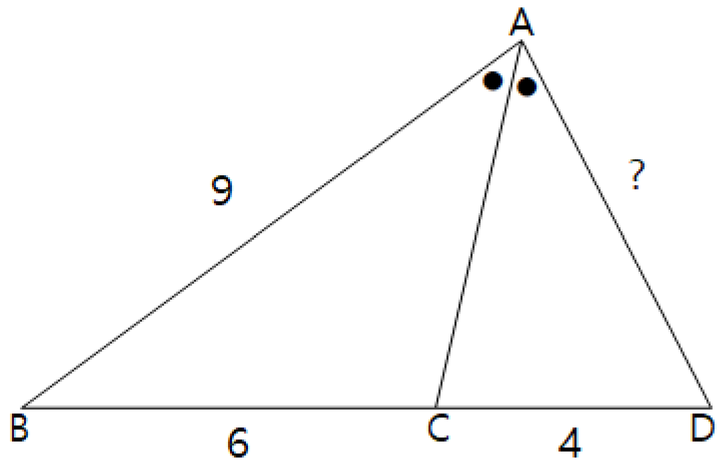
Is math and science homework mechanical drudgery?

It seems that at least some people think that math and science homework is mechanical drudgery devoid of creativity and imagination. They think that you just need to apply formulas, calculate things in prescribed ways, and get answers. In contrast, when you write a paper for your humanities class, you need to be creative and imaginative since there is neither unique answer nor prescribed way of solving the problems. They say that math and science homework is like cooking just by following a cookbook. You just cook dishes as prescribed by the cookbook.

They may be right, but only as far as THEIR math and science courses are concerned, i.e. low-level math and science courses such as those for high school students and college freshmen. I guess that I don't think that this cookbook method of solving problems works for higher-level courses or high school Math and Science Olympiad questions; you have to think hard and understand the problems before delving into them. You may, in most cases, need to tackle the problems in many different ways before finding out the right one that leads to the correct solution.

I was lucky enough to learn at an early age that math and science problem solving is not mechanical drudgery. I feel that it is somewhat unfortunate that those claim that it is merely mechanical drudgery haven't had the chance to learn that it is not.

Consider the following 9th grade level Korean mathematics problem.



If the angle BAC and the angle DAC are same, and the length of each side is as indicated, what is the length of AD? Unless you find a clever “trick” to solve this problem, it is very hard to get the answer. (The answer is at the end of this essay.) You need to have creativity to find such a trick.

Japanese Fields Medalist Heisuke Hironaka wrote in “The Joy of Study” that he used to spend a lot of time solving difficult geometry problems when he was young. In the book, he showed one of them which took him a week to figure out. Even though he provided a hint, I couldn’t solve it. He recalled that times spent on solving such problems were helpful later when he performed real mathematical research.

Perhaps the way math and science are taught is wrong. We should encourage imagination in our teaching, if not creativity.

In 2009, I attended a talk about physics education by Professor Mazur at Harvard University. He noted that he used to think that he was a good teacher, since he always received very high grades on the students' evaluations of his course.

However, he realized that this was a misperception. There is a multiple-choice type test called the FCI, which consists of about 30 questions that deal with Newtonian mechanics. This test focuses more on concepts than on problem solving skills. He had his students take this test before and after they took his course and compared them. Surprisingly, he found out that there was not much difference in their performance before and after the course.

Then he said that the conventional physics problems checked only whether students are able to use physics formulas to plug in appropriate variables, rather than whether they actually understood the concepts.

As an example, he showed that students could easily solve electric circuit problems by using Kirchhoff's laws but failed to solve other electric circuit problems that focused more on concepts. The conceptual problems should be easier once students understand the concept, since no algebra or formulas are needed. About half of the students got 0 or 2 points out of 10 on the conceptual problems.

Then, he presented his remedy to this problem; he proposed a new teaching method that can enhance students' understanding of concepts. If you are interested in this pedagogy, which he used with successful results, please check my journal entry on September 28th, 2009.

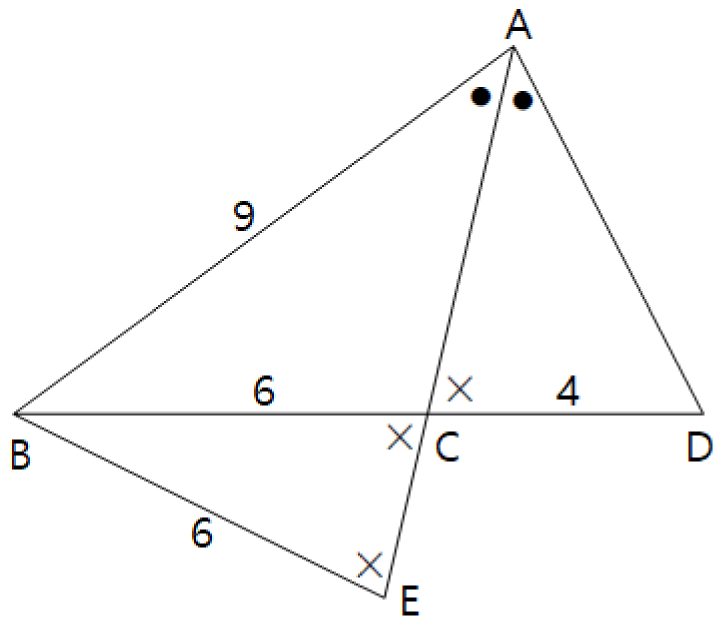
Anyhow, I think he is right. It's much more important to learn the concepts than to learn how to use physics formulas without thinking. I also think that standardized tests such as the SAT should ask such questions, even though it may turn out to be too hard to make enough problems.

Like homework, actual math and science research are not mechanical drudgery but requires tricks, new concepts and critical thinking. In a long answer to an internet question "What is it like to understand advanced mathematics? Does it feel analogous to having mastery of another language like in programming or linguistics?" "Anonymous" wrote "To me, the biggest misconception that non-mathematicians have about how mathematicians work is that there is some mysterious mental faculty that is used to crack a research problem all at once."

“Anonymous” also wrote, “In any case, by the time a problem gets to be a research problem, it's almost guaranteed that simple pattern matching won't finish it.”

I agree with this view. When I performed loop quantum gravity research, I accidentally found out a mysterious formula that fit our theoretical data. By theoretical data, I mean that we obtained them without performing actual physical experiments; my co-author wrote a program as prescribed by me, and he performed the program using a computer and obtained the data. At first, I had no idea why the mysterious formula held. As “anonymous” said, there was no “mysterious mental faculty that is used to crack” this problem. It is as if you look at the above 9th grade geometry problem, and cannot come up with any idea that would crack the problem. Then, 4 years later, I suddenly realized the first hint to the right solution, and introduced a new concept. A year later, I performed another trick, and gained more insight. Two years later, I found a “better” trick that supercedes the earlier trick. This example shows that “simple pattern matching” doesn’t finish a research problem, but tricks, new concepts and critical thinking are also needed.

In conclusion, it is unfortunate that some students erroneously think that math and science are mechanical drudgery because our way of teaching math and science is flawed. We should remedy this situation since real math and real science are not mechanical drudgery. Albert Einstein said, "Imagination is more important than knowledge." Math and science are not about knowledge, but about imagination, and we must be able to give such an impression to our students.



The trick is drawing an isosceles triangle BCE. Then the triangle AEB and the triangle ACD are similar, as the angle AEB and ACD are same, and the angle BAE and DAC are same. This implies that the ratio of their sides must be same. Thus, we have 6:9=4:x. x is thus 6.