Opinion

Technology, Education, and the Single Salary Schedule

It is due to scientific progress and technological innovation, more than any other reason, that crop yields have gone up, that starvation has decreased, that human longevity has increased, and that the material conditions of our lives have continually improved. Our best hope for addressing resource scarcity, plagues, and other less forseeable disasters is continued scientific and technological progress. We must produce scientists and engineers. Systemic changes are required to produce more. And the more the better. Changing the culture of mathematics and science education by increasing the percentage of mathematics and science teachers with more than a shallow knowledge of the subjects they are teaching may be the solution.

I regularly hear students tell me that they were "never good at math". Almost any student can be good at math—certainly at primary and secondary school levels. This failure is not inherent in the subject matter. I believe that my students' attitudes about math are transmitted to them by underprepared teachers who were themselves not good at math. Richard Ingersoll at the University of Pennsylvania has found that 35 percent of high-school mathematics classes are taught by someone without even a minor in mathematics or a mathematics-related subject.[1] These teachers often have to look at solution manuals to solve classroom problems.

Genuine knowlege of the subject matter will not guarantee that a teacher will be successful, much less compelling, but successful and compelling teaching certainly requires genuine subject knowledge. Mathematics and science teachers should have degrees in the subjects they teach. The "No Child Left Behind" act does nothing towards this goal. A "highly qualified" high-school mathematics teacher, for instance, must only pass a certification exam. (In some states, such as Georgia, you can score less than 50 percent and "pass".[2]) The majority of mathematics-instruction certification exams, according to a study by the Education Trust, were dominated by high-school level material (mostly tenth to eleventh grade material).[3] A teacher who passes a certification exam but does not have a mathematics degree is unlikely to have a confident, much less deep, knowledge of the subject matter.

According to the Center for the Study of Teaching, the best predictor of student acheivement in science and mathematics is the presence of a teacher with a bachelor's degree in the subject taught and who is fully certified.[4] California is attempting to put more teachers with mathematics and science degrees in the classroom; the state's university system just inaugurated an accelerated program to prepare mathematics and science majors for the classroom. In June 2005 California State University Chancellor Charles Reed said, "Math and science is tied to California's economic future. Nothing we can do could be more important than preparing math and science teachers for California students."[5]

California proposes some economic incentives in the form of student loan forgiveness (up to US$19,000) in order to achieve their goal.[6] The National Academies, whose recent report on educational reform emphasizes the importance of teacher content expertise, advocates programs like California's as its primary recommendation for increasing the number of mathematics and science teachers with degrees in these subjects.[7] What these incentives do not address is that, according to a study by Ingersoll, 39 percent of K–12 teachers leave teaching altogether within five years (he estimates a slightly higher percentage for math/science teachers). 66 percent of math and science teachers cite "poor salary" as a reason for leaving.[8]

California's plan may yield more mathematics and science teachers with degrees—but does not increase their incentive to stay in teaching after entering the profession. Higher salaries for these teachers—possibly much higher—are almost certainly required to achieve this goal. This solution, surprisingly, is not discussed in the National Academies' report. Salary differentiation is not new in education—it is standard at universities where harder-to-attract positions (such as medical professors) are paid more than others (for instance, journalism professors).

There are two significant obstacles to this proposal: its cost and opposition from teachers' unions. Taxpayers will have to pay these salary premiums. Taxpayers must be convinced that the costs of better mathematics and science education will be more than outweighed by the benefits. It is possible that this will not occur until some catastrophic event (such as an energy crisis or plague) inspires the recognition that continued technological innovation requires better mathematics and science education.

The second obstacle is union opposition. Teachers' unions are not opposed to paying teachers more. What they argue though is that all teachers are equally valuable and all should be paid more. This position is enshrined in the "single salary schedule" used in 96 percent of public schools[9]: under this system, teacher pay is determined by longevity and by the attainment of any advanced degrees. What is proposed here is a bifurcated salary schedule—secondary school science and mathematics teachers should be paid on a different schedule. The relative "value" of teachers of different subjects is not in question. The only issue addressed here is how to address society's (our) technological needs.

A direct benefit of this proposal would be an increase in the production of science and mathematics degrees. Some of these degree earners, originally motivated to teach, will likely be drawn to business, government, and the pursuit of advanced degrees. It is reasonable to believe that an indirect benefit will in time be a measurable change in our cultural attitudes towards mathematics and the sciences.

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[1] *Craig D. Jerald,* All Talk, No Action, *The Education Trust, 2002.*

[2] *"Not good enough: A content analysis of teacher licensing examinations",* Thinking K–16, *Volume 3, Issue 1, The Education Trust, 1999.*

[3] *ibid.*

[4] *The National Academies' Committee on Science, Engineering, and Public Policy,* Rising Above the Gathering Storm, *The National Academies Press, 2005, p. 5-5.*

[5] *Tanya Schevitz,* San Francisco Chronicle, *1 June 2005.*

[6] *ibid.*

[7] Rising Above the Gathering Storm, *p. 5-1.*

[8] *R. Ingersoll, "Turnover among mathematics and science teachers in the U.S.", prepared for the National Commision on Mathematics and Science Teaching for the 21st Century, 2000.*

[9] *K. Gruber, S. Wiley, S. Broughman, G. Strizek, M. Burian-Fitzgerald, U. S. Department of Education,* 1999–2000 Schools and Staffing Surveys, *2002.*

Letters to the Editor

Definitions of Fractions as a Discriminator

The timely review "Mathematicians and mathematics textbooks for prospective elementary teachers" by Raven McCrory (*Notices* **53**, No. 1) is a start at making a critical appraisal of the recent texts written by mathematicians for a math content course given to prospective elementary school teachers. How do these texts compare to the traditional texts and to each other? As a means to address these questions, McCrory proposes to focus on the definition of fractions in each of the four mathematician-authored texts (one by S. Beckmann, one by T. H. Parker and S. J. Baldridge, one by H. H. Wu, and one by me [AMS 2003]). She concludes that the definitions are not word-for-word identical, even though it is evident that they are logically equivalent. Rather than compare the explanations for clarity, completeness, and depth, she dwells on the fact that the definitions are not literally identical. This is the wrong emphasis.

In her conclusions, McCrory writes, "The problems with definition of fractions illustrate the complexity of this endeavor, and suggest that we have a long way to go before we reach conclusive answers to the questions of what mathematics we should teach prospective elementary teachers and how it should be presented." Yet all four mathematician-authored texts include fractions. She continues in the next paragraph, "…there is no single 'correct' version of this mathematics." There certainly is. Its essential points and difficulties are written out in detail in Book VII of Euclid's *Elements*. That leaves us with the question of how fractions should be presented to elementary teachers. There is much more to this than the wording of definitions. Prospective elementary school teachers can learn this material, in the depth it is presented in my text, as I've observed year after year in my course. McCrory continues, "and we do not know what confusion is generated over time by the small but significant differences in what teachers are taught." If she means differences in wording, then this is nonsense. If she means the difference between how these four texts present fractions and how it is presented in one of the traditional texts that she quotes at the top of the right column of page 25, she is absolutely right.

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Response to Jensen

I appreciate Gary Jensen's thoughtful response to my recent article (*Notices* **53**, No. 1) and want to apologize for my error in citing his book. I have personally owned the book (Jensen, G. R., *Arithmetic for Teachers: With Applications and Topics from Geometry*, American Mathematical Society, Providence, RI, 2003) since the first week it was published and have shared it with many people. This was an oversight on my part.

The problem that Jensen points to with my article suggests that I have not made clear an essential point. It is not that the definitions of fractions in these books fail to be identical. No one would expect several different books to contain identical language in their definitions. Rather, the question is whether the definition in a given book will help future teachers make mathematical sense of other approaches or definitions he or she encounters as a student and teacher. Jensen says that the definitions are logically equivalent, and he is no doubt right. My point is that learning a single, correct definition (especially one that is full of subtlety) may not equip a teacher to understand the logical equivalence of other definitions.

These books, especially those by mathematicians, include nuances across definitions. While perfectly clear to the mathematically sophisticated, such subtleties are beyond the ken of most students preparing to be elementary teachers. I am not suggesting that these students could not, or do not, understand the presentation of the mathematics in a given book. At my own institution, as at Jensen's, we have very good elementary education students who work diligently to succeed and, for the most part, learn what we try to teach them. My argument goes to how they will be able to use that knowledge when confronted with a different version of fractions. These prospective teachers will see numerous treatments of fractions: their own elementary, middle and high school textbooks; the mathematics books and classes they take in college; and then the wide-ranging, sometimes inconsistent materials with which they teach; as well as district, state, and national standards for K-8 mathematics. We must pay attention to giving them the "profound understanding of fundamental mathematics" (Ma, L., *Knowing and teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States*, Lawrence Erlbaum, Mahway, NJ, 1998) that will enable them to see and understand the logical and practical equivalence of the many versions of fractions (and other mathematical ideas) they will encounter. Presenting correct mathematics in their undergraduate textbooks and courses is the beginning, but not the end, of this effort.

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Molière and Mathematics

From time to time we hear of nonmathematicians being averse to mathematics. The writer Molière can help nonmathematicians appreciate math. He tells of a person who wants to learn prose. But as soon the tutor starts teaching prose to the person, the learner realizes he had been speaking and writing prose all his life. Similarly, nonmathematicians do not (wish to) realize that they have been doing certain mathematics since they started learning their nonmathematical disciplines. I consider how a taxonomy of function and sets is isomorphic to (expressing) four nonmathematical fields.

First, social science says the state may be democratic or dependent on citizen participation, isolated from citizens, or can be anarchic. Mathematics would say democracy means the state is a function of citizens, isolation means state and citizens are disjoint sets without either being a function of the other, and anarchy denotes there is only one set containing individuality alone. Second, religion speaks of asceticism where institutions may be dependent on a transforming individual spirituality, dualism means institutions isolated from spiritual individuals, and individuals escaping the world mean one set exists with the sole member as the person. Mathematics would say institutions can be a function of spirituality transforming the world, institutions and spirituality as mutually exclusive are disjoint sets, and individuals as fleeing the world mean there is one set containing spirituality alone as the member. Third, in philosophy, phenomenology says words depend on culture or values, dualism denotes that words are exclusive of values, or we have only values and existentialism. Mathematics would say that phenomenology means words are a function of values, dualism means words and values are disjoint sets, and existentialism means we have only a set containing values and no words or reasoning. Fourth, in theology, theism says God is dependent on our historical acts, deism means God and the world are mutually exclusive, while atheism says only the world exists and there is no God. In mathematics, theism would mean God is a function of history, deism denotes God and the world as disjoint sets, and atheism means only one set with one member as persons.

The above implies that religion, social science, theology, and philosophy do mathematics as soon as they articulate their own fields.

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Selected Reviews in the *Bulletin*

The new features in the January *Bulletin* are excellent, and I especially enjoyed the "Selected Mathematical Reviews". But I suggest that these reviews be looked at critically and clarifying comments be appended where appropriate.

A case in point is the reprinted review of "The ergodic theoretical proof of Szemeredi's theorem" (Furstenberg, Katznelson, and Ornstein, *J. Analyse Math.* **31**, 1977). I found the reviewer's paraphrase of the main result, Theorem 1.4, is extremely confusing. The following clarification may help readers who were as puzzled as I was. The result in question is this:

If T is a measure-preserving transformation in a probability measure space and A is a set of positive measure, then for any integer $k > 1$ there is an integer $n > 0$ such that the intersection of the sets $T^{jn}(A)$, $(j = 0, \ldots, k-1)$, has positive measure.

The reviewer added the true but pointless conclusion that A contains a set B of positive measure (which is never mentioned again). And he considerably weakened the theorem by inserting the unnecessary hypothesis that T is invertible.

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Mathematics in the Media

Philip Davis's perspectives on mathematics and the media are insightful ("The media and mathematics look at each other", *Opinion*, by Philip J. Davis, March 2006 *Notices of the AMS*, Vol. 53, No. 3, p. 317). The AMS Public Awareness Office appreciates his interest and experience, and his articulation on the challenges, and wishes to point readers to "Math in the Media", a collection of monthly postings including "Tony Phillips' Take on Math in the Media", "Math Digest", and "Reviews" of books, plays, and films with mathematical themes, at www.ams.org/mathmedia. The resource presents an overview of how mathematics is currently handled by the media.

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Submitting Letters to the Editor

The *Notices* invites readers to submit letters and opinion pieces on topics related to mathematics. Electronic submissions are preferred (notices-letters@ams.org); see the masthead for postal mail addresses. Opinion pieces are usually one printed page in length (about 800 words). Letters are normally less than one page long, and shorter letters are preferred.