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The Ineffectiveness of Mathematical Education in American Society

Mathematics is a fundamental element of modern society, acting as the foundation for numerous important fields, including, but not limited to, computer science, physics, chemistry and engineering. Without mathematics, many of the devices that run society, such as phones, computers, cars and even the internet, would simply not exist. Moreover, at least some level of mathematics is required to enter many industries and companies throughout the nation. With the United States being one of the largest superpowers in the world, it's ironic that the vast majority of students in the U.S. are deemed below proficient in their mathematical capabilities ("U.S. Math Education Is Broken"). For the past four decades, mathematicians and educators around the nation have attempted to address the problem of America's decaying mathematical prowess (Klein). Despite their endeavors, however, one problem has proven nearly impossible to solve: "The teacher's arbitrary assignment of the … problems in arithmetic … cannot be felt by the pupil as a real problem and a personal problem" (Klein). In other words, American students simply don't care about learning math. And understandably so; math is often seen as an abstract field too difficult for the average student (Li and Schoenfeld). Even so, it is very possible that these problems may be alleviated in the coming years. With society's technological and scientific advances, mathematics can be taught more effectively through the use of mastery learning and the restructuring of mathematical courses in a way that focuses on building mathematical intuition in a more understandable and approachable manner for students.

Unfortunately, many students nowadays do not have the mathematical ability to carry out even the simplest operations. They often rank below proficient in their mathematical ability when taking the National Assessment of Academic Proficiency (NAEP), with “the 2015 NAEP [rating] 40% of fourth-graders, 33% of eighth-graders and 25% of 12th-graders as ‘proficient’ or ‘advanced’ in math” (DeSilver). In other words, only a quarter of the high school students tested had the mathematical ability to effectively enter the U.S. labor force. The 2015 NEAP also highlights the fact that American students tend to perform poorly relative to other developed countries (DeSilver). The fact that, of the global superpowers, such as the U.S., China, and Russia, only American students tend to score poorly reflects the idea that this problem is specific to the United States, therefore occurring as a byproduct of the American education system. American students are so incompetent, in fact, that they cannot solve even basic arithmetic problems, with “under half of U.S. eighth graders [being able to] correctly place three fractions – 2/7, 1/2, 5/9 – in ascending order. “This question … was categorized as ‘medium’ in difficulty and students could even use calculators to solve it” (“U.S. Math Education Is Broken”). If students cannot solve even the simplest of math problems, they cannot be expected to function as adults. Math is imperative to many important life skills, such as financing, which uses math to predict changes in the economy, cooking, which uses math to create precise measurements in ingredient lists, and more. And the substandard caliber of current mathematical education will prevent students from developing them. Furthermore, students’ mathematical abilities must be improved so that the country can maintain its leadership in future technological and economic development (“U.S. Math Education Is Broken”). In brief, America desperately needs new methods of teaching mathematics so students can perform at the level necessary in the modern world, simply because students do not understand fundamental mathematical concepts.

Considering America's second-rate mathematical ability, relative to other countries, it's not surprising that American students generally consider math a difficult subject, thereby triggering inadequate test results. While American students can perform poorly in math for a myriad of reasons, such as learning disabilities and low motivation (Cicerchia), ultimately they fail due to the United States' inability to teach math on a conceptual level, preventing students from truly understanding, enjoying, and caring about the subject (Cicerchia). Teaching mathematics on a conceptual level emphasizes the idea that students should learn math on a theoretical level first, using a proof-based approach before learning to apply those theories immediately after. Without a conceptual understanding of mathematics, students struggle understanding mathematical concepts, especially when they get to higher levels:

> Through much of elementary and part of middle school, you can sort of poke along with nothing but algorithmic knowledge — where you're recognizing problem types and properly applying algorithms to them — and the big drop-off comes when you hit algebra and it becomes much [more] apparent that math is really about reasoning and problem-solving. (Jaeger)

Furthermore, a lack of conceptual understanding and only an abstract understanding in many math classrooms throughout the nation results in students viewing math as a mundane subject, with no real-world applications (Cicerchia). To observe the impacts of conceptual teaching instead of theoretical teaching, one can look to Japan, a country which consistently outperforms the U.S. in mathematical exams and has a deep focus on conceptual learning. Students in Japan learn theorems with proofs first, such as "[deriving] the formula for finding the area of a rectangle," then learn to apply it to a different concept, like "[using] what they learned to do the same for parallelograms" (Jaeger). This proof-based theory to application method transformed how math was viewed throughout Japan: “It was not dull misery but challenging, stimulating and even fun” (Jaeger). Thus, in comparison, the lack of conceptual understanding of mathematical ideas in America paints math as boring and trivial. Restructuring American curricula into a more understandable format, such as the one found in Japan, would allow students to master mathematical ideas fluently.

Although it may seem like American educators haven’t done much to halt the decay of mathematical ability over the past decades, the United States Department of Education has implemented a few different systems in classrooms to help combat the problem. The biggest and most widespread solution is known as the Common Core State Standards for Mathematics (CCSSM). The CCSSM provides guidelines for many classrooms throughout the nation to teach and benchmark students in mathematics. Considering that approximately 82.5% of the United States’ schools follow the CCSSM, one would think that the program effectively solves the problem of inadequate mathematical education in the America (“Standards in Your State | Common Core State Standards Initiative”). However, nothing could be further from the truth. The CCSSM “encourages teachers to teach to the test” (Armstrong). With this approach, the students fail to build mathematical intuition and skills necessary in daily life and instead learn how to perform well on tests, which ends unsuccessfully anyways, as portrayed by the NAEP. This approach hinders their mathematical capabilities and teaches students that mathematics is only important for test taking (Armstrong). Simply put, the point of the CCSSM is to take tests instead of learning math well, preventing students from truly understanding the concepts they need to learn math effectively, and instead further reinforces the banality of the content in students’ minds.

Besides teaching life skills to students, mathematics is also vital to childrens' brain development. Students who lack a quality math education tend to have weaker quantitative reasoning skills and do not secrete the developmental chemicals required for proper mental development (Zacharopoulos et al.). Furthermore, these children will not have the intuition necessary for any mathematical capabilities in the future, with "adolescent students who specifically lack mathematical education [exhibiting] reduced brain inhibition levels in a key brain area involved in reasoning and cognitive learning" (Zacharopoulos et al.). Students with hindered mathematical education also undergo "neural changes in regions that are involved in skill acquisition of math, primarily in frontoparietal regions," making it harder to develop those skills later on (Zacharopoulos et al.). This idea is known as brain plasticity, which is crucial for neurological development and mandates mathematical education for its creation (Frost). Historically speaking, children with little mathematical ability also experience developmental disorders, such as memory loss and learning disabilities (Frost). All in all, a proper mathematical education is crucial, not only for the development of life skills, but also for the prevention of learning disabilities in students throughout the nation.

America's ranking in mathematical capabilities insinuates that a new system must be implemented in order to resolve the problem of America's falling mathematical standards. Mastery learning could be the answer to this seemingly insurmountable problem. Mastery learning is "a teaching and learning approach that aims for pupils to develop deep understanding of maths rather than being able to memorise key procedures or resort to rote learning" (Almond). Rather than learning by rote memorization, this method emphasizes learning by proof and application, which is the most effective way of teaching conceptual understanding (Almond). Learning by proof and application allows students to have a stronger grasp as to what formulas and theorems represent symbolically and how they can be manipulated for different purposes. Mastery learning also has six steps for teaching concepts, allowing students to go at their own pace. The process starts with pre-assessments, gauging where each student is in their educational paths. The next step calls for group based initial instruction, during which students start off in a "normal" classroom environment. Following this, students undergo regular formative assessment, allowing teachers a chance to identify possible areas of weakness in the class. Subsequently, the students experience corrective instruction, in which students meet one-on-one with teachers. Finally, they have parallel formative assessments, equivalent to a "final" grade for the activity, and enrichment activities, for advanced students who didn't require corrective instruction (Bouchrika). When all six steps are employed, students will gain the freedom to do what they need to in order to comprehend the content, whether it be personalized instruction or independent learning. Moreover, learning at one's own pace allows students a better understanding of what they are learning, as it encourages them to learn it in a way best suited to them. With mastery learning being so effective in theory, one may wonder why it hasn't already been implemented throughout the United States. Unfortunately, the technology required to implement mastery learning, such as online learning platforms and grading systems, were not advanced enough until recently. However, with new online platforms, such as Google Classroom and Schoology, this problem has been alleviated (Wang). In fact, the idea of such technology existing today is proven by the existence of Khan Academy, an online educational platform that teaches mathematics very effectively with the help of mastery learning (Pattani). Mastery learning can be seen in numerous countries, but especially in Singapore, the country that ranked first in the 2015 NAEP for mathematical literacy. Singapore "has championed the … approach to mastery maths," and its success in the 2015 Programme for International Student Assessment

(PISA), the NAEP comparison test used in other countries, can be largely attributed to their enactment of mastery learning (Almond). Looking to Singapore for inspiration, it is certainly possible for the United States to effectively administer mastery learning throughout classrooms, thus improving the average numeracy of students throughout the nation.

As revolutionary as mastery learning could be for the United States, it may still not be enough. Thus, Math classes throughout the country may need to be restructured en masse to create more comprehensible course sequences for students. Luckily, they can be systematically reformatted based on eight different criteria or targets, which aim to outline how an ideal math class would function:

> Four of the targets focus on student behavior indicative of mathematical power: deep understanding of concepts and schemas, mathematical thinking, communication about mathematics and a positive disposition toward mathematics. The other four targets focus on the instructional setting: student-centered tasks, a variety of work formats, mathematical tools and assessment alternatives. (B. Nelson)

These eight targets are based off of seven learning principles, similar to those of mastery learning: “1) knowledge is constructed; 2) all students can grapple with complex ideas; 3) conceptual learning is effective; 4) prior knowledge influences learning; 5) learning is a social act; 6) change in cognitive structure is a goal of teaching and 7) students must be actively engaged to learn” (B. Nelson). As these concepts are so similar to mastery learning’s ideals, it is understandable that a large-scale reform of mathematical curricula could be very compatible with mastery learning. The difference between mastery learning and this restructuring method is that mastery learning focuses on how students are taught whereas the restructuring method focuses on what they’re taught (Almond). Therefore, the modernization of mathematics courses could effectively complement mastery learning in a way that allows students to efficiently understand material. Using these ideas, the U.S. can reorganize mathematical courses for a proof and concept based learning technique instead of memorization, which would be very beneficial for all types of students throughout the nation.

Undoubtedly, without drastic changes in the mathematics curriculum throughout the United States, the country will gradually lose its economic and technological edge over the coming years. For Americans to maintain a competitive advantage in the global market, students will have to become more proficient in math over the next decades, as the deficiency of mathematical ability will negatively impact all industries, not just STEM related ones (L. Nelson). An increase in mathematical potential, on the other hand, will lead to a more competitive economy in the long run, as suggested by Eric Hanushek. As “a Stanford economist who researches cognitive skills and economic growth, [he] has estimated that a 25-point gain on PISA over 20 years would add $44 trillion to the US economy over the same time period” (L. Nelson). Even more than that, mathematics is essential to preventing developmental disorders in students and to teach them important real-world skills they will require in their adult lives. In essence, the United States is in dire need of a new method of teaching mathematics, and the mechanisms of mastery learning and restructuring mathematical courses could be the key to unlock a new era of mathematical prowess throughout the nation.

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