this question correctly.

An analysis of PISA results and students' responses to the questionnaire found that for every one-unit increase in the index of memorisation, the chance of answering this question successfully decreased by almost 31% across OECD countries. Students who reported using memorisation the most when they study were four times less likely to solve this problem than students who reported using memorisation the least.

Likelihood of success in solving mathematics problems using memorisation strategies

Use of memorisation vs. *other learning strategies*



How to read this figure: In the Slovak Republic, a one-unit increase in the index of memorisation is associated with a 50% decrease in the probability of success on "REVOLVING DOOR, Question 2".

Note: The 16 countries that opted for the easy booklet are not included in the analyses.

Countries and economies are ranked in ascending order of the odds ratio of success on the item "REVOLVING DOOR, Question 2".

Source: OECD, PISA 2012 Database.

The bottom line: In some situations, memorisation is useful, even necessary. It can give students enough concrete facts on which to reflect; it can limit anxiety by reducing mathematics to a set of simple facts, rules and procedures; and it can help to develop fluency with numbers early in a child's development, before the child is asked to tackle more complex problems. But to perform at the very top, 15-year-olds need to learn mathematics in a more reflective, ambitious and creative way – one that involves exploring alternative ways of finding solutions, making connections, adopting different perspectives and looking for meaning. So yes, you can use your memory, just use it strategically.

For more information

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See "How teachers teach and students learn: Strategies for success at school", *OECD Education Working Papers*, OECD Publishing, Paris.

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