



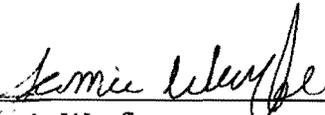
A Comparison of Mathematics Curricula and how it Relates to STEM/STEAM College
Graduation Rates

Senior Project

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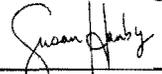
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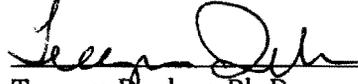
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Abstract

This paper looks at the curriculum and standards for mathematics in the U.S and compares them to the Curricula and Standards of other nations. Using the results from Trends in International Mathematics and Science Study (TIMSS) 2015 study and commonly chosen college majors, the author will draw a conclusion as to steps the U.S should take to promote more interest in STEM/STEAM career fields as well as topics for further study .

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Introduction

Science, Technology, Engineering, Arts and Math (STEM/STEAM), has been a highly debated topic among U.S educational officials in the recent decades. With the implementation of common core and standardized tests being used to measure mastery the U.S appears to be pushing for more people to take an interest in STEM fields. This is because, according to Bybee “As stressed in the National Academies report *Rising Above the Gathering Storm*, students must acquire such skills as adaptability, complex communication, social skills, nonroutine problem solving, self-management, and systems thinking to compete in the modern economy. To the degree that STEM curricula incorporate group activities, laboratory investigations, and projects, they afford the opportunity for students to develop these essential 21st-century skills and prepare them to become citizens who are better able to make decisions about personal health, energy efficiency, environmental quality, resource use, and national security” (2010).

It’s clear that the U.S wants to better educate its younger citizens in STEM/STEAM concepts to continue to compete in an ever-growing global economy. While the U.S is eager to implement STEM/STEAM learning into its K-12 classrooms, different implementation strategies may be more effective than the current and or previous styles. This paper will evaluate the effectiveness of the U.S math curriculum by comparing it to the curricula and standards in other nations pertaining to math education. The push in U.S will also be measured by seeing how the math standards and curricula impact university STEM/STEAM degree desires and the U.S’s national rank on the

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Trends in International Mathematics and Science Study (TIMSS) 2015 study. The nations being compared to the U.S are China, Korea, England, and Australia.

What is TIMSS, and how does the U.S compare?

TIMSS “is an international comparative study designed to measure trends in mathematics and science achievement at the fourth and eighth grades, as well as to collect information about educational contexts (such as students’ schools, teachers, and homes) that may be related to student achievement”. In 4th grade math the U.S ranked measurably less than China, Korea, and England while scoring measurably better than Australia. In 8th grade math Korea and China scored better than the U.S, England scored equally with the U.S and again Australia scored measurably less than the U.S (Provasnik, Malley, Stephens, Landros, Perkins, & Tang 2016). Curriculum and Standards being taught in mathematics is an obvious difference between the five different nations. So, how is math being taught in these nations that are scoring better than U.S students, and how is this math competency related to student desire to pursue STEM/STEAM degrees.

Curricula

U.S

While the majority of the U.S adopted the Common Core State Standards rolled out, the wording and teaching of these standards vary from state to state. This, coupled with the fact that some states have not adopted common core (Education Week, 2018) make it hard to fit the U.S into a single box. This idea is emphasized by the fact that in the TIMSS review the state of Florida was singled out, doing better in 4th grade math than the rest of the nation and falling below Australia and the rest of the nation in 8th grade

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math (Provasnik et al. 2016). Because of its widespread use in the nation, Common Core State Standards will be the national standards of the U.S.

These standards expect kindergartners to be able to count to 100 by ones and by tens. By 5th grade, according to common core, children should understand the concept of volume and be able to relate it to the operations of multiplication and addition, as well as solve real-world problems involving volume. The high school standards expect students to be able to construct an “informal argument for the formulas for the circumference of a circle, area of a circle, volume of a cylinder, pyramid, and cone.” (Gewertz 2019).

Students in the U.S often don't receive a teacher that specializes in math until fifth or sixth grade. Before then, students are learning all core material from one individual, which can lead to a more cursory understanding of fundamentals than might be useful in a STEM/STEAM career.

U.K

In England, the math curriculum is set up in stages that should be moved through at relatively the same pace, but it dependent on student security in the mastery of the concepts (Department of Education: England, 2014). For example, Year one students are taught to read and write numbers from 1 to 20 in numerals and words while Year two students are taught to read and write numbers to at least 100 in numerals and in words. The English curriculum truly focuses on allowing students to understand and master the fundamentals of mathematics before moving on to more advanced concepts (Department of Education: England, 2014).

Australia

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In Australia the curriculum focuses on Algebra/ Number Sense, Geometry/Measurements, and Probability and Statistics; mainly focusing on the ability to understand and apply mathematical sense to real world problems (Australian Curriculum, Assessment and Reporting Authority, 2019). For example in Year 3, Australian students be able to identify angles, make 3-D object models, conduct chance experiments, measure length, width, and time (ACURA, 2019).

South Korea

The Korean curriculum is very different from the U.S Curriculum. Education is very important in South Korea, and very competitive. Students are expected to do a lot of outside studying and preparation (Future School South Korean Education Curriculum 2019). This is also shown in the density of their curriculum, by the end of their first year of elementary school students should be able to do the following:

- Using and applying number: The numbers 1 to 5
- Using and applying number: The numbers 6 to 9
- The number system: Ordinal numbers 1 to 9
- Using and applying number: Zero and counting numbers 1 to 9
- Using and applying number: The number 10
- Using and applying number: Numbers 11 to 20
- Using and applying number: Using place value to order numbers up to 20
- Reasoning: Simple addition up to the number 10
- Reasoning: Simple addition up to the number 20
- Calculations: Subtraction up to the number 10
- Calculations: Subtraction by Comparison
- Calculations: Subtraction up to the number 20 and beyond
- Calculations: The numbers 20 to 99 Calculation 10-100: Counting by 1, 2, 5, and 10 to 100 and More (Future School Elementary, 2019).

By the end of middle school students are required to know

- Multiplication: Multiples and factors of whole numbers
- Surds (Irrational Numbers): Introducing surds
- Surds (Irrational Numbers): Some rules for the operations with surds
- Surds (Irrational Numbers): Simplifying surds
- Surds (Irrational Numbers): Creating entire surds
- Surds (Irrational Numbers): Adding and subtracting like surds
- Surds (Irrational Numbers): Expanding surds

Surds (Irrational Numbers): Binomial expansions
Surds (Irrational Numbers): Conjugate binomials with surds
Surds (Irrational Numbers): Rationalizing the denominator
Algebraic expressions: Algebraic expressions.
Algebraic expressions: Substitution into algebraic expressions.
Algebraic expressions: Directed numbers: addition and subtraction.
Algebraic expressions: Directed numbers: multiplication and division.
Algebraic expressions: Simplifying algebraic expressions: adding like terms.
Algebraic expressions: Simplifying algebraic Expressions: subtracting like terms.
Algebraic expressions: Simplifying Algebraic expressions: combining addition and subtraction.
Algebraic expressions: Simplifying algebraic expressions: multiplication
Algebraic expressions: Simplifying algebraic expressions: division
Algebraic expressions: Expanding algebraic expressions: multiplication
Algebraic expressions: Expanding algebraic expressions: negative multiplier
Algebraic expressions: Expanding and simplifying algebraic expressions and again, much more ((Future School Middle, 2019).

Another unique thing South Korea does is a free semester.

The Free Semester is a one-semester system in middle schools that aims to enhance the happiness and well-being of students by giving them opportunities to explore dreams and aptitudes through participatory instructions, diverse learning experiences, and flexible curricula. Students are encouraged to develop key competencies through experience-based activities (e.g., discussions, science labs, project-based learning) and Free Semester activities (e.g., career exploration, theme-based learning, fine arts/physical activities, club activities). The Free Semester has been implemented since 2016 in middle schools nationwide, and Korea expects to achieve happy education by enhancing students' satisfaction in schools, parents' faith in public education, teachers' satisfaction at work, and so forth (Korean Ministry of Education).

This ability to work on passions while learning core content with the emphasis South Korea puts on community and education along with the high expectations could be leading to higher test results than their U.S counterparts.

China

The Chinese Math Curriculum appears to be similar to the curriculum in Korea as far as topics covered and age range of mastery. However, it also helps that many Chinese elementary schools, unlike in the U.S, have a specialized math teacher to give students a good foundation in math (Ferrerias and Olson). The Chinese math curriculum is mainly based on the following:

- **Number and Quantity**—In elementary schools, students are expected to master arithmetic operations with natural numbers, to understand the concepts of time, distance, area, weight, volume, capacity, and angles, and the units used to measure them, to understand that fractions and decimals may refer to parts of a set or parts of a whole, and to use estimation strategies in computation, problem solving, and checking computations. The junior high school curriculum includes negatives, arithmetic operations with integers and rational numbers, absolute value, prime and composite numbers, and arithmetic and geometric sequences.
- **Geometry**—In Grades 1 to 3, students learn to identify, explore, and manipulate geometric figures. In Grades 4 to 5, students are expected to express numerical relationships in and among geometric figures. In Grades 6 to 7, students develop spatial and visual reasoning. In Grades 8 to 9, students study plane geometry as an introduction to the concept of mathematical proof and learn to appreciate it for its intrinsic value.
- **Algebra**—Students learn to solve problems using symbolic representations. In elementary school, students learn to express relationships in equations or sentences, evaluate algebraic expressions, and solve simple linear equations. In junior high school, students learn to use equations or inequalities to represent the relationships among the quantities described in questions, solve linear equations and inequalities with one variable and simultaneous linear equations with two unknowns, factor polynomials, solve quadratic equations, and represent linear and quadratic functions in graphs.
- **Statistics and Probability**—This strand has strong connections to Algebra as well as to Number and Quantity. Students are introduced to the concept of probability, interpretation of data, and problem solving with statistics. In elementary school, students mastering this academic content will be able to create and interpret simple

statistical tables and pie charts. In junior high school, students learn about frequency, mean, median, and mode, and how to use computers and software to calculate with statistics, and make tables and graphs.

- **Mathematical Connections**—To encourage meaningful learning, this strand emphasizes integration among the other four strands and the transfer of mathematical knowledge and reasoning from school to daily life, as well as to other subjects, such as science and technology. (Mullis, Martin, Goh, and Cotter, 2016).

College Majors

U.S

The standards and high stakes testing appear leading students away from STEM/STEAM. “Overall, 79,900 associate's degrees (8 percent) were conferred in science, technology, engineering, and mathematics (STEM) fields in 2015–16” (Undergraduate Degree Fields 2018). As far as bachelor’s degrees go, over half were concentrated in Business, Health Professions, History and Social Sciences, Psychology, Biomed, and engineering. In total only about 355,000 out of the 1.9 million bachelors earned in 2015-16 (18%) were related to STEM fields, with 33% of the degrees being awarded to Asian Americans (Undergraduate Degree Fields 2018).

U.K

Not only have these different curriculum/standards lead to better or equivalent results on TIMSS when compared to the U.S, but some of the most popular college majors for British university students are: Business, Natural Sciences, Engineering and Technology, Medicine, Law, Social Sciences, Sports Science, Media and Communication, Arts, and Hospitality and Tourism (Most Popular Degrees in the UK). There are some overlapping majors with the U.S, but overall it shows that more STEM degree fields are popular in the U.K than in the U.S. With that being said, perhaps the U.K’s more guidance based math curriculum is more conducive to STEM interest as

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opposed to the U.S method of “drill and kill”: giving students worksheet after worksheet and emphasizing rote memorization over in depth understanding of fundamental concepts.

Australia

Australia did consistently worse than the U.S on TIMSS in 2015, however, there are still overlapping popular majors with the U.S. Common Majors from Australia are; Business and Management, Medicine, Accounting, Dentistry, Law ,Creative Arts and Design, Education, Engineering, Environmental Science, and Computer Science/ IT (W, 2012). It is possible the focus on real world applications while in school may turn students away from heavy STEM/STEAM carrer fields in the future, or make it less appealing. It also shows that there may not be that high a correlation between TIMSS results of a nation and popular college majors for students of that nation.

South Korea

There was not a definitive list of majors for South Korean students like there was for the other nations discussed in the paper. However, this is to be expected because South Korea is one of the top sending countries in the world, meaning most of their college students choose to study abroad (Mani, 2019). This did not make it impossible to connect South Korea with STEM/STEAM degree achievement however. According to Chandler (2012) 1 in 4 South Korean students elect to major in in engineering as opposed to 1 in 20 American students. In addition to being more likely to choose engineering as a degree abroad, Koreans are also lead back home with promises of high salaries, and even exemption from military service and no tuition in exchange for government work (2012).

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However, it is not all good news for Korea. According to Mani (2019) Korea is looking to change their practices in education to relieve some of the stress the high stakes Korean education and job market are placing on its diminishing younger generation (2019). Korea did outdo the U.S in TIMMS and in STEM/STEAM desire, but at what cost to its citizens?

China

Commonly Chosen majors in China are: Clinical Medicine, International Economics and Trade, Computer Science and Technology, Business Administration, Chinese Language and Literature, Civil Engineering, Mechanical Engineering, Architecture, Communication Engineering, and Chinese Language Training (Most Popular Majors in China, 2010). The focus of the standards/curriculum of both China and South Korea, along with their community affiliations seems to make STEM/STEAM career fields more desirable.

China, like Korea, also sends students abroad to earn their degrees, and is one of the biggest threats to U.S STEM/STEAM. According to Herman (2018) in 2016 China had 4.7 Million recent STEM graduates, and that 70% of U.S international students enrolled in U.S STEM/STEAM programs (62%) were from China or India (2018).

Conclusion

Summary

In the 1960's when the USSR launched Sputnik to space, Americans became jolted and took a long hard look at how to get American children interested in STEM (Herman, 2018). The push for STEM/STEAM in the education system today, like in the past, is not showing any signs of slowing down anytime soon, nor should it. In

order for the U.S to remain competitive in the global market of the 21st century U.S students need to learn different approaches to solving major problems. This kind of abstract thinking is best brought out by a good STEM/STEAM curriculum.

Proposal

In order to get more U.S students interested and graduated in STEM/STEAM fields, U.S educators should focus more on the understanding of the material rather than high stakes testing at the end of every school year, giving students more of a chance to work at their own pace with support from both their parents/community and their teacher. This can be achieved by teachers looking more for mastery than rote memorization and probing the students to make more connections to the material and gathering a deeper understanding. This type of curriculum correlates with how the U.K, China, and Korea teach mathematics, and has been shown to be a fairly effective in motivating students to pursue STEM/STEAM careers.

Another thing is that may benefit the U.S is to not go into truly advanced math like calculus in mandated schooling and saving such courses for college. By focusing on the basics and expecting mastery, students will be more prepared for upper level mathematics because they understand the fundamentals on a much deeper level. In addition to saving higher level math for college/university degrees, it might also be beneficial to have elementary school grades to have STEM/STEAM specialists to teach students so that more time and effort can be spent not just on Math and Science, but on all core material. These decisions are what appear to be allowing South Korea and China to surpass the U.S in STEM/STEAM achievement.

A final proposal would be for more U.S students to have the opportunity to explore potential career fields like is expected in Korea during their semester break. This is important because there are a multitude of personalities in a generation, and so not everyone will be cut out for a STEM/ STEAM career. By allowing students to explore their likes and dislikes from an early age will help them focus their studies in a manner best suited for them. This in turn, will lead to more productive members in society. Also, it allows students interested in STEM/STEAM fields to get hands-on experiences and build credibility and relationships that may help them get jobs later on.

Proposal for Further Research

Before a nationwide curriculum change is implemented, pilot the proposed curriculum in certain areas so educators in the fields can provide insight into the practicality and help work out any unforeseen issues; these pilot teachers would also be able to help, via professional development, instruct other individuals on the program and how it would work. A nationwide overhaul of the math curriculum could result in mass confusion and disdain for the program before results could be shown.

More research is also needed to see how community influence/ home influence impacts student achievement in mathematics. China and South Korea place high value on their teachers and on education in general. Families in these countries have high standards and push their students toward them. If the U.S held it's children to these higher standards, and gently nurtured and pushed them towards achievement, would the U.S have better achievement? Also, if U.S students are held to higher

standards, what kind of stress/effects will these standards have on students physical and mental health?

This paper also took only a cursory look at the curricula of the aforementioned countries. Other factors, such as pre-service teacher education and classroom/school dynamics may have also played a role in the outcome of the TIMSS results of 2015

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