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The Efficacy of Mathematics Education

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The Efficacy of Mathematics Education

Abstract

Evidence supports the notion that mathematics education in the United States is inadequate. There is also evidence that mathematics education deficiencies extend internationally. The worldwide mathematics education deficit appears large enough that improving student performance in this educational problem area could yield great economic benefit. To improve the efficacy of mathematics education, education's root problems must first be understood. Often supposed educational root problems are considered and contrasted against potential deficiencies of mathematics methodologies and curricula that are based on mainstream educational philosophies. The educational philosophies utilized to form early-grade mathematics methodologies and related curricula are judged to be the main reasons for low levels of interest in the subject of mathematics by student populations. An exploration of available literature in regard to how the human brain learns is provided. Two unifications are resultantly hypothesized: interest and learning appear to be mentally intertwined, this unification may serve as the basis for a more effective educational methodology; children are nearly universally interested in the visual arts, arithmetic and geometric mathematical principles are intertwined with the visual arts principles of linear perspective and proportion. An early grade curriculum that relates those mathematical principles via artistic methods (similar to those developed and utilized by master artists and engineers of the Renaissance era) may prove broadly effective at equitably increasing students' mathematical achievement. Future research in such a direction is highly recommended.

Keywords

Mathematics, Education, Art, Educational Philosophy, Educational Methodology, Educational Curriculum, Effective Learning, A Very Brief History of Education, Science of Learning

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Cover Page Footnote

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The Efficacy of Mathematics Education

Eric Geimer

This literature review uncovers severe deficiencies in modern mathematics education. These deficiencies extend beyond the United States (US), internationally. Effectively reversing these mathematics education deficiencies could yield great economic benefit (Peterson, Woessmann, Hanushek, and Lastra-Anadón, 2011, p. V). Large-scale educational problems appear to be highly wicked. By wicked the author means intractably multifaceted to an indeterminate degree. Behind the wickedness of education-related problems are the very educational philosophies utilized to form methodologies and curricula.

Current mathematics curricula create an unintentionally induced low level of interest in mathematics. There have been recent research efforts regarding how the human mind learns (Tsai, Kunter, Lüdtke, Trautwein, & Ryan, 2008), specifically regarding mathematics (Gunderson, Ramirez, Beilock, & Levine, 2012). Hypothetically a new educational methodology based on student interest and an early grade mathematics curriculum based on a blend of arithmetic, geometric, and artistic linear perspectives and proportions could lead to lower rates of student disinterest regarding mathematics, and resultantly to greater, more equitable mathematical proficiency throughout current and future student populations.

Indications of a Problem

The US' educational apparatus is not effectively and equitably educating the American student body such that they will be able to maintain and improve upon the society they inherit to a competitive degree. For the US to stay competitive education must change so that Science, Technology, Engineering and Mathematics (STEM) subject matter related capital is adequately produced (United States Commission on National Security, 2001, p. IX,); data from the 2012 the Program for International Student Assessment (PISA) shows that American students performed below average in mathematics, ranking 26 out of the 34 OECD countries with participating student bodies (OECD, 2013, p. 1).

The achievement gap between US students and their peers in other industrialized nations regarding mathematics knowledge has existed, and grown, for the past forty years (Ornstein, 2010). This timespan is the total span of time that measurements have been taken.

Overcoming the longstanding problem of poor performance in math by the US student body may yield substantial economic benefit (Peterson, et al., 2011). Economic growth has been projected should American students increase their average mathematical comprehension. Should parity with South Korean students be reached per capita GDP growth is estimated to increase by 1.3%, annually. That represents an additional \$75,000,000,000,000.00 over the next 80 years (Peterson, et al., 2011).

Discovering how widespread the problem of non-optimal mathematics proficiency is could yield important information. National distributions of mathematical achievement are consistently highly negatively skewed no matter national rank regarding mathematics proficiency (Huang, 2009). Based on Huang's analysis all ranked nations would benefit economically from a marked improvement in the effectiveness of their national mathematics education systems. This is due to the increased reasoning prowess afforded individuals with retained mathematical proficiency. Mathematics allows for greater problem solving ability. An inability to adequately address problems that arise in markets may lead to a reduction in the economic growth of nations. Therefore, nations offering relatively inferior mathematics educations may see their economic growth lag behind peer nations that provide superior mathematics educations.

Commonly Proposed Causations of National Educational Performance

Lay hypotheses such as the notion that societal composition including differences in ethnicity, gender, and/or race somehow account for a nation's average mathematical proficiency are evidentially baseless Horn (1990), Caporrimo (1990), Drew (1992), Huang and Waxman (1993), Catsambis (1994), Sax (1994), and Hall, Davis, Bolen and Chia (1999). Such notions have been relegated to the status of careless prejudice in modern times. Other commonly cited factors such as a government's educational policy, an education system's structure, educational standards, or education workers' unions, if they play a role in the US student body's mathematics deficit, cannot account for the high levels of negative skew observable in the performance of all national student bodies' mathematics performances. Modern education appears to be a "wicked problem." Wicked problems are so persistent that they seem insoluble. Unlike tame problems found in chess or cost accounting, wicked problems tend to shift when solutions are attempted. "Their solutions are never right or wrong, just better or worse"

(Mascarenhas, 2009, p. 1). Thus, there may be some other, common, root-factor at play in regard to the worldwide mathematics education dilemma that, when applied, eliminates math education's "wickedness."

Educational Philosophies as Cause of the Mathematics Education Dilemma

Not all current, major institutions and organizations prevalent in the industrialized world have practices only based on scientifically garnered data. "Institutional theory" indicates that there are deep, resilient aspects of prior cultures in any modern social structure (Scott, 2004). Resultantly educational systems and their associated methodologies and curriculum are not concretely, scientifically derived and defined systems:

"Philosophy provides... curriculum specialists, with a framework for organiz[ation]... It [provides] purpose... subjects... of value, how students learn, and what methods and material to use. Philosophy determin[es] the goals of education, subject content['s]... organization, the process of teaching and learning, and... what experiences and activities to stress..." (Ornstein, 1990, p. 102)

Math education is failing students because none of the founding minds of the major educational philosophies around which methodologies and curricula are designed knew how to most effectively and efficiently induce learning in the minds of students. There is evidence that current education systems are turning students off from the subject of mathematics to such a degree that merely the anxiety produced when contemplating mathematical tasks can induce physical pain (Lyons & Beilock, 2012). Mathematics is integral to interfacing with the world; positive changes in STEM areas are derived through that interface. If learning mathematics is shown to students as what it is, an intimate aspect of reality, as well as a tool to use in multiple contexts, a greater number of students may become engrossed by the study of mathematics. Research has shown that mathematical beauty correlates with activity in the brain in the same way people experience beauty as derived from other sources (Zeki, Romaya, Benincasa, & Atiyah, 2014, p. 1). Educational systems can be made to make use of this correlation.

Effectively Inducing States of Learning

The problem with widely utilized mathematics curricula is that the vast majority of students in modern math classes are disinterested (Moody, 1977), (Mora, 2011).

Learning is most efficiently induced when the mind wanders into a psychological state known as “interest experience.” This psychological state is related to the psychological state known as “flow” (Csikszentmihalyi, 2008). The brain enters these states due to stimuli that elicit actions driven by internal enjoyment rather than external pressure. Interest experience is not being effectively induced the majority of the time pupils currently spend in the classroom, or in the majority of pupils (Tsai, Kunter, Lüdtke, Trautwein, & Ryan, 2008).

Tsai et al.’s 2008 findings seem to be a scientific base on which to build an educational methodology that could enhance knowledge retention for students in any subject, including mathematics. This methodology would enhance learning rates of subject material by promoting curricula that had previously been shown to provoke interest in a majority of pupils in a given grade range. The visual arts appear to be of nearly universal interest to young children. Supporting evidence of this near universal interest in visually artistic endeavors is the long-term success of child oriented art supply companies such as “Crayola.” The visual arts may be the key to establishing a modern, widely effective, scientifically testable early grade mathematics curriculum. There are physiological changes that occur on the neuronal level within parts of the human brain. There are also associated alterations in mental processing of mathematical logic in relation to experience with spatial stimuli, although the exact processes and associations (as of 2008) remained unclear (Ansari, 2008). Spatial and mathematical development is intertwined (Gunderson, Ramirez, Beilock, & Levine, 2012).

The Renaissance as a Model for Mathematics Education

The discovery by Brunelleschi that geometric principles utilized in engineering and architecture could also be utilized to accurately depict three-dimensional space in two-dimensions set the groundwork for the masterful artistry that followed, throughout the Renaissance (Alberti, Kemp, 1991). The masters of the Renaissance did not only have a natural predisposition for success in the arts, but combined studies in math and art to achieve their profound skills. The Renaissance masters’ study of mathematics improved their spatial

awareness, and their practice to improve spatial awareness also improved their mathematical comprehension. Many including Leonardo Da Vinci, Michelangelo, and Raphael became engineers and architects, too.

The PISA 2012 US Country Note lays out five mathematically related weaknesses most faced by American students, including:

- Substantial mathematization of a real-world situation – requiring students to establish a mathematical model of a given real-world situation in the form of a term or an equation with variables for geometric or physical quantities, before further actions (especially calculations) can take place. Students have to understand the situation and activate and apply the appropriate mathematical content
- Reasoning in a geometric context – requiring authentic reasoning in a planar or spatial geometric context by using geometric concepts and facts (OECD, 2013, p. 3)

The utility of mathematics is so great because this cognitive tool allows humanity to model reality more effectively than any other. Mathematics' singularly great utility is the reason for its importance. The best way to communicate the importance of mathematics to students is to showcase its utility. This communication should occur at an early age. The most effective way to achieve this communication may be to utilize the Renaissance derived principles of perspective and proportion over a Cartesian coordinate system. An example of a similar practice can be seen in this image taken at the 2012 Sarasota, FL Chalk Festival:

One can imagine how such curriculum could be employed to communicate math's connectedness to our world all the way from basic arithmetic problems such as additions of sets of numbers and explorations of their constituent parts, to geometric principles, all the way to expressions of sine and cosine illustrated as naturally by the student as these concepts are in the natural world. In this way, activation of student's interest experience may be tapped. Students may be more likely to retain the contents of mathematics lessons, especially in relation to geometric reasoning, allowing for application of mathematical logic when solving real-world problems.

Conclusion

This work illustrates a unity of interest and learning, and further illustrates how principles of basic math and visual art can form the basis for a universally effective, early grade mathematics curriculum. Incorporating or pairing mathematics education with the visual arts will excite and expand the intellectual scope of students. Historical evidence from the Renaissance era supports this hypothesis. The historical evidence also illustrates how expansion of mathematical comprehension leads to economic benefit through increased inquiry and invention.

Educational philosophies are the root cause of the wickedness of educational dilemmas. The knowledge base for development of scientifically derived educational methodologies, specifically an early grade mathematics curriculum exists. This curriculum will likely blend arithmetic and geometric concepts with artistic, linear perspective and proportion decreasing student disinterest of mathematics. An increase in frequency of mathematical proficiency may result, which could lead to greater economic growth (Peterson, et al., 2011). Future, related research is recommended. Research should be conducted first, toward the development of an optimized curriculum. Second, social science research in an actual classroom setting should occur to study the effects of the hypothetical curriculum compared to traditional curricula.

References

- Alberti, L., & Kemp, M. (1991). *On painting*. London: ePenguin.
- Ansari, D. (2008). Effects of development and enculturation on number representation in the brain. *Nature Reviews Neuroscience*, 9(4), 278-291. doi:10.1038/nrn2334
- Aquinas, T. (1953). The teacher. In R. W. Mulligan, J. V. McGlynn, R. W. Schmidt & J. Kenny (Eds.), *TRUTH* Retrieved from <http://dhsprory.org/thomas/QDdeVer.htm>
- Bagley, W. (1938). *An essentialist's platform for the advancement of American education*. Baltimore, MD
- Bestor, A. (1988). *Educational wastelands: The retreat from learning in our public schools*. (2 ed., pp. 1-304). Champaign, IL: University of Illinois Press.
- Brameld, T. (2000). *Education as power*. New York, NY: Caddo Gap Pr.
- Caporrimo, R. (1990, August). Gender, confidence, math: Why aren't the girls where the boys are? Paper presented at the annual meeting of the American Psychological Association, Boston.
- Catsambis, S. (1994). The path to math: Gender and racial-ethnic differences in mathematics participation from middle school to high school. *Sociology of Education*, 199-215.
- Comptroller General of the U.S., W. C. (1976). *The National Assessment of Educational Progress: Its Results Need to be Made More Useful*. Report to the Congress by the Comptroller General of the United States.
- Cottle, P. (2011). A State-by-State Science and Engineering Readiness Index (SERI): Grading States on Their K-12 Preparation of Future Scientists and Engineers. In *A SP Forum on Education* (p. 7).
- Csikszentmihalyi, M. (2008). *Flow: The psychology of optimal experience*. (1st ed., p. 336). New York, NY: Harper Perennial Modern Classics. Retrieved from <http://www.amazon.com/Flow-The-Psychology-Optimal-Experience/dp/0061339202>
- Dewey, J. (1897). My Pedagogic Creed. *The School Journal*, 77-80.
- Drew, D. (1992, April). Affective and behavioral components of undergraduate science education. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.
- Education Commission of the States, D. s. (1976). *Mathematics Technical Report: Summary Volume*. National Assessment of Educational Progress.
- Gunderson, E. A., Ramirez, G., Beilock, S. L., & Levine, S. C. (2012). The relation between spatial skill and early number knowledge: The role of the linear number line. *Developmental Psychology*, 48(5), 1229-1241. doi:10.1037/a0027433
- Hall, C. W., Davis, N. B., Bolen, L. M., & Chia, R. (1999). Gender and Racial Differences in Mathematical Performance. *Journal Of Social Psychology*, 139(6), 677-689.
- Hayes, W. (2008). *The progressive education movement, is it still a factor in today's schools?*. United Kingdom: Rowman & Littlefield Pub Inc.
- Horn, L. (1990, April). Trends in high school math and science course taking: Effects of gender and ethnicity. Trends in high school math and science course taking: Effects of gender and ethnicity. Paper presented at the annual meeting of the American Educational Research Association, Boston.

- Hirsch, E. D. (1988). *Cultural literacy: What every American needs to know*. New York: Random House, Inc.
- Hirsch, E. D. (2009). *The making of Americans*. New Haven and London: Yale University Press.
- Huang, M. (2009). Beyond Horse Race Comparisons of National Performance Averages: Math Performance Variation within and between Classrooms in 38 Countries. *Educational Research And Evaluation*, 15(4), 327-342.
- Huang, S.L., & Waxman, H.C. (1993, May). Comparing Asian- and Anglo-American students' motivation and perceptions of the learning environment in mathematics. Paper presented at the annual conference of the National Association for Asian and Pacific American Education, New York.
- Hutchins, M. (1953). *University of utopia*. (2 ed., pp. 1-103). Chicago, IL: University of Chicago Press.
- Lyons IM, Beilock SL (2012) When Math Hurts: Math Anxiety Predicts Pain Network Activation in Anticipation of Doing Math. *PLoS ONE* 7(10): e48076
doi:10.1371/journal.pone.0048076
- Lopata, C., Wallace, N. V., & Finn, K. V. (2005). Comparison Of Academic Achievement between Montessori and Traditional Education Programs. *Journal Of Research In Childhood Education*, 20(1), 5.
- Mascarenhas, O. (2009). *Innovation as defining and resolving wicked problems*. Unpublished manuscript, ENT 470/570 , <http://www.google.com/>
- Moody, W. B. (1977). Arithmetic: must it be mechanical monotony and individualized boredom?. *Arithmetic Teacher*, 2465-69.
- Mora, R. (2011). "School Is So Boring": High-Stakes Testing and Boredom at an Urban Middle School. *Penn GSE Perspectives on Urban Education*, 9(1)
- Newman, J. H., & Svaglic, M. J. (1982). *The Idea of a University, defined and illustrated in nine discourses delivered to the Catholics of Dublin in occasional lectures and essays addressed*. University of Notre Dame
- Organization for Economic Co-operation and Development (OECD)(2013) *PISA (Program for International Student Assessment) United States- Key Findings*. OECD. Retrieved from: <http://www.oecd.org/pisa/keyfindings/PISA-2012-results-US.pdf>
- Ornstein, A. C. (1990). Philosophy as a basis for curriculum decisions. *High School Journal*, 74102-109.
- Ornstein, A. C. (2010). Achievement Gaps in Education. *Society*, 47(5), 424-429.
- Ornstein, A. C., & Levine, D. U. (1990). *School Effectiveness and Reform: Guidelines for Action*. The Clearing House, 64(2), 115-118.
- Peterson, P. E., Woessmann, L., Hanushek, E. A., Lastra-Anadon, C. X., & Harvard University, P. (2011). *Globally Challenged: Are U.S. Students Ready to Compete? The Latest on Each State's International Standing in Math and Reading*. PEPG 11-03. Program On Education Policy And Governance, Harvard University
- Pritchett, L., & Viarengo, M. (2009). *The illusion of equality: the educational consequences of blinding the weak states*. Centre for Global Development.

- Scott, R. Department of Education, State Board of Education. (2013). *Letter to chairman of the Florida state board of education*. Retrieved from Florida State Government website: <http://www.flgov.com/wp-content/uploads/2013/09/ChairmanChartrand092313.pdf>
- Scott, W. R. (2004). Institutional theory P408-14 In: Encyclopedia of Social Theory, George Ritzer, ed.
- Thompson, B., Education Commission of the States, (2009). "International Benchmarking. The Progress of Education Reform. Volume 10, Number 2." Education Commission Of The States ERIC, EBSCO host.
- Tsai, Y., Kunter, M., Lüdtke, O., Trautwein, U., & Ryan, R. M. (2008). What makes lessons interesting? The role of situational and individual factors in three school subjects. *Journal Of Educational Psychology*, 100(2), 460-472. doi:10.1037/0022-United States Commission on National Security, The, (2001). Road Map for National Security: Imperative for Change. Report of the U.S. Commission on National Security / 21st Century (Phase III), p. I
- Weinberg, D. R. (2012). The Need for Precision. *Montessori Life: A Publication Of The American Montessori Society*, 24(2), 28-29.
- Zeki, S., Romaya, J. P., Benincasa, D. M., & Atiyah, M. F. (2014). The experience of mathematical beauty and its neural correlates. *Name: Frontiers in Human Neuroscience*, 8, 68.