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An Agent of Change: *NSF Sponsored Mathematics Curriculum Development*

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ABSTRACT:

This article identifies factors that make it difficult for publishers of commercial textbooks to make significant changes consistent with curricular visions put forth by the National Council of Teachers of Mathematics (NCTM). Central among these factors is the lack of consensus of state standards on what and when certain topics in mathematics should be addressed. The variability of grade placement of key mathematics learning goals across different state standards results in excessive repetition and superficial treatment of topics in school mathematics textbooks.

In response to the NCTM release of their Curriculum and Evaluation Standards for School Mathematics (1989) the National Science Foundation funded 13 different projects to construct mathematics curriculum materials consistent with the vision put forth in the document. During the last 15 years innovative curriculum materials were developed, piloted, revised, and are now used in many schools throughout the United States. Some have become more popular than others, but collectively they comprise between 10-20 percent of the mathematics textbooks being used today in K-12 classrooms.

This article highlights the impact of this massive effort to bring about change in mathematics teaching and learning in K-12 schools. In addition to the impact on students' mathematics learning, the new mathematics curriculum materials have also influenced teacher practice as well as the professional growth and development of classroom teachers. The availability of comprehensive innovative curriculum materials consistent

with the vision of NCTM has stimulated an enormous amount of research in schools, and influenced textbooks being developed by commercial publishers. It has also become a political issue that has stimulated discussions about mathematics curriculum involving a wide range of constituents at the state and national levels.

The National Science Foundation's effort to stimulate the development of mathematics curriculum materials (textbooks) based on a new model — one that relies on a cycle of curriculum design, implementation, and refinement based on field trials — has stimulated discussion, collaboration and action through the world of textbook publishing. The effort produced an array of different K-12 mathematics textbook series, K-12 (see Table 1). Some might describe the impact of NSF support for curriculum development as a 'ripple' within a large ocean of the textbook publishing world. Others, a 'wave' that significantly impacted a small group of schools, teachers and students. Still others might view the result as a massive wave — changing the very landscape of textbook publishing and implementation. The ultimate impact is likely too early to know.

CHALLENGES FOR SCHOOL TEXTBOOK PUBLISHERS

It seems reasonable that textbooks sold and used by millions of K-12 students and their teachers should be carefully researched by the authors and publishers prior to their distribution to insure that they are effective resources in helping students learn mathematics. However, historically mathematics textbooks have not been researched and piloted before being sold commercially [Tyson-Bernstein, 1988]. The challenges of developing research based

mathematics textbooks for K-12 schools were discussed by Willoughby:

“A carefully conceived, well-written textbook takes several years to develop. A well-written, adequately tested textbook series takes much longer, since the books in the series ought to be field tested longitudinally (one grade at a time), if anything really new is being done. The only way publishers can satisfy the insatiable demand by adoption committees for the latest thing is to fake it.” [Willoughby, 2002, p. 141]

Willoughby’s description applies to the majority of the K-12 mathematics textbooks that are used in schools today. Whitman echoes the same theme as he describes how some textbooks are rapidly assembled within development houses [Whitman, 2004]. While recognizable names of authors are visible on the cover of textbooks, these authors may have played very minor roles in writing the materials. Whitman points out that the constant demand for textbooks with new copyright dates precludes publishers from field-testing their K-12 products over several years to study their impact on student learning.

The production of textbooks is a very big business in the United States and a variety of factors work against careful research and development efforts by commercial publishers. For example:

1. No common set of mathematics curriculum standards exists in the USA. Although the National Council of Teachers of Mathematics, and other groups such as Achieve and the College Board, have proposed standards there is no national consensus on what students should learn or when they should learn it. Instead, most states develop and require school districts to follow state curriculum frameworks which specify learning goals by grade or by course.
2. As a result of the lack of agreed upon standards, there is wide variation in the placement of topics in current mathematics textbooks. For example, one state may expect students to become fluent with multiplication facts in grade 2, whereas another state may expect fluency in grade 4 (Reys, 2006). Thus, textbooks sold in each of these states must include the same topic in multiple grades.
3. Short timelines imposed by state textbook adoption committees often preclude thoughtful and research-based development of textbooks. It takes years to

develop a new textbook series, and more years to field-test its effectiveness. Yet states often issue their standards or framework within one or two years of their adoption deadline. This tight timeline makes any longitudinal research study of the impact of textbooks on student learning impossible to implement.

4. Many teachers are resistant to significant changes in curriculum and textbook format. There is comfort and security in using the same textbook for several years because teachers are familiar with the order of content and often have well established lessons. Textbook sales representatives capitalize on this comfort of using the same textbook by ‘rolling over’ current users of one edition to the next edition of their textbooks. Teachers are already familiar with the material, and it requires little or very limited new learning to implement the new edition.

Despite these factors, new K-12 mathematics textbooks are published regularly. They are new in copyright and tend to incorporate features of mathematics curricula that have the largest market share and thus significant change is rare. As a result few of these textbooks are new in the sense of having different content, format or style. Historically, commercial publishers of textbooks have been unwilling to commit significant resources to develop mathematics textbooks that differed significantly from those textbooks that were already successful in the market place [Reys & Reys, 2006]. The most obvious changing feature of mathematics textbooks has been their growth in size. This is reflected in lengthy textbooks, often exceeding 700 pages. As noted earlier, variability in the standards or learning goals across states is a major contributor of the growing size of textbooks. Consequently, publishers cover the standards of multiple states in the same textbook, and a significant amount of content is duplicated from grade to grade. Often the duplicated content receives shallow or superficial treatment in multiple grades, resulting in the characterization of the mathematics curriculum in the United States as being “a mile wide and an inch deep” (Schmidt, McKnight, and Raizen, 1997).

A LARGE-SCALE EFFORT TO CHANGE MATHEMATICS CURRICULUM MATERIALS

Change is slow, more similar to ocean tides gradually changing the landscape, than significant changes resulting from a tidal wave. Ripples result when still water is disturbed. It is safe to say that the landscape of K-12 mathematics curriculum was ‘still water’ in the 1980s,

TABLE 1. *Comprehensive mathematics curriculum development projects funded by NSF*

Project Name	Grades	Curriculum Development Sponsor	Initial Commercial Publisher
<i>Investigations in Number, Data and Space</i>	K-5	TERC	Scott Foresman
<i>Math Trailblazers</i>	K-5	University of Illinois-Chicago	Kendall/Hunt
<i>Everyday Mathematics</i>	K-5	University of Chicago	SRA/McGraw Hill
<i>MATH Thematics</i>	6-8	University of Montana	McDougal Littell
<i>MathScape: Seeing and Thinking Mathematically</i>	6-8	Education Development Center	Glencoe/McGraw Hill
<i>Mathematics in Context</i>	5-8	University of Wisconsin	Holt, Rinehart, & Winston
<i>Connected Mathematics Project</i>	6-8	Michigan State University	Prentice Hall
<i>Middle School Mathematics Through Applications (MMAP)</i>	6-8	Institute for Research on Learning	Unpublished
<i>Contemporary Mathematics in Context (Core-Plus)</i>	9-12	Western Michigan University	Everyday Learning Corporation
<i>Math Connections</i>	9-12	MathConx	IT'S ABOUT TIME, Inc.
<i>Systemic Initiative for Montana Mathematics and Science (SIMMS) Integrated Mathematics</i>	9-12	Montana Council of Teachers of Mathematics	Kendall/Hunt
<i>Interactive Mathematics Program (IMP)</i>	9-12	Sonoma State University	Key Curriculum Press
<i>Mathematics: Modeling Our World (MMOW/ARISE)</i>	9-12	COMAP	W.H. Freeman & Co.

only occasionally disturbed by emerging technology. In 1989 the National Council of Teachers of Mathematics published the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). This document provided a new vision for K-12 mathematics and it resulted from years of work that was supported by more than 25 professional organizations, including organizations composed mostly of mathematicians, such as the American Mathematical Society and the Mathematical Association of America.

One of the challenges the NCTM *Standards* presented was the development of new curriculum materials for mathematics teaching that would better support student learning. Given the history of commercial publishers being uneasy about risking millions of dollars to develop a textbook series that is significantly different from the market leaders, it seemed unlikely that new mathematics

textbooks reflecting the vision of the NCTM *Standards* would be forthcoming.

The National Science Foundation, concerned with mathematics performance reported by National Assessment of Educational Progress and the consistently low performance on international assessments since 1970, made a decision to support the development of research based K-12 mathematics textbooks. The NSF realized that the vision put forth by the NCTM *Standards* might take many different forms, and ultimately funded 13 different projects that spanned K-12 (shown in Table 1) (Reys, et al., 1999). These curricula were extensively field-tested in schools and then revised before becoming commercially available. The resulting mathematics curricula represent notable exceptions to traditional textbooks that typically lack a research and development phase prior to release (Trafton, et al., 1999).

The NSF-supported mathematics textbooks have been reviewed by committees of the US Department of Education and AAAS (Kulm, et al., 1997) and judged of exemplary quality compared to other commercially available textbooks. Studies have consistently reported positive growth in the mathematics learning, particularly related to reasoning and problem solving, as a result of use of the new curriculum materials (Senk & Thompson, 2003).

One testimony to the impact of NSF's effort is that tens of thousands of children are using these textbooks every day in schools throughout the United States. In some places NSF-supported mathematics textbooks are used by all schools in a district. In other places, teachers are using units or modules to supplement their current mathematics textbook. Estimates of the market share of NSF-supported textbooks range from 10-20 percent of students and teachers, indicating that the impact is more of a wave than a ripple (Education Market Research, 2006). Significant use of these textbooks is evidence that NSF's effort to stimulate new models of textbooks has been successful. However, the story does not stop there.

FAR REACHING IMPACT OF NSF-SUPPORTED MATHEMATICS CURRICULUM DEVELOPMENT

The mathematics curriculum materials produced with NSF support have provided a wide range of K-12 curricular options for students, teachers and schools. However, NSF's initiative has extended beyond school users, generating healthy discussions and some unanticipated by-products. While the impact may be short of a tsunami, it has generated significant waves in different directions including teacher development, teacher practice, research activity, and the textbook publishing industry. In addition, it has stimulated increased attention to K-12 school mathematics by the community of research mathematicians.

Impact on Professional Development Activities

As teachers began using these K-12 NSF-supported curriculum materials it became clear that many were unable to implement the programs in the spirit that the authors intended. In some cases, teachers lacked the necessary content knowledge in mathematics to respond to questions their students asked. In other cases, teachers were uncomfortable with the active involvement of students in groups, and classroom management issues surfaced. As a result, professional development specifically organized to support teacher learning is essential (Ball, 1996). Developers of the

curriculum materials and others have organized and provided professional development to strengthen teachers overall mathematical knowledge as well as their pedagogical expertise. In addition, many teacher education institutions focused attention on the K-12 curriculum materials to prepare new teachers (Papick, et al., 1999).

Impact on Teachers' Practice

A number of initiatives — local, statewide and national — have emerged to support the professional development of mathematics teachers using the NSF-supported curricula. As a result, many teachers have changed from teacher-centered to student-centered instruction. Thus students assume a greater responsibility for learning and helping their peers. There is growing research that shows teacher's knowledge of mathematics is also growing from their use of mathematics curricula. These teachers are learning mathematics as they teach (Remillard, 2005).

Impact on Students' Perception of Mathematics

Students have often viewed mathematics as a spectator sport. That is, mathematical procedures are demonstrated and then the procedure is practiced, and often these procedures are devoid of any meaningful context or focus on understanding. Consequently, memorization rather than sense making is associated with mathematics learning. As a result, many students and parents don't understand mathematics and what developed an unhealthy and distorted view it.

The NSF-supported materials embed mathematical concepts and skills in problem solving contexts. Although the learning activities are challenging, it is rare to hear students ask 'When are we going to use this?' as the context reflects challenging problems that are embedded within a realistic setting. As a result a higher percent of students engaged in these mathematics curricula at the secondary level are choosing to take more mathematics classes in high school (Harwell, et al., in press).

Impact on Commercially Developed Textbooks

Imitation is said to be the highest form of flattery. An examination of recently produced mathematics textbooks by commercial publishers shows that some problems and approaches used in the NSF-supported mathematics curricula are surfacing in commercially developed textbooks (Reys, et al., 2004). Adopting and adapting some of the

ideas put forth in the NSF-supported mathematics curricula by commercial publishers is one of the indirect ways that the NSF-supported projects have impacted the larger spectrum of mathematics textbooks. Since commercially developed mathematics textbooks tend to be widely used in middle and secondary mathematics programs, their inclusion of more interesting, rich and challenging problems reflects a major impact from the NSF-supported mathematics curricula.

Impact on Research in the Field

NSF-supported mathematics curricula have been the focus of much research in the mathematics education community. Some research has been done as part of the research and development model that each of the curriculum projects followed. In addition, many research studies have investigated the impact of NSF-supported mathematics curricula on student learning as well as on teacher use. In fact, a review of articles reporting student learning outcomes related to mathematics curriculum in the *Journal for Research in Mathematics Education* from 1996-2006 reveals that over 80% (14 out of 16) involved NSF-supported mathematics curricula. This predominance of mathematics curriculum research involving NSF-supported mathematics textbooks is also reflected in doctoral dissertations. Research on mathematics curriculum has addressed many different issues including curriculum analysis, teachers' use of curriculum materials, and student and teacher learning associated with curriculum materials.

Increased Involvement of Research Mathematicians in K-12 Mathematics Programs

More mathematicians have become interested in K-12 mathematics programs. Some have expressed concern about changes occurring in the K-12 mathematics curriculum (Wu, 1997). Other mathematicians have taken opposing views in support of many of the changes (Kilpatrick, 1997; Cuoco, 2003; Ralston, 2004). These 'tugs of war' provide opportunities for healthy debate and constructive dialogue. However, reasoned debate has not always been the norm. Thus, in some circles, mathematicians and mathematics educators are viewed as holding opposite views and advancing different agendas. In fact, this is an overgeneralization as many mathematicians and mathematics educators share common goals and work together to develop and implement strategies to support the improvement of school mathematics programs.

Politics and Policy

The NSF-funded mathematics textbooks provide a clear alternative to traditional textbooks that are commercially developed. They also provide the basis for enacting a different vision for teaching and learning. Thus, the textbooks themselves are often the impetus for philosophical clashes between reform and anti-reform groups. For example, at the state level it was reported that "California's mathematics policy followed a persuasive (albeit deceptive) campaign alleging the failure of the current reform movement in mathematics education" and the NSF-supported mathematics curricula were at the epicenter of these discussions (Jacobs and Becker, 2000). The anti-reform movement was led by organized groups of politically savvy individuals who knew how to influence policy. The story of one school textbook adoption committee was recently chronicled and illustrates the range of issues and personal biases that surfaced, how opinions were persuaded, the value attached to research evidence and ultimately how decisions were made (Newman, 2004). The story is a reminder that "decisions about educational reform are driven far more by political considerations, such as the prevailing public mood, than they are by any systematic effort to improve instruction" or learning (Dow, 1991).

SUMMARY

A careful review of the impact of NSF mathematics curriculum development initiative over the last two decades must look beyond the number of textbooks sold and the number of students and teachers using the textbooks. The initiative has:

- influenced the mathematics content that students in the United States have an opportunity to learn;
- fostered the belief that mathematics learning should be meaningful and that learning mathematics should be a sense making experience;
- helped teachers increase their knowledge of mathematics;
- helped teachers establish more effective ways of helping their students learn mathematics;
- influenced commercially developed textbooks to incorporate mathematical problems, activities, ideas and developmental approaches based on an active learning model;
- encouraged mathematicians to become involved in reviewing and shaping mathematics textbooks; and
- stimulated an unprecedented wave of research activity focusing on the impact of mathematics curricula on teachers and students.

Focusing on an element of the educational system as basic as textbooks, used by virtually every teacher and student in the country on a daily basis, provides a powerful means of promoting change in practice. While time and continued

monitoring of the field will tell the story of the true impact of this effort, there is clear evidence that NSF-supported curriculum innovation has generated more than a ripple or wave of change.

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