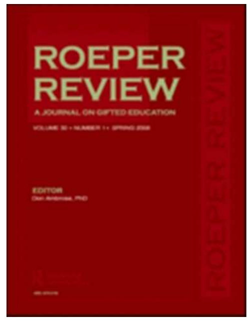

Dimensions of Mathematical Thinking and Learning in ACCEL (Special Issue: Wisdom in a Changing World)

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Dimensions of Mathematical Thinking and Learning in ACCEL

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Abstract: Sternberg summarizes the history of identification of giftedness in the 20th century and presents a case for the shortcomings of measures such as IQ for problem solving skills required in the 21st century. The *A*ctive *C*oncerned *C*itizenship and *E*thical *L*eadership (ACCEL) model is proposed to replace the outdated construct of IQ, particularly for the field of gifted education. In this commentary, the mathematical dimensions of ACCEL are teased out in contrast to its presence in psychometric testing. Further, what is considered as relevant in mathematics for learners today is addressed in relation to the skills outlined in the ACCEL model.

Keywords: IQ; ACCEL model; Interdisciplinary mathematics; Mathematical Modeling; Standardized Testing; Mathematics Curricula

Introduction

Psychometry as a discipline has a long history of intertwinement with mathematics. Modern day intelligence tests evolved out of the original Binet-Simon test and the Stanford-Binet test developed by Lewis Terman. These tests consist of subtests which measure numerical reasoning, digit memory, letter-number sequencing, digit symbol-coding, picture completion, block design, matrix reasoning, symbol and object assembly. In other words logical, quantitative and visualspatial reasoning play a significant role in IQ tests (Sriraman, 2009). High scores on the Stanford-Binet have been used as an indicator of giftedness and a predictor of academic success in school and beyond. To a person schooled in mathematics, an IQ test very much resembles a *traditional* math test if one ignores the verbal part. The implication is that someone who performs well on an IQ test is predicted to be successful in traditional school mathematics. This begs the question: what is “traditional” school mathematics?

The Changing nature of Mathematics

Simply put, traditional school mathematics in the U.S is anchored in a curriculum that views Calculus as its pinnacle. In other words, the courses that are taken in the K-12 curriculum, particularly in high school, namely Algebra, Geometry, Functions and Pre- Calculus develop the foundations needed to study Calculus. The Calculus sequence also serves as the gateway/gatekeeper course(s) at the college level into other disciplines like Engineering, Physics and so on, or in modern parlance to the STEM disciplines. The question then becomes the relevance of 300+ year old mathematics, namely the Calculus of Sir Isaac Newton (and Leibniz) in the 21st century. Is it still relevant? and why is traditional school mathematics still anchored in it? This is a fundamental question for mathematics curriculum analogous to Sternberg’s phrase for IQ- “has an idea outlived its usefulness?”

In the 21st century, mathematics is inundated with problems that require statistical and big-data analytic methods, and new inter-disciplinary line of inquiry that emerged from problems in biology. In other words is Calculus more or less obsolete other than serving as a sieve or a gatekeeper course at universities for entry into other majors? It is very relevant to students of Physics whose curriculum includes classical physics (mechanics, optics etc.), and the language of multivariable Calculus forms the bedrock of Physics in the language in which it is expressed. Therefore one cannot dismiss Calculus entirely. However, 20th century mathematics developed as a reaction to foundational issues in 19th century mathematics in the domains of analysis, set theory and geometry. Bressoud (2005) captures the essence of traditional mathematics that became a part of U.S curricula as one that required *introspection*, with *New Math* of the 1960s as an outcome. Set theory in *New Math* mathematics is a journey into its logical foundations and the architecture of rigor, and a glimpse into pure areas of mathematics (algebra, analysis and topology). He further claims that in the latter part of the 20th century, the discipline of mathematics missed opportunities with relevant problems that were present in industry. During this period of insularity, discrete mathematics unlike continuous mathematics (which leads to Calculus) did make inroads into solving real world problems that required the use of optimization techniques from graph theory (e.g., optimizing airplane routes, bus routes; the traveling salesman problem etc.).

The (not so) Changing nature of Testing

In the 1990s one sees a nuanced shift in the nature of testing particularly in the Scholastic Aptitude Test (SAT), which like the American College Testing (ACT) was rooted in items requiring traditional algebra-geometry-pre Calculus. The SAT began to have more "applied" problems that required the additional skill of applying the relevant mathematics. This slight change in the SAT was co-incidental with the National Science Foundation sending a call for more mathematical modeling and statistics in the school curricula and funded 9 multi-million dollar statewide systemic initiatives in mathematics and science in Connecticut, Maine, Montana, Louisiana, Michigan, California, Arkansas, Delaware and New York. This was the biggest reform push since the *New Math* of the 1960s and signaled an awareness of the need to adapt the mathematics curricula to problems that were relevant for industry. Mathematical modeling was deemed extremely relevant to the problems being solved in the physical and natural sciences (e.g., modeling the spread of infectious diseases; modeling population, modeling complex systems, modeling climate change etc.). Core Plus Mathematics (CPM) and Systemic Initiative for Montana Mathematics and Science (SIMMS) are good examples of high school curricula that successfully integrate mathematical modeling, discrete mathematics and statistical thinking relevant for real world problems. Although there is a push to engage younger students in STEM in order to develop interest, there are no systemic efforts per se. In spite of the changing nature of mathematics and the changing nature of problems requiring mathematics (see next section), ironically testing like IQ measures still continues to be anchored around the traditional mathematics curriculum. It is no coincidence that high scores on the SAT correlate highly with IQ scores and is used by defenders of traditional testing to perpetuate the status quo. The paradox is- a high IQ predicts high "traditional" academic achievement, and in turn results in high scores on the SAT, which translates to "success"; which is then used to defend traditional testing measures!

Sternberg's "Big 10" – the relevance of interdisciplinary mathematics

Very often initiatives are simply a reaction to policy directives from "the sky is falling" type reports from different national agencies. The ten questions posed by Sternberg are very relevant to the mathematical sciences because answering many of them require the ability to handle "big data" and the use of avant-garde data analytic skills (from statistics). Many of the problems occur at the intersection of biology, mathematics and computer science in interdisciplinary areas such as mathematical biology, mathematical genetics and bio physics. In 2002 John Ewing, the erstwhile director of the American Mathematical Society predicted the increasing presence of problems from biology which would require the attention of mathematicians, especially those that involved hitherto unimaginable sets of data (e.g., the human Genome project). Many national bodies in the U.S including *The National Commission on Mathematics and Science Teaching for the 21st Century* increasingly lament the under preparation of students for the current economy and workforce with calls for connecting mathematics (internally) and externally to relevant problems. *The National Academies Report* Bio2010 specifically recommends the transformation of undergraduate programs to accommodate, assimilate, synthesize and pursue inter-disciplinary approaches to the training of biologists. Biology and Mathematics have traditionally been *very* separate disciplines before the advent of biomedical research and biological datasets (Reed, 2004). Biology now requires computational approaches to understand data sets, as well as algorithms that mathematics can offer. Mathematics on the other hand is more or less divorced from biology other than contrived exercises in a Calculus or Differential equations book. Mathematical Biology is a new discipline today that requires training in both biology and computational mathematics to tackle problems that require inter-disciplinary skills. Numerous other examples of good problems are presented by Sternberg- which involve “decision making” skills based on available data, and those that require ethical skills based on qualitatively analyzing information. Philosophy as a discipline today is also increasingly relevant in ethical problems that arise at the frontiers of medical and military technology.

The current flux and unpredictability of globalization and its impact on the US work force is much debated. An underlying feature is concerns about maintaining competitiveness in a world shrunk by advances in information technology (e.g out sourcing of jobs). For example, being a radiologist once conferred job security in the medical system, however a radiology technician can just as easily perform the mechanical aspects of the job such as taking an MRI etc., and results can be sent to radiologists in other parts of the world that can interpret the results and make a diagnosis, for a fraction of the cost! The same is true for jobs in Accounting, Law and even Engineering, where the trained and very often surplus workforce from a different country easily compiles excel worksheets, summarizes law briefs and produces designs for a fraction of the cost incurred in the U.S.

Concluding thoughts- Is the sky falling?

The results from the 2016 U.S presidential elections indicates that a large segment of the American public feels disenfranchised and threatened by globalization. When one also factors in results from international comparison tests like Program for International Student Assessment (PISA) and Trends in Mathematics and Science Study (TIMSS), U.S performance suggests a lag in math and science competencies compared to other developed countries of the world, especially at the K-8 level. It begs the question: Why do students who score well on traditional standardized tests often perform poorly in more complex "real life" situations where mathematical thinking is needed? Recent studies based on models & modeling perspectives of mathematical thinking and learning demonstrate that the knowledge and abilities that students develop tends to be significantly different depending on whether learning activities focus on: (a) realizing mathematics - by first teaching what is to be learned and then applying these concepts or abilities in realistic situations, or (b) mathematizing reality – that is by first putting students in sense-making situations where the conceptual systems that they develop on their own are later de-contextualized and formalized (Lesh & Sriraman, 2005). The answer might lie in Sternberg's statement:

"The problems that society needs its gifted individuals to solve in the 21st century require much more than IQ—they require as well as analytical, IQ-like skills, also creative, practical, and wisdom-based and ethical skills."

Long ago, the American pragmatist John Dewey emphasized the fact that making science practical involves significantly different educational goals than making practice scientific. Similarly the goal of measurement should not be to succumb to the Flynn effect- i.e., invoking a measure and tweaking it simply because it can be used to confer "objectivity". The essential message in the ACCEL model proposed by Sternberg is that the creative, ethical and practical dimensions need to be cultivated in tandem with analytical skills. The latter without the former is akin to a person having an enormous mathematical tool kit obtained from traditional schooling, yet unable to apply it to a relevant and practical problem.

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