Why Change?

The past twenty years have witnessed a growing and intensified public demand to raise academic achievement for all students. This demand reflects the historic shifts from an agricultural-based economy and society in the 19th century, to an industrial economy and urbanized society in the early and mid 20th century, to a knowledge-based global economy and data driven digital society in the late 20th and 21st centuries.

Mathematics has been valued for its applications in national defense, industrial processes, financial management, medicine and all of the social sciences. For these reasons, student achievement in mathematics, along with English language arts, has been used as one indicator of the general health of schools as well as of the nation's general intellectual capacity. Periodically, startling statistics and events have awakened the public's interest in students' mathematics competence. For example, in 1941, at the beginning of America's involvement in World War II, in a test of 4,200 candidates for naval officer, 62% failed math reasoning---a critical faculty for navigation at sea. The general population was not much better. In 1950, only 35% of persons over 25 years of age finished four years of high school, and less than 14% of African-Americans did. For many of those students who did manage to graduate high school, only two math courses were commonly required. Those courses often consisted of business math, consumer math, or general math, all of which were basically arithmetic at a middle school reading level dressed as a high school text.

Despite massive support for higher education offered by the GI Bill, by the late 1950s less than 8% of the population had completed four years of college, and less than 4% of African- Americans had. (The GI Bill did much more for high school graduation rates than college.) High-level mathematics achievement was reserved for a small elite group. But in 1957, the Soviet Union's launch of Sputnik shocked the country. In the midst of the nuclear-tipped Cold War, fear swept the nation that America's best and brightest in math and science may not be the world's best and brightest. The First International Mathematics and Science Study conducted during the 1960s documented America's lackluster performance in mathematics and science as compared to other First World countries.

By 1970, 78% of the nation's 25 to 29 year olds had graduated from high school, 43% had completed at least one year of college, and 22% had completed four years of college. The baby boomers were by far the best-educated cohort America had ever seen at the time. But the OPEC oil embargoes and resulting recessions in 1974 and 1978 again jolted the American public to the reality of global competition as Sputnik had a generation earlier. This time, however, the threat was more economic than military. High mathematics achievement could no longer be reserved just for the few. Intellectually skilled workers were needed throughout the emerging knowledge-based economy.

In the midst of the 1982 recession, President Reagan commissioned his Secretary of Education to study the condition of American education in relation to changed global economics. More workers needed higher intellectual skills for the rapidly developing military, industrial, financial, and medical applications and innovations. The result was a landmark 1983 report entitled, *A Nation At Risk*, which warned that American education was adrift in a "rising tide of mediocrity" that was equivalent to "a unilateral act of educational disarmament". The Second International Math and Science Studies (SIMSS) conducted in the mid-1980s confirmed the *Nation At Risk's* assessments. Other subsequent reports throughout the 1980s continued to toll the bell for change as they documented the mathematical deficiencies of American students in skills, understanding and non-routine problem solving. Even the research community was alarmed at America's growing dependence on importing foreign-born research scientists.

By the late 1980s and early 1990s, the mathematics education community responded with a host of reports that called for fundamental changes and upgrades in mathematics education. These reports advocated not only more years and higher levels of mathematics for students to graduate high school, along with better trained and paid teachers, but also a *re-conceptualization* of what constituted important mathematics content, effective teaching practices and authentic assessments[1]. These upgraded learning goals required students to acquire a deeper understanding of the core concepts of mathematical and scientific content. Students needed to become comfortable, confident and competent with the processes of scientific inquiry; no longer was it sufficient merely to master mindless robotic mathematical tasks akin to the factory assembly line.

All of these reports delineated an expanded concept of "basic math" found in the elementary grades to include higher-order algebraic and geometric thinking, statistical inference, probability, modeling, and use of calculator and computer technology to solve multi-system problems with large data sets. Moreover, rather than organizing mathematics education into an amalgam of isolated topics, these reports advocated the integration of mathematics topics into fewer core concepts to delve deeply into

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[1] These reports include: the National Council of Teachers of Mathematics' (NCTM), *Curriculum and Evaluation Standards for School Mathematics* (1989); the National Research Council's (NRC) *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (1989); NRC's *Reshaping School Mathematics: A Philosophy and Framework for Curriculum* (1990); NRC's *Summit on Mathematics Assessment* (1991); and NCTM's *Professional Standards for Teaching Mathematics* (1991).

mathematics' "big ideas." The 1989 National Council of Teachers of Mathematics *Curriculum and Evaluation Standards*, for example, stressed the importance of mathematical reasoning and communication skills for the purpose of fostering “mathematical power," for *all* students. NCTM’s *Professional Teaching Standards* have called for changes in the traditional "teacher-telling/student-listening" teaching paradigm. Teachers are urged to lecture less and facilitate more inquiry-based learning activities. By stimulating students' active experimentation with engaging mathematical problems in interesting contexts, teachers can instill in students a deeper understanding of mathematics. Accordingly, assessment of a student's mathematical knowledge must extend beyond computational proficiency to include non-routine problem solving embedded in an application context.

While there has been widespread acknowledgment and acceptance of the *NCTM Standards*, how to actually implement change in the classroom on an everyday basis remains problematic. The NCTM *Standards* are learning goals. They are not a curriculum detailed enough to enable regular classroom mathematics teachers to implement *standards*-based lessons on an everyday basis, 180 days a year. Recognizing this problem, the National Science Foundation responded in 1989 by supporting the development of thirteen NCTM standards-based mathematics curricula materials projects, K-12, that are intended to be "full replacement" texts. At the high school level, these texts include:

- *The Interactive Mathematics Program (IMP),*
- *CORE-Plus Mathematics Project,*
- *Applications Reform in Secondary Education (ARISE),*

- *Math Connections, and*
- *Systemic Initiative for Montana Mathematics and Science (SIMMS*).

(For a synopsis of the common features of these NSF-sponsored mathematics curricula and their rationale, see Appendix A. Common Features of an NSF Curriculum)

The Interactive Mathematics program (IMP)

This report details the research results on student achievement using the *Interactive Mathematics Program (IMP)* in Philadelphia public schools. *IMP* was one of the first NSF-sponsored, standards-based, full-replacement, high school mathematics curriculum projects. Like other new curricula sponsored by the NSF, IMP is a high performance curriculum requiring instructional practices that deeply embody *NCTM's Curriculum, Teaching and Assessment Standards.* IMP consists of 20 highly contextualized thematic units built around large problems. (See Appendix B, Detail of IMP Math Topics)

The IMP writing team consisted of two mathematicians from San Francisco State University, Dan Fendell and Diane Resek, and two mathematics educators from the EQUALS program at University of California at Berkeley, Sherry Fraser and Lynne Alper. The design parameters for this new curriculum were as follows:

1. It had to fully embody the content recommendations and spirit of the 1989 National Council of Teachers of Mathematics *Curriculum and Evaluation Standards.*
2. It had to be mathematically challenging for the best and the brightest students.
3. It had to be a curriculum accessible to all students.

The first IMP units were written in 1989 and were field tested in a limited number of classrooms in three high schools in the Berkeley, California area. Over the next several years, as more units were written, other pilot sites were added. Subsequent feedback from IMP teachers, including Philadelphia teachers, resulted in numerous rewrites for each unit prior to the finished product. The 9th grade level, or first year of IMP, became commercially available in August 1996. The fourth year of IMP became commercially available in August 1999. In short, it has taken ten years to fully write and field test the complete four years of IMP.

IMP in Philadelphia

In March 1992, a four and one half year contract was awarded by San Francisco State University Foundation (SFSUF) to PATHS/PRISM: The Philadelphia Partnership for Education, a local education fund, for the purpose of administering the dissemination of the pre-publication pilot version of *The Interactive Mathematics Program.* The contract was funded by a grant from the National Science Foundation to SFSUF.

IMP in Philadelphia began in the 1993-94 school year with nine teachers representing six out of thirty-five public high schools. Approximately 300 9th grade students out of a total Philadelphia 9th grade student enrollment of 15,000--roughly 2%--were enrolled in IMP the first year. (See Appendix for a time line of IMP's implementation in Philadelphia. Philadelphia Expense Timeline)

Because the IMP authors retained copyright control over the dissemination of the pre-publication IMP unit booklets, the implementation standards of IMP could be set very high. All initial IMP teachers received the following:

1. ten days of training per year in each level of IMP (240 hours total),
2. on-going classroom mentoring,
3. a course load reduction of 1.5 periods,
4. a period where two IMP teachers would team-teach,
5. a classroom set of graphic calculators and LCD overhead,
6. a classroom set of manipulatives and other supplies,
7. regular citywide follow-up teacher meetings.

The above implementation standards were fairly uniform wherever IMP was being piloted in the country. The IMP authors would not grant any school permission to use the pre-publication copyrighted materials unless they agreed to these standards. In addition, in Philadelphia, four part-time co-directors facilitated the implementation of IMP. These local co-directors performed a variety of tasks which included: co-teaching IMP classes, mentoring other teachers, helping to procure materials, collecting and analyzing student achievement data, helping to prepare school budget for the program, and generally ensuring district fidelity to the implementation model. (See Appendix under Implementation Standards)

Prior to 1996, there existed neither Philadelphia nor Pennsylvania State math standards, nor any standards-based testing. There were also neither Philadelphia nor Pennsylvania accountability systems. In short, there were no external sanctions/incentives based on student achievement data. As a result, despite the many national reports released during the 1980s that documented the deficiencies in mathematics education as it was currently being taught, principals and other administrators had difficulty advocating the local need for change among their mathematics teaching staffs. In this environment, teacher recruitment for IMP relied on “heroic volunteers.” Recruiting new IMP teachers proved difficult in part because, in order to take part in the program, teachers were required to undergo extensive professional development and additional preparation. The reduction in teacher load was at best a mild incentive for teachers to participate, as this was the only way to compensate them for the considerable increase in preparation time associated with being the first to pilot a new program.

The cost of training a teacher in IMP for four years in the early years in Philadelphia was approximately $102,000. Roughly 80% of this cost was for the 1.5 teaching period reduction in course load. Later, the 1.5 period reduction per teacher was discontinued. By the 1999-2000 year, neither the School District of Philadelphia nor any of the surrounding suburban districts were providing their teachers with a reduction in course load. Many schools adopted various models of intensive block scheduling, which provided a reduction in teaching load. Nonetheless, even without a course load reduction of 1.5 periods per teacher, the costs of implementing a new standards-based curriculum are considerably greater then merely purchasing a new textbook series. (See Appendix on Four Year Implementation Cost)

Over the years, the number of Philadelphia IMP teachers has steadily grown to involve nearly 20% of all the high school staff. However, the first school to adopt IMP for its entire student body was in the Philadelphia suburbs—not the city. Strath Haven High School in the Wallingford/Swarthmore school district was the first high school to go all IMP in 1996-97. By September 2000, approximately 20 Philadelphia suburban districts were using IMP or other NSF standards-based materials in both their middle and high schools.