

On Being a Mathematical Citizen: The Natural NExT Step

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Excerpts from the ninth James R. C. Leitzel Lecture delivered at MathFest 2007 in San Jose, California. The complete text of the lecture, with extensive references links, is available at www.stolaf.edu/people/steen/Papers/07leitzel_lect.html.

I am truly honored to join the distinguished list of speakers in this lecture series dedicated to the memory of my good friend Jim Leitzel. Most of you probably knew Jim through his leadership of Project NExT. Jim also led several MAA initiatives in mathematics education, including *A Call for Change*, MAA's pioneering recommendations for preparing teachers of mathematics. A builder of mathematical communities, Jim was a model mathematical citizen and my inspiration for this talk.

My thesis today is that by virtue of our training, mathematicians have distinctive habits of mind that can enhance public discussion of public issues. More importantly, we have a professional obligation to move beyond the boundaries of our own discipline to bring our special skills of analysis and clarification to bear on important public policy discussions.

As evidence for this proposition, I have selected a few issues in education that can benefit from mathematicians' insights. I do not mean to imply that education is the only such arena; it just happens to be the one I know best. Others may find issues in health, environment, or energy equally compelling. I surely don't need to persuade you that mathematics is ubiquitous. What I would like to convince you is that to be a mathematical citizen, you need to use your mathematics for more than mathematics itself.

Undergraduate Education

I begin with something close to all our hearts: measuring the value of college education. The increasing importance and cost of higher education has generated mounting calls for greater public accountability. Here I will touch on just three examples to illustrate my thesis: measures of quantity (graduation rates), of quality (general education), and of readiness (alignment).

Graduation rates are widely accepted as a primary benchmark in higher education. Yet anyone who thinks carefully about the definition and calculation of a graduation rate will see trouble. And mathematicians are among society's most expert advisors on matters of definition and calculation.

Official graduation rates are based only on students who enter in the fall term as full time degree-seeking students. Moreover, the definition counts as graduates only those who finish at the institution where they first enroll. Students who meet these conditions are now a minority in American higher education.

This raises an interesting challenge for mathematicians to ponder: how best to define graduation rate? Scholars have proposed a variety of alternatives, for example, using continued study as a measure of "success," or tracking separately different types of students (e.g., transfers in, transfers out), or comparing the difference between actual and expected rates based on student characteristics.

The definition of graduation rate is no small matter: these rates influence public perception of institutional performance and the flow of money to higher education. But parents and taxpayers also want direct evidence of quality. Several instruments now claim to assess the broad outcomes of higher education independent of major, e.g., the Collegiate Learning Assessment (CLA) and the National Survey of Student Engagement (NSSE).

A recent study raises questions that should interest a mathematical mind about the potential use of such instruments to compare colleges. It turns out that undergraduates studying the same disciplines on different campuses have academic experiences that are more similar to each other than to students studying different subjects on the same campus. So, under circumstances in which variation within institutions exceeds variation across institutions, what mischief might emerge if these instruments are used to compare institutions?

The need for clarity is also evident in the transition from high school to college. Admissions and placement tests slight the higher-level cognitive skills that are critical to success in college mathematics. Required high school exit exams assess a significantly different portfolio of skills than those found on mathematics placement exams. ACT recommends an empirically validated college readiness benchmark in mathematics that is far below the skills that standards-writers claim are expected by colleges. There seems to be a huge gap between skills that mathematicians claim are necessary for college success and the reality of many college programs in which math avoidance is common, anticipated, and perhaps even enabled.

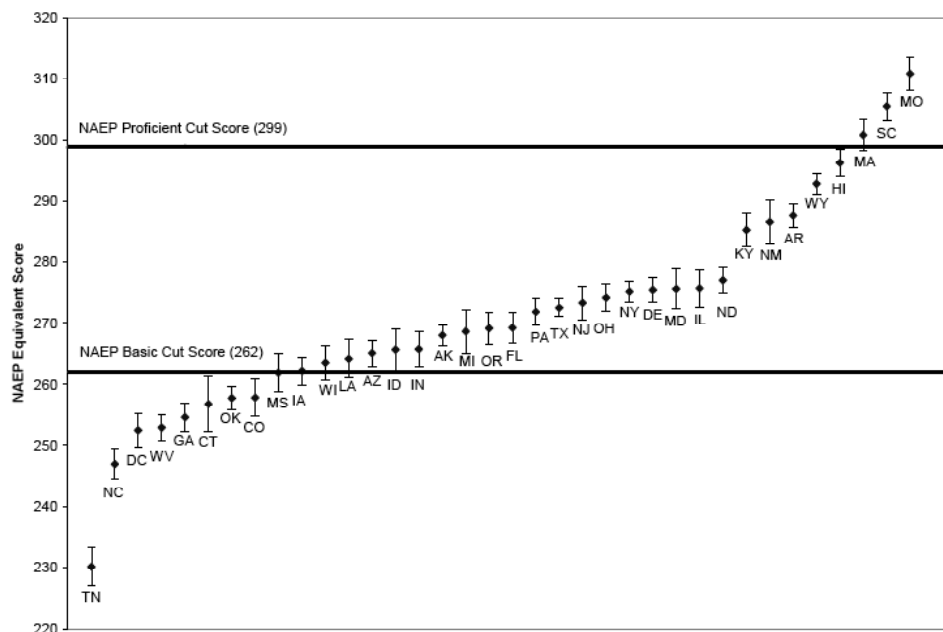
As you may suspect, I have no intention of resolving any of these challenges. Indeed, the whole point of this talk is that working on problems such as these is *your* job. I turn instead to a suite of similar challenges at the secondary level, beginning, as before, with graduation rates.

Secondary Education

Until very recently, the American public believed that almost every American graduated from high school. In fact, the national high school graduation rate peaked in 1969 at about 77% and has been falling ever since. Now, apparently, only two out of three students who begin ninth grade graduate four years later.

I say "apparently" since calculating the percent of students who graduate from high school is anything but simple. At least half a dozen methods are in common use, each giving quite different results. Only recently have state governors agreed to adopt a standard method. The result has been a series of headlines warning citizens that many previously reported high school graduation rates need to be lowered. This makes officials squirm, but it is a good opportunity for mathematically-minded folks to help the public understand why such rates are so complicated.

Recently, business leaders and educators have joined forces to urge that, to be prepared for college, all students should take Algebra II. Anything else, it is said, represents "the soft bigotry of low expectations." Consequently, enrollments in Algebra II have more than doubled in the last two decades; roughly two-thirds of the states now require Algebra II for graduation.



State vs. National Proficiency Levels for 8th Grade Mathematics

Comparison of proficiency levels on state tests with the proficiency (upper line) and basic (lower line) levels established by the National Assessment of Educational Progress (NAEP). Vertical bars indicate uncertainty ranges for state estimates.

Despite all this, employers still complain that graduates cannot use percentages and graphs, mathematics scores on the 12th grade National Assessment of Educational Progress (NAEP) have hardly budged, and college enrollments in remedial mathematics are as high as ever. Why can't we see benefits from all this added study?

Here's what seems to have happened: People argued that since applied courses had little intellectual content, everyone should take academic courses. As a consequence, many of *these* courses then lost their intellectual bite. They became "fake" academic courses: "pseudo-algebra" delivering only a steady drill on skills required to pass state tests. It seems that we've just downshifted from cookbook calculus to automated algebra.

Social scientists recognize this effect as Campbell's law—a kind of uncertainty principle for public policy: "The more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures ... " I call it the Perversity Principle of educational reform: the more importance we place on specific results, the less likely we are to achieve them in the form we intend.

A good example is the effect on education of the way schools are judged under the No Child Left Behind (NCLB) law: by the percent of students who are proficient. When proficiency percents are used as the primary standard for judgment, teachers gradually focus most of their effort on students whose proficiency is in doubt to the neglect of those who are far above or far below the desired cut score. The challenge of monitoring progress without undesirable side effects is a dilemma in need of mathematicians' insight.

NCLB requires states to report the percentage of students who are proficient according to each state's own standards. When researchers compared state standards, they found enormous variation in the definitions of proficiency—and corresponding variation in the percentage of students deemed proficient. Indeed, what many states call "proficient" is closer to what the national NAEP test rates as merely "basic."

Would mathematicians produce standards with such huge variation from state to state? I rather doubt it. As mathematical citizens, MAA members and NExT alumni should be active participants in setting these state proficiency levels. I'm sure that's what Jim Leitzel would be doing.

The NCLB law has also increased the significance of high-stakes tests. Scoring of standardized tests is a complex process that rests on several questionable assumptions, not least that the mathematical ability of students and the difficulty of test items can be placed on a common scale that operates along only one dimension. But student performance varies unpredictably depending on which items they have practiced.

Moreover, the more questions probe complex thought, the less well student performance fits the scoring theory. Consequently, test designers avoid precisely the questions that would reveal most about student proficiency. Scores on these tests are rarely meaningful enough to justify high stakes consequences. This is another arena much in need of mathematicians' thoughtful engagement.

STEMs and Flowers

I close with a different kind of challenge. It is expressed in *Beyond the Basics: Achieving a Liberal Education for All Children*, edited by Chester Finn and Diane Ravitch. It seems that Finn and Ravitch, who have been among the most forceful advocates for aggressive state standards monitored by high stakes assessment, have just discovered the Perversity Principle. It turns out, they report, that if you test only reading and mathematics, only reading and mathematics get taught. "We didn't see how completely standards-based reform would turn into a basic-skills testing frenzy or the negative impact that it would have on educational quality." They worry that current trends will lead to "STEMs without flowers," to the gradual death of liberal learning in higher education and to accelerating advantage of the have-a-lots over the have-littles.

This is also a dialogue in which mathematicians should participate—not by *applying* mathematics, but by *unfolding* mathematics as part of, rather than in opposition to, the goals of liberal education. Many whose own mathematics education never revealed this face of mathematics have a hard time seeing our discipline that way. It is our responsibility to help them do so now. If Jim were here I'm sure he would eagerly take up this new challenge. STEM *with* flowers offers us an excellent opportunity to engage the world as mathematical citizens.