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Improving Mathematical Ability in the United States

Emma Winegar
Augsburg College

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Emma Winegar, Augsburg College

Emma Winegar is a sophomore at Augsburg College in Minneapolis, planning to graduate in 2014 with a major in mathematics and a minor in computer science. She has also received a certificate in digital design and enjoys studying art. After completing her bachelor's degree, Emma plans to go on to graduate school.
Abstract
The United States has a deficit in the abilities of its citizens to comprehend mathematics, as compared with similar countries. Many people experience math anxiety, and in turn hate mathematics and shy away from it at all costs. Problems with the current curriculum and teaching styles in schools limit students from being successful in mathematics. Improving mathematical ability will not only lessen anxiety, but will improve society as a whole. Mathematics is crucial to survival in modern day society. It is important that the issue of the overall low level of mathematical proficiency in the U.S. be solved. This paper discusses the misunderstanding of mathematics, what affects math ability, problems with learning math, differences in math education in other countries, and ways in which the ability of the population can be improved in the future.
1. Introduction

Mathematical skills are important in everyday life tasks such as going to the grocery store, calculating your taxes, balancing your checkbook, and in most careers. It is pertinent for everyone to have at least some mathematical ability in order for society to function smoothly. The U.S. ranks surprisingly low for math proficiency. Students in the U.S. rank below students in 31 other countries in math testing (Resmovits). There is no reason that they should rank this low, because every child is obligated to go to school until they are sixteen years old. This should be enough time for the majority of students to become at least somewhat proficient in math. However, many people are still not proficient in it after graduating from high school, and many fear the subject. Helping students grasp more mathematical concepts would benefit individuals as well as the U.S. in general. In order to learn how to do this, it is important to know how much math ability we are born with, how children learn math, what deficiencies children can have with learning mathematical concepts, and what the current system is for teaching math in schools. Then it will be possible to assess the information to find solutions to increase the national average math proficiency. Schools need to start teaching more concepts to students when they are younger, and focus less on teaching students how to calculate and more on teaching them how to solve problems. Math is like a language in that people are able to learn it easier the younger they are. The low mathematical ability of students will affect advancement in technology, which in turn will affect long-term economic growth (Peterson). Raising math proficiency will help individuals, the economy, and the efficiency of the country.

2. Understanding Mathematics and its Purpose

First, it is important to know how people view mathematics. As Jo Boaler, a renowned mathematics professor and author, discovered, when you ask American students what math is, they usually answer “numbers” or “lots of rules” (15). However, when you ask professors the same question, they answer “the study of patterns” or “a set of connected ideas” (15). In other subjects, students and professors have more similar answers to this simple question. Why is math so different? If math were represented correctly to students, it would make sense that their definition of math would coincide with their teacher’s. So, it is apparent that math is being misrepresented in schools. Precision and repetitions of rules are overemphasized in the curriculum. In turn, students are not taught enough about different patterns within mathematics. When they are, teachers do not necessarily communicate to them how it relates to the broad study of mathematics. Oftentimes, students are merely talked to, given a set of problems to do, and sent on their way.
They do not gain a universal understanding of concepts; they instead learn different methods of how to calculate answers without knowing why they are doing the calculations. Truly, mathematics is about “illuminating relationships such as those found in shapes and in nature” (18). Math is conceptual rather than procedural, as it is based on ideas rather than rules (Westbury et al. 42). In order for students to appreciate math more, teachers need to illuminate patterns, relationships, and broad concepts. Teachers need to explain to their students how and why each calculation they do is relevant and important for increased understanding. Textbooks need to include this information as well. Additionally, math can be understood as a language, which will be discussed in the following section.

3. What Affects Math Ability?

Each person has a different understanding of math. Some are able to learn it easily, while others need more time to learn it. Part of the reason for this has to do with genetics. There are genes that affect how proficient we are in mathematics. However, there is no “math gene” (Devlin xvi). Although people have differing mathematical abilities due to hereditary traits, Keith Devlin argues that everyone has the ability to communicate mathematically. People often shy away from math, because they do not know what it truly is and thus do not understand it (xvi-xvii). Many think of it as simply numbers and rules, as discussed in section 2. Devlin has deduced that everyone is born with the ability to do math, as people have had concepts of abstract numbers for about 8,000 years, and the brain could not have evolved much since then (2-3). He argues that mathematical thinking requires the same functions of the brain as using language (2). As summed up in the book In Search of More Effective Mathematics Education, “[m]athematics must be understood not as a set of procedures for finding single right answers, but rather as a language with signs and symbols and terms that help us investigate, reason, and communicate…Mathematical problem solving must become central if mathematics education is to respect the nature of the discipline…[and] if we are interested in developing the capacity for lifelong learning” (Westbury et al. 34). It seems counterintuitive to associate math as a language. To the contrary, there are many different ways to communicate mathematical concepts; you can use numbers, symbols, letters, pictures, and words. It is important that mathematics be communicated clearly and concisely. The language used in proofs and theorems, for example, is as direct and to the point as possible. Mathematical thinking requires a creative process, as there are multiple ways to solve problems. Even the simplest formulas require complex proofs. Math requires specific language with no added embellishments. In this way, it can be considered its own language entirely. Unlike
other languages, it makes use of specific symbols and numbers regularly. Letters become symbols and are used as themselves rather than only in words. Math is unique in that it combines different means of communication to form a whole new language. If the idea of math as a language were portrayed to students, it would become more interesting and useful to them.

In order to find out how we can better teach mathematics, it is important to know the degree in which mathematical capabilities are innate. An innate skill is one existing from birth. One innate sense is called number sense, which derives from the Approximate Number System (ANS). The ANS is defined as “a primitive mental system of nonverbal representations that supports an intuitive sense of number in human adults, children, infants, and other animal species” (Mazzocco, Feigenson, Halberda). All animals have some number sense; many scientists argue that even infants are born with number sense (Stix). Other experts, like psychologist Jean Piaget, argue that infants’ brains are “blank slates… when it comes to making calculations in the crib,” or in other words, it takes years of experience for them to grasp mathematical concepts (Stix). While it is true that infants are not born knowing about mathematics, they are born with the ability to recognize quantity differences (Mazzocco, Feigenson, Halberda). Subsequently, more complicated math concepts are based on the approximation theory, and studies have shown that humans, along with other species, are born with the ability to approximate the relative size of things. People, however, must learn how to communicate the concepts in everyday language. Children born without this innate ability often have trouble with math in the future. Studies have shown that a child’s ANS precision before schooling predicts how high his or her math ability will be after schooling (Mazzocco, Feigenson, Halberda). Neuroscientist Stanislas Dehaene argues that there are ways to help children born without number sense improve their ability, which may prevent them from having as many difficulties in math classes in the future (Stix). This can be applied to all children; if all of them are exposed to math at an earlier age, they will learn it at a faster rate.

According to Roger Highfield, the amount of exposure children have to math before they begin school greatly affects their math ability in the future. He argues that parents who incorporate math into their child’s daily life have more impact on their child’s math ability than preschool programs. While studies have shown that quality preschool programs increased the math ability of children, their parents’ education, especially the mother’s, had the greatest influence (Highfield). Children whose parents do activities with them involving math are “provid[e]d with the mental structures needed to learn new things” (Highfield). If more parents made an effort to teach their children math at home, they would be better prepared
to learn math in school. The key is to play math games or do different activities involving math that the children find interest in, rather than to have them crunch numbers. Crunching numbers can be useful, but understanding deep math concepts comes from solving word problems, not finding a single solution to a problem. Crunching numbers involves merely doing the same type of calculation over and over again, whereas solving word problems involves more complex processes by combining multiple calculations with logic.

Because mathematics can be thought of as a language, it makes sense that learning mathematical skills as a person's brain is growing and developing greatly improves fluency. Many people in the U.S. struggle to learn a new language, so it makes sense that they struggle to learn mathematics as well. It is a commonly known fact that it is easier for a person to become bilingual if from a young age, he or she is in an environment where two different languages are being spoken daily. It is simply easier to learn a language the younger a person is. In order to learn how to see, speak, and comprehend language, people need to observe how others do these things. It is the same with mathematics. If a child never learns the number system or hears people doing calculations, after a certain amount of time, they could not be able to grasp the workings of mathematics, or at least have an increasingly difficult time as time passes. It is thus important that schools expose youth to mathematics as early as possible.

4. Problems with Learning Mathematics

One problem with learning mathematics is math anxiety, which is often associated with mathematical learning disabilities, but is often neglected. Math anxiety is related to math performance; studies have shown that when math anxiety decreases, math performance increases (Krizinger, Kaufmann, Willmes). A person experiencing math anxiety will often avoid doing math problems, which causes a vicious cycle in which the student does not learn important concepts and in turn becomes even more anxious and self-conscious about their abilities. Many people are afraid of math or simply do not like it. This idea that they are bad at math can also stem from knowing that family members have not excelled in math, from hearing societal biases that mathematics is difficult, and from being discouraged by others. Learning math takes longer for some, but the end goal of comprehension is attainable. Understanding math concepts (especially from an early age) is key for liking and not fearing math, as well as for reducing math anxiety.

Once a person experiences math anxiety from a lack of understanding, they make excuses for why they are not as proficient at math. They may claim that their mind is not built to do math, that their future career will not involve math so
they do not need math skills anyways, or that they will never catch up so they might as well stop trying ("Math-Anxiety"). However, all three of these excuses are false. Anyone can become proficient at math. Although math is a human construction, it is used in virtually every career field and is vital for survival. Thus, the excuse, "I don't need math" is not valid. Subsequently, since anyone can learn math, it is never too late to gain additional math skills. People of all ages and at all skill levels have the ability to catch up in math. Learning new concepts or even reviewing previously studied concepts is challenging, but it is well worth the effort. Along with skill, it increases how people feel about themselves.

Many children in the U.S. dread math class. Some have trouble learning it, and others experience anxiety from the subject. The majority of people I tell that I'm majoring in mathematics state their amazement and quickly say how math is not their strong suit, or that they hate math. People from various backgrounds do not feel capable with mathematics. However, it does not have to be this way. As Jo Boaler pointed out, people in the U.S. are fascinated with math problems even though they may not realize it. Sudoku puzzles have recently become popular in the U.S., for example, and solving them involves logical reasoning. People put the math they learn in school and the math they do in daily life in separate categories: they have in the past and still do today. What it comes down to, according to Boaler, is that math is currently misrepresented in schools (15). Students do not understand what math truly is through the current curriculum in schools. They do not see the big picture of the problems they are asked to solve. The concepts they learn remain separate from one another, which leads to frustration and fear of the subject. However, math has the potential to be loved and appreciated by everyone if it is taught correctly and if people make an effort to learn it.

5. Math Education in the U.S. Compared to Other Countries

When mathematical ability is compared between different countries, Japanese and Chinese students consistently rank above American and Western European students. Part of the disparity between the scores may be due to the differences in culture. It has been found that language has to do with the disparity. Japanese and Chinese languages have an easier way of communicating numbers than English, French, German, and similar European languages. Kevin Miller's study showed that the difference in language accounted for the one-year lag of English-speaking students to Chinese-speaking students when learning to count (Devlin 65). While Chinese children could count to 40 by age four, American children could only count to 15. Only by age five could American children count to 40 (65). Chinese and Japanese numbers are easier to learn; they do not have
the special rules of counting that English has, and the words for the numbers are shorter. In addition to differences in languages, there are differences in curriculum.

Currently, math education in the U.S. consists of basic arithmetic in elementary school, review of arithmetic and starting algebra in middle school, and finally getting to algebra, geometry, and calculus in high school. Textbooks in the U.S. “treat topics with a ‘mile-wide, inch-deep’ approach” (4brevard.com). Typically, eighth grade textbooks in the U.S. have about 35 subjects, while eighth grade textbooks in Japan or Germany have only five or six (4brevard.com). Teachers are not able to go as in depth for topics in the U.S. as they are in other countries. Instead, they are forced to gloss over topics. In turn, students need review of the topics in later years, since they are not able to remember them well. Students in other countries such as Japan do not spend as much time on arithmetic or on repeating lessons; they are able to begin teaching algebra and geometry starting in middle school. They focus on “how to use math rather than how to do math” (4brevard.com). This is crucial for students’ understanding. Along with slower and more repetitive teaching of curriculum in the U.S., there are more tests given to students.

There are more tests given in the U.S. than anywhere else in the world (Kohn). Standardized tests are even given to elementary school students, as early as the first grade. Most other countries do not use standardized tests for students below the high school level (Kohn). Oftentimes, as Alfie Kohn believes, standardized testing only tests superficial thinking. This is because students guess on harder questions or even skip tough parts of the tests, so a high score may not reflect a student’s abilities accurately. Schools put time and money into efforts to prepare students for the tests, when students could be learning about more advanced topics and the school could be using the money to benefit the students more. For international tests, it is hard to know if countries are only testing their brightest students. However, the tests have become more accurate over time (Brown). While standardized tests and studies help us compare different students’, schools’, states’, and countries’ differing abilities in subjects, there is no reason for the U.S. to require so many of them. Preparing for so many tests hinders students’ educations, as they are put under pressure to do well on the tests rather than focus on more important subjects. Once the standardized tests are over, students have not learned as much as they would have without the time to prepare for the tests. The U.S. needs to look at what other countries are doing successfully in order to learn what can be done to further develop math ability of students.

6. Changed Needed in Curriculum and Teaching Style
The U.S. math curriculum needs to be changed. The current curriculum is too focused on repeating arithmetic concepts. While it is important to know basic arithmetic in order to proceed to other subjects, there is no reason why students should still be stuck learning simple arithmetic in their ninth year of schooling. Some students may need that much time to understand concepts, but many are being held back from reaching their full potential. The current system neither allows for students to excel above the level of their classmates nor for students to go at a slower pace than their classmates to effectively grasp material. Students need a clear understanding of what exactly they are learning. If all they see are numbers and formulas, they are not being taught with a good curriculum. Students would learn more if definitions were explained to them in terms that they could grasp easily. They should also be exposed to examples that they can understand and relate to.

Another change that needs to be made is in teaching style. The traditional style of teaching involves students taking notes from teachers and doing numerous examples, with very little student involvement in many cases. Students become discouraged when the entire class period is spent listening to a teacher give a lecture (Boaler). They are more likely to give up on problems as well as on math itself when they do not understand the concepts. Children need inspiration from their teachers, not endless lecturing (Boaler). An ideal classroom is one with an inviting environment in which students are encouraged to participate in their learning and are never put down for asking questions. Inspiring teachers are not the ones who directly follow the traditional style of teaching. They find ways to reach out to each and every student to make sure they are learning the material effectively and not becoming discouraged. With math, it is vastly important that teachers reach out to students, since so many people fear the subject and are quick to give up on exploring it further.

Currently, students see math as being a set of rules rather than a creative process. To the contrary, solving problems requires creative thinking. However, students are not often exposed to the creative process; they are merely informed to use certain processes for certain problems. As Boaler points out, a “clear difference between the work of mathematicians and schoolchildren is that mathematicians work on long and complicated problems that involve combining many areas of mathematics...[which] stands in stark contrast to the short questions that fill the hours of math classes and that involve the repetition of isolated procedures” (24). There is not enough creative problem solving with the current system. Instead of continuing with the rigid traditional system, there should be more flexibility in teaching styles in which teachers can decide what
creative problems and projects to give to their students. It was found that effectively teaching problem solving “was associated with an emphasis on the most difficult mathematical concepts and skills in the curriculum” (Westbury et al. 46). Teachers should give their students complex problems, and the students should then be encouraged to work together to solve them, with guidance. This would be a better application of students’ knowledge than having them repeat similar problems over and over; repetition is only good up to a point. Once students understand a set of concepts, they should be challenged to combine them together, rather than being expected to drill out the same types of problems separately for each individual concept. This new method of teaching would inspire teachers to find new ways to challenge their students and themselves.

People who support the traditional way of teaching argue that their way of teaching is working, since math scores have gone up recently. However, a slight increase in scores on a standardized test is not enough to justify that the traditional way is working. The traditional method has been in place for decades, and still millions of children hate math and are not proficient in it. One argument is that the problem is not the way of teaching, but the lack of motivation from students. This is partially true; there are students who give up on math without giving it the effort needed to learn it. However, the job of math teachers is to effectively convey concepts, create interest for students, and encourage and help students succeed. The traditional method is too rigid and does not convey how math can be used in the world outside of school.

7. Conclusion

When it comes to math proficiency, students in the United States fall below students in many other countries. Many do not know what mathematics truly is, since math is misrepresented in schools. The misrepresentation affects the students, as many of them never find respect or a liking for math. In turn, not as many students go into STEM (Science, Technology, Engineering, and Mathematics) majors. STEM majors are the highest paid out of all other majors, yet still people are shying away from majoring in STEM subjects. All of the majors require mathematical courses and ways of thinking. A person's choice in college major is related to their aptitude in mathematics (Dickson). Many students either never consider majoring in STEM fields, or end up switching majors. This cycle is the effect of misrepresentation of mathematics in schools. If students were challenged more in math class with problem solving rather than tedious computations, they would be more prepared for STEM courses in college. In order to improve the overall ability of students, the curriculum needs to include more
complicated problems rather than repetitive computational problems, and subjects such as algebra and geometry need to be introduced at an earlier age. This will allow for fewer students to experience anxiety with these concepts in the future. As people age, it is increasingly difficult for them to learn a language. Since math can be considered as a language, it follows that it becomes more difficult to learn as people age. This raises the importance for young students to be introduced to as many topics as they will be able to understand. If more concepts are introduced when students were younger, in subsequent years, teachers can go more in depth with the topics. Changes to the curriculum and teaching styles will allow for an increased proficiency of mathematical ability.
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