

Are memorizing formulas well and good arithmetic skills essential to become a good theoretical physicist or a good mathematician?

When I took quantum mechanics, a student asked the professor what the relation between \hbar and h was. I could tell the answer right away. It is given by $\hbar = \frac{h}{2\pi}$. I memorized this formula by heart. However, he could not tell the answer right away, but he began to figure it out himself. As $E = hf = \hbar\omega$, and $\omega = 2\pi f$, we have $hf = \hbar(2\pi f)$. So, he concluded $\hbar = \frac{h}{2\pi}$. I was refreshingly surprised. One of the most world-renowned physicists could not tell off the top of his head such a simple formula that I memorized by heart!

This doesn't seem to be an isolated case. In his memoir, the Breakthrough prize winner, late string theorist Polchinski wrote¹

Indeed, I have always felt that I did not have an especially good memory. In one of my first classes in college, the instructor told us that you do not need a good memory to do physics because you can derive everything from first principles.

It seems that many physics professors share this view. Many physics professors whose classes I took gave us chances to bring "cheat sheet" on which we could write physics formulas for the final exams; not only would it give an opportunity to review what we have learned by writing out important formulas, but also it would free us from memorizing too complicated formulas. Some of them even allowed to bring class notes or textbooks. I cannot imagine that would happen for a history class or a foreign language class. It seems that memory plays less important roles in physics than in history or in foreign languages.

Memorizing formulas well is not the only skill that is not essential to become a good theoretical physicist.

Mandelbrot, a renowned mathematician, who received the Wolf Prize for physics (the most renowned physics prize after the Nobel Prize and the Breakthrough Prize) admitted that he had a hard time multiplying as he had never learned multiplication table.

This is not the only isolated case. Poincaré, a very-renowned mathematician in the 19th and 20th century, wrote in his book "Science and method" that Gauss (a very-renowned mathematician in the 18th and 19th century) had been very good at calculation, but there were exceptions to this rule that mathematicians must be good at calculation. Then, he went on to say that he cannot call them exceptions because "the exceptions would be more

¹Memories of a Theoretical Physicist, arxiv.org/abs/1708.09093

numerous than the cases of conformity with the rule.” He wrote, “on the contrary, it was Gauss who was an exception.” Then, he went on to say, as for himself, he was “absolutely incapable of doing an addition sum without a mistake.”

In a Korean book, I read about an experiment conducted by an education researcher. A boy was very good at arithmetics. I cannot remember his grade exactly, but he was either a pre-schooler or in the 1st or 2nd grade. He was much better at arithmetics than his elder sister two or three years older. The education researcher showed him a set of many pencils. She spread them out on a table so that they can occupy a certain area. She asked the boy how many pencils were there. The boy counted them and answered correctly. Then, she removed some of them in front of him and widened the distance between the pencils so that they could occupy the same area as before. Then, she asked the boy again how many pencils were there. He answered the same answer as before, believing that there was still the same number of pencils. So, the education researcher asked him to count them again. There was less number of pencils! The boy was confused. The boy’s sister who was worse at arithmetics than him was present and clucked her tongue as she was watching her little brother. I am sure that she would be a better mathematician than him, even though she is worse at arithmetics.

Memorizing formulas well and good arithmetic ability are not essential skills to become a good theoretical physicist or good mathematicians. I am sorry that Korean college entrance physics and math exams do not provide formulas on the exam sheet; Korean students are required to memorize them by themselves. While there are formulas that one must memorize to become a competent mathematician or physicist, most of the formulas that Korean students are required to memorize are kind of the ones that are enough to look up on the Internet, when they need them.

Moreover, I believe that too much emphasis is placed on complicated arithmetics for the Korean elementary school students, even though on positive sides, there are much fewer Koreans who cannot properly do very basic arithmetics than people in other countries. For example, I read that an Indian professor in the United States had been surprised, because one of his university engineering student divided by 10, using long hand division, and answered that the original number and the answer were the same. On another occasion, one of his students tried to use a calculator to figure out the half of $2\frac{1}{2}$, but he failed, so he calculated by hand himself, and obtained $1\frac{1}{2}$. Even though I do believe that everybody needs to perform very basic arithmetics, such as the first American engineering student failed to do, and have a good understanding of fractions and decimal numbers, they should not be required to perform complicated arithmetics - such as multiplication of a three digit number and a two digit number - without mistakes, which are required for the 4th graders in South Korea.

I am very sorry that many young Korean students believe that they can’t be good mathematicians because they are not good at arithmetics. A renowned Korean mathematician wrote that his teacher when he was a student noted in his report card that he would not succeed if he sought a career in mathematics, but his future was bright because he was good at other subjects.

You should never be discouraged of your dream to become a good mathematician or a good theoretical physicist, *simply* because you are not good at arithmetics. Korean education should also put less emphasis on drills of *complicated* arithmetics.