

Journal of Mathematics Education at Teachers College

Spring – Summer 2010
Inaugural Issue

A CENTURY OF LEADERSHIP IN
MATHEMATICS AND ITS TEACHING

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Teachers College, Columbia University
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The *Journal of Mathematics Education at Teachers College* is a publication of the Program in Mathematics and Education at Teachers College Columbia University in the City of New York.

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This issue's cover and those of future issues will honor past and current contributors to the Teachers College Program in Mathematics and Education. Photographs are drawn from the Teachers College archives and personal collections.

This issue honors NCTM 2010 Lifetime Achievement Medalist, Dr. Henry O. Pollak, who has completed 22 years as a member of the Program in Mathematics and Education at Teachers College. Dr. Pollak has contributed so much to the mathematical preparation of the Program's graduates and to the communities of mathematics and mathematics education professionals in the United States and throughout the world.

David Eugene Smith, also pictured on the front cover, was the founding professor of the Teachers College Program in Mathematics and Education. Like Dr. Pollak, Professor Smith was widely respected by both mathematicians and educators.

Aims and Scope

The *JMETC* is a re-creation of an earlier publication by the Teachers College Columbia University Program in Mathematics and Education. As a peer reviewed, semi-annual journal, it is intended to provide dissemination opportunities for writers of practice-based or research contributions to the general field of Mathematics Education. Each issue of the *JMETC* will focus upon an educational theme. Themes planned for the 2010-2011 issues are: *Teacher Education, International Education, Curriculum, Technology, and Equity*—all centered upon mathematics and its teaching. The *JMETC* will have a distinctive niche in the world of education publishing. Our readers are educators from pre K-12 and college and university levels, and from many different disciplines and job positions—teachers, principals, superintendents, professors of education, and other leaders in education.

Manuscript Submission

We seek conversational manuscripts (2500-3000 words in length) that are insightful and helpful to mathematics educators. Articles should contain fresh information, possibly research-based, that gives practical guidance readers can use to improve practice. Examples from classroom experience are encouraged. Articles must not have been accepted for publication elsewhere. All manuscripts may be submitted electronically at www.tc.edu/jmetc. This system will help keep the submission and review process as efficient as possible.

Abstract and keywords. All manuscripts must include an abstract with keywords. Abstracts describing the essence of the manuscript should not exceed 150 words. All inquiries should be sent to Ms. Krystle Hecker, P.O. Box 210, Teachers College Columbia University, 525 W. 120th St., New York, NY 10027.

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Call for Papers

The “theme” of the fall issue of the *Journal of Mathematics Education at Teachers College* will be *International Mathematics Education*. This “call for papers” is an invitation to mathematics education professionals, especially Teachers College students, alumni and friends, to submit articles of approximately 2500-3000 words describing research, experiments, projects, innovations, or practices related to international or comparative mathematics education. Articles should be submitted to www.tc.edu/jmetc by September 1, 2010. The fall issue’s guest editor, Dr. Juliana Connelly, will send contributed articles to editorial panels for “blind review.” Reviews will be completed by October 1, 2010, and final drafts of selected papers are to be submitted by November 1, 2010. Publication is expected in late November, 2010.

Call for Volunteers

This *Call for Volunteers* is an invitation to mathematics educators with experience in reading/writing professional papers to join the editorial/review panels for the Fall 2010 and subsequent issues of *JMETC*. Reviewers are expected to complete assigned reviews no later than 3 weeks from receipt of the blind manuscripts in order to expedite the publication process. Reviewers are responsible for editorial suggestions, fact and citation checking, and identification of similar works that may be helpful to contributors whose submissions seem appropriate for publication. Neither authors’ nor reviewers’ names and affiliations will be shared; however, editors’/reviewers’ comments may be sent to contributors of manuscripts to guide further submissions without identifying the editor/reviewer.

If you wish to be considered for review assignments, please request a *Reviewer Information Form* from Ms. Hecker. Return the completed form to Ms. Krystle Hecker at JMETS@tc.columbia.edu or Teachers College, Columbia University, 525 W 120th St., Box 210, New York, NY 10027.

Looking Ahead

Anticipated themes for future issues are:

Spring 2011	Curriculum
Fall 2011	Technology
Spring 2012	Equity
Fall 2012	Leadership
Spring 2013	Psychology

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Examining What Teachers Do When They Display Their Best Practice: Teaching Mathematics for Understanding

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University of Michigan

Despite several decades of research in psychology and mathematics education pointing to the importance of learning mathematics with understanding, other research on teachers' instructional practice in mathematics classrooms has found a remarkably consistent characterization of mathematics teaching in the United States as generally doing little to help students develop a deep understanding of mathematical ideas. Because the practice of *teaching mathematics for understanding* is so rarely encountered, it has not been extensively studied empirically. This paper summarizes the findings of an analysis of selected mathematical and pedagogical features of the lesson materials found in the portfolio entries submitted by candidates seeking certification by the National Board for Professional Teaching Standards in the area of Early Adolescence/Mathematics. These lessons were selected by teachers and were intended to display "best practice" examples of their teaching mathematics for understanding. Some implications for further research and for teacher education are also discussed.

The Learning Principle, promulgated in NCTM's (2000) *Principles and Standards for School Mathematics*, states: "Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge." This assertion, and its elaboration in the PSSM document, rests on a foundation of several decades of research in psychology and mathematics education pointing to the importance of *learning mathematics with understanding*. Over at least the past 60 years, a solid body of research evidence has been amassed, pointing to both the benefits of teaching for understanding in mathematics and the difficulties that occur when students do not understand the mathematics they are taught (e.g., Brownell & Moser, 1949; Brownell & Sims, 1946; Carpenter, Fennema, & Franke, 1996; Carpenter et al., 1989; Cohen, McLaughlin, & Talbert, 1993; Fuson & Briars, 1990; Hiebert & Wearne, 1993; Hiebert et al., 1996). For that reason, teaching mathematics for understanding has long been a valued goal of mathematics educators. Though there is no universal consensus on the critical features of mathematics instruction that leads to student understanding, there is broad agreement from research and professional judgment that a conceptually oriented version of mathematics instruction involves mathematical tasks that are drawn from a broad array of school mathematics content domains and are cognitively demanding, as well as pedagogical practices that are suitable to support collaboration and discourse among students, and thoughtful engagement with mathematical reasoning, problem solving, and explanation (e.g., Fennema & Romberg, 1999; Hiebert & Carpenter, 1992).

Despite the longstanding recognition of the importance of teaching mathematics for understanding, research findings have been remarkably consistent for several

decades in suggesting that teaching mathematics for understanding is not the norm in mathematics classrooms in the United States. Whether examining survey data (e.g., from the National Assessment of Educational Progress [NAEP]) or classroom observation data (e.g., from the Trends in International Mathematics and Science Study [TIMSS] video studies), researchers have found that typical classroom mathematics teaching in the United States tends not to use challenging tasks, nor to promote students' thinking about and engagement with mathematical ideas, and thus fails to help students develop understanding of the mathematics they are learning. Though research has not captured many examples of teaching for understanding in U.S. mathematics classrooms, except in the case of a few exceptional teachers of mathematics, it might be possible to find more examples if we examined teaching in some way other than large-scale samples of typical classroom practice. For example, we might study samples of classroom instruction that mathematics teachers consider their "best practice" in teaching toward understanding.

This paper summarizes just such a study conducted at the University of Michigan, in which we used data gathered originally by the National Board for Professional Teaching Standards (NBPTS) as part of the Board's efforts to recognize highly accomplished teachers of mathematics for young adolescents. The portfolio entries that teachers submit when applying for NBPTS certification offer a glimpse at instructional practice that teachers consider worthy of evaluation in a process designed to identify highly accomplished teaching. In that sense, they represent teachers' best practice. The entries examined in this study were specifically structured to capture mathematics teachers' instructional practices in teaching for and assessing understanding.

Study Context, Methods, and Findings

The NBPTS was established in 1987 as a nonprofit, nonpartisan organization to promote the recognition of highly accomplished teaching practice. A voluntary, national system was established under the auspices of NBPTS to certify accomplished practice in a number of fields. Except for generalist certifications, each field is defined by content area (e.g., mathematics) and students' development level (e.g., Early Adolescence, ages 11-15). Teachers receive NBPTS recognition by demonstrating knowledge and professional practice of many kinds via a complex assessment system consisting of two parts: in one, teachers completed an on-demand, test-center-administered set of exercises to evaluate certain aspects of their content and pedagogical content knowledge; in the other, candidates submitted a portfolio that included contextualized samples of their teaching practice and reflections on their work. In this study, we examined two of the six portfolio entries submitted by candidates seeking NBPTS recognition in 1998-99 in the area of Early Adolescence/Mathematics (EA/M). The two portfolio entries we examined—Developing Mathematical Understanding and Assessing Mathematical Understanding—captured teaching practice via classroom artifacts, samples of student work, and teachers' reflective narratives.

We have published two reports based on the two-phase analysis conducted in this study. In one paper (Silver, Mesa, Morris, Star, & Benken, 2009), we reported an analysis of the mathematical and pedagogical features we found in the submitted portfolio entries. In the first phase of the analysis, we did not distinguish between teachers who received NBPTS certification and those who did not. In another paper (Silver & Mesa, in press), we reported a comparative analysis of the portfolio entries submitted by the teachers who were awarded NBPTS recognition and those who were not. Details regarding the research methods used to code and analyze the portfolio entries can be found in Silver et al. (2009). In this paper, I summarize the major outcomes of both phases of analysis in our study, emphasizing implications for teacher education, professional development, and research. The objective is to assist teacher educators and staff developers to enable novice and future teachers to balance routine lessons with cognitively challenging ones in the mathematics instruction of America's young adolescents, and to suggest directions for future research.

Phase One

In Phase One of our study, we examined the instructional materials selected and submitted by mathematics teachers seeking NBPTS certification at the early adolescent level (EA/M). Our objective was to

determine what these materials revealed about how these teachers engage in teaching for understanding in mathematics classrooms. The dataset consisted of individual portfolios focusing on Developing Understanding and Assessing Understanding. Portfolios were submitted by 32 teachers, randomly selected for this study from among 250 applicants for NBPTS certification in 1998-99. Portfolios included classroom artifacts, such as lesson materials and student work samples, annotated by teachers. In addition, teachers included teacher narratives, in which they described their class, their teaching, where a particular lesson might fit into the overall plan of their instruction, and the goals for a particular lesson. In essence, these are self-selected examples of what the teachers consider their best professional practice.

Our data analysis explored selected mathematical and pedagogical features of the portfolios. Mathematical features included an examination of content/topic areas chosen by teachers for their lessons (using the National Assessment of Educational Progress [NAEP] mathematics content framework of number and operations, measurement, geometry, algebra and functions, data analysis, statistics, and probability), as well as the level of cognitive demand of the tasks included in the portfolios. Tasks were categorized as high or low with respect to their cognitive demand, with high cognitive demand lessons providing opportunities for students to explain, describe, justify, compare, or assess; to make decisions and choices; to plan and formulate questions; to exhibit creativity; and to work with more than one representation in a meaningful way. Lessons with low cognitive demand were characterized as opportunities for students to demonstrate routine applications of known procedures or to work with a complex assembly of routine subtasks or non-mathematical activities. We used a generous criterion for coding the cognitive demand of a multi-part mathematics task; namely, if some part of the task was judged to be high in cognitive demand, then the entire task was categorized as high demand.

We found that there was broad representation of topic areas in the portfolio submissions. In the Developing Understanding (DU) portfolio submissions, the most common content topic was geometry (about 28%); in the Assessing Understanding (AU) portfolio submissions, the most common topic was algebra (about 35%). With respect to cognitive demand, looking across all the submissions, we found that 70% of DU entries had low cognitive demand, and about 62% of AU entries were judged to be low in cognitive demand. We also noted that roughly half of the teachers included no high cognitive demand tasks in either the DU or AU portfolio; the other half of the teachers included at least one cognitively demanding task, with roughly 20% including one, roughly 25% including two, and roughly 10% including three tasks judged to have high cognitive demand.

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We also examined selected pedagogical features of the tasks that teachers included in their portfolios, including the use of out-of-school contexts or interdisciplinary activities, hands-on activities, cooperative grouping, technology, and student explanations. We found that nearly 90% of the DU entries contained tasks involving out-of-school contexts, slightly less involved hands-on activities (roughly 80%), group work (a little more than 60%), technology (roughly 60%), and student explanations (about 20%). About 90% of AU entries contained tasks involving out-of-school contexts, slightly less involved hands-on activities (about 80%), followed by group work (nearly 40%), technology and student explanations (both nearly 30%).

In sum, we found that there was a balanced treatment of topic areas in the submitted tasks, but that the tasks tended not to be cognitively challenging. Further, we found that the portfolio entries reflected a considerable amount of pedagogical innovation, especially in regard to the use of applied contexts, hands-on activities, and group work and technology. When we probed these entries to see if there was a relationship between the presence of cognitively demanding tasks and the use of particular pedagogical features, we found that innovative pedagogy was not linked to the use of cognitively challenging or demanding tasks. Even in our highly select sample of teachers who applied for NBPTS certification—thereby indicating that they thought of themselves as potentially highly accomplished teachers—we found little evidence that innovative pedagogy was used to support students' engagement with cognitively demanding tasks. Such findings are consistent with some other research studies (e.g., Cohen, 1990; Ferrini-Mundy & Schram, 1997) and many anecdotes, suggesting that teachers may implement reform pedagogy in a superficial manner that does not realize its potential.

Phase Two

In this phase of the work, we contrasted the mathematical and pedagogical features found in the portfolio entries of teachers who were awarded NBPTS certification and those who were not. This is of particular interest, given that a number of studies have tried to ascertain whether students achieve better in classes taught by NBPTS certified teachers than in classrooms where the teachers are not NBPTS certified. In the sample of 32 teachers, there were 17 people who were awarded NBPTS certification and 15 who were not.

We found a strong relationship between a teacher's NBPTS certification status and the presence or absence of cognitively demanding tasks in that teacher's portfolio submissions. In particular, nearly 60% of the teachers who submitted at least one high-demand task were awarded NBPTS certification, and only 20% of the teachers who submitted no high-demand tasks were awarded NBPTS

certification. That is, three in five teachers who submitted at least one cognitively demanding task were awarded NBPTS certification, and only one in five teachers who submitted no cognitively demanding tasks was awarded NBPTS certification.

For pedagogical features, our analysis showed similar levels of outside mathematics, hands-on, group work, and interdisciplinary activities in the portfolio submissions of teachers who earned NBPTS certification and those who did not. There was some variation for technology usage, with nearly 80% of NBPTS-certified teachers submitting tasks involving technology, in contrast to about 50% of the teachers who did not receive NBPTS certification. Perhaps because the pedagogical features were roughly equally distributed between NBPTS awardees and non-awardees, when we probed again for a relationship between the presence of cognitively demanding tasks and the use of particular pedagogical features, we found that innovative pedagogy was not linked to the use of cognitively demanding tasks.

In sum, we found that earning NBPTS certification was positively associated with cognitively demanding tasks. That is, teachers who were awarded NBPTS certification were far more likely than their colleagues who were not awarded certification to include high-demand mathematics tasks in the portfolio submissions we examined. We found no such association with pedagogical innovation. The innovative pedagogical features we examined—applications in contexts other than mathematics, multi-person collaboration, technology, or physical (hands-on) materials—were heavily used by the teachers in our sample, regardless of either their NBPTS certification status or their use of cognitively demanding tasks.

In general, we found essentially no connection between pedagogical innovation and the use of cognitively demanding mathematics tasks in instruction. Yet, we did find one possibly interesting interaction. The teachers in our sample who not only were awarded NBPTS certification but also submitted at least one cognitively demanding mathematics task appeared to be more consistent than were other teachers in our sample in the use of innovative pedagogy. Though we did not find statistically significant differences, the suggestion of a difference regarding consistency of usage is worth pursuing in follow-up studies with larger samples.

Discussion

Our analysis of the cognitive demand of the tasks submitted in the portfolio entries indicated that about one-half of the teachers submitted at least one task that we judged to be cognitively demanding. This finding may be interpreted as quite positive because this represents a much higher incidence of cognitively demanding tasks than

would be predicted from prior studies of mathematics teaching practice in the middle grades (e.g., Jacobs et al., 2006; Stigler & Hiebert, 1999). As noted above, prior research on instructional practice in mathematics classrooms has found that daily instruction in elementary and middle grades mathematics classrooms almost always involves teachers and students engaging in cognitively *undemanding* activities, such as recalling facts and applying well-rehearsed procedures to answer simple questions.

On the other hand, the fact that about half of the teachers in our sample failed to include in their portfolio entries even a single task that was judged to be cognitively demanding can also be viewed as disappointing because these teachers were showcasing their *best* practice. Nothing in the directions provided by the NBPTS for the assembly of portfolios for EA/M certification, nor in the accompanying materials (such as the teaching standards themselves), appears to discourage the inclusion of cognitively demanding tasks. In fact, the NBPTS process encourages submission of lessons that showcase students' thoughtful engagement with mathematics. Thus, our finding suggests that these teachers either did not use such tasks in their instruction (and hence they were unavailable for selection as portfolio entries), or they did not consider mathematical demand to be a characteristic of highly accomplished mathematics teaching (and hence they chose not to display it in their instructional samples), or their definition of demanding tasks was related to pedagogical rather than cognitive features (and hence demand was interpreted to be about increasing pedagogical complexity and innovation).

Our analysis of the portfolio entries submitted by candidates seeking certification as highly accomplished teachers by the National Board for Professional Teaching Standards in the area of Early Adolescence/Mathematics has offered a rare glimpse at the instructional practice of American teachers as they attempt to teach mathematics for understanding. Our analysis has revealed a form of instructional practice that, at least in some ways, deviates from the canonical portrayal of mathematics teaching derived from several decades of observational and survey research. In particular, the lessons that teachers submitted in their portfolio entries contained activities that treated a broad range of content topics (rather than being narrowly focused on number and algebra) that very often involved tasks situated in contexts outside mathematics itself and that frequently called for multi-person collaboration, as well as the use of technology and hands-on materials. These findings suggest greater diversity in content treatment and pedagogical approaches than has been evident in most other research on mathematics teaching in the middle grades, and they may reflect both the penetration of "reform" ideas (e.g., NCTM, 1989, 1991) into the instructional practice of those teachers who wish to display highly accomplished teaching and the feasibility

of those pedagogical approaches in American classrooms. On the other hand, our findings also suggest that there are several aspects of teaching mathematics for understanding that will require more systematic attention if they are to become a regular feature of instruction in U.S. classrooms.

The lower frequency of high-demand tasks, when compared to the higher incidence of innovative pedagogical features (contexts outside mathematics, collaboration, technology, hands-on materials), may suggest a need to explicate clearly the role and value of cognitively demanding tasks in the mathematics classroom. The critical link between student learning and the cognitive demand of tasks used in instruction has become more apparent in recent years as a result of the publication of research reports from QUASAR (Stein & Lane, 1996) and the 1999 TIMSS Video Study (Hiebert et al., 2005), and professional development materials that have been developed to promote attention to the centrality of cognitive demand and the challenges that teachers encounter in using high-demand tasks in the mathematics classroom (e.g., Stein et al., 2000). It is possible that these ideas might be taking hold more firmly than was evident in our sample drawn from samples of teaching in 1998-99, but our finding here of an apparent disconnect between innovative pedagogy and cognitive demand signals that teachers are likely to need explicit guidance about how pedagogical innovations could play a key role in increasing the cognitive demands of mathematical tasks, and thereby enhancing students' opportunities to learn mathematics.

Our analysis of cognitive demands in the mathematics tasks submitted by teachers in our sample indicated that the assessment (AU) entries were more balanced with respect to cognitive demands than were the teaching (DU) entries. Overall, a higher percentage of AU entries contained cognitively demanding tasks than was the case for the DU entries. Moreover, in all topic areas except geometry, the ratio of low-demand to high-demand tasks in AU entries was closer to one than in the DU entries (see Silver et al., 2009, Table 5). Though we cannot be certain about the reason for this finding—perhaps it reflects a different view of teaching and assessment—this and other detected differences between the DU and AU entries point to the potential importance of considering teachers' assessment practice as part of any attempt to understand classroom instruction. In general, research on classroom instruction has not included explicit attention to assessment practices, and our findings suggest that it might be important to do so in the future.

Coda

Our investigation of the portfolio entries was not intended to be a validation study of the NBPTS certification process, and a replication involving a larger sample would

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be needed to make strong claims. Nevertheless, some of our findings do offer some validation of that process. In particular, the lack of correspondence between the awarding of NBPTS certification and the use of pedagogical features can be taken as evidence that the portfolio evaluation process is not heavily influenced by possibly superficial implementation of pedagogical innovation. And the positive association of low-demand mathematics tasks with non-certified teachers and high-demand mathematics tasks with certified teachers suggests that there is some reason to think that the instructional practice of those teachers awarded NBPTS certification is in fact “highly accomplished” in one mathematically important way that is not an explicit part of the NBPTS certification process. Moreover, the finding that at least some of the innovative pedagogy was used in connection with high-demand tasks by NBPTS-certified teachers and not by those who were not awarded certification provides yet another indicator that the NBPTS certification process is reasonably well aligned with some other views of high quality mathematics teaching in the field.

Given research evidence indicating both that teachers in the middle grades find it difficult to enact cognitively demanding tasks in mathematics instruction (Stein et al., 1996) and that the consistent, effective use of cognitively demanding tasks in the mathematics classroom increases student achievement (Stein & Lane, 1996), our findings suggest that there may be something to learn from NBPTS-certified teachers about how to utilize such tasks effectively in the mathematics classroom. According to our analysis of the data examined in this study—teacher-selected samples of practice chosen by individuals seeking special recognition—the teachers who were awarded NBPTS certification appeared to deploy cognitively demanding tasks more proficiently than did their counterparts who were not awarded NBPTS certification.

It is worth noting two special aspects of the data analyzed in this study that may merit attention from other researchers who seek to understand high quality mathematics teaching. First, the lesson materials and artifacts analyzed in this study were selected by teachers and submitted for evaluation in a process intended to identify highly accomplished teaching. It is reasonable to assume that the samples represented lessons that the teachers considered to be their best practice. In large-scale observational studies of teaching and in surveys, it is common to request samples of or information about typical teaching practice. Some scholars (e.g., Silver, 2003) have suggested the potential value of also examining instruction that is atypical in some way to detect, for example, what teachers might be capable of doing or inclined to do when they try to exhibit their very best work. The NBPTS portfolio entries offer one example of what such atypical data might look like, and our analysis of these data offers one example of what might be learned.

Second, the data examined were of a hybrid form that combines some features of the data collected via direct observation and data collected via survey responses. Like direct observation, the portfolio entries displayed important details of classroom lessons; similar to survey data, the portfolio entries permitted access to the teacher’s perspective. Although the NBPTS portfolio data might appear overly limited as a source of information about teaching practice because the records do not include direct observation of actual teaching, the data in the NBPTS portfolio submissions are in many ways quite similar to those that have been used and validated by other researchers to study classroom practice using alternatives to direct observation and survey methods, such as “scoop” sampling of instructional artifacts (e.g., lesson plans, student work) to characterize instructional activity (Borko et al., 2005) and using classroom assignments to judge instructional quality (Clare & Aschbacher, 2001; Matsumura, Garnier, Pascal, & Valdés, 2002). Researchers interested in alternatives to direct observation methods (which are invasive, labor-intensive, expensive, and impractical on a large scale) and survey methods (which involve questions susceptible to multiple interpretations, have questionable validity, and provide little information about the details of instructional lessons) might be wise to consider data like those collected in the NBPTS portfolio process to open another window on classroom instructional practice.

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