Re-Forming and Re-Norming Instruction: Lessons from the Delaware Mathematics LSC

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Three middle school mathematics teachers lean in toward the video screen. It is hard to hear some of the student remarks because of indifferent audio and the ambient noise of nearby knots of teachers huddled around other computer screens. "What did she say? Play that back, please." Nearly 70 Delaware teachers have shouldered the mantle of School-Based Teacher Learners-to-Leaders as they study the problem-solving behaviors of students deemed "at-risk" in secondary mathematics. They are playing and re-playing a brief video vignette featuring a group of students embroiled in a discussion of a rather challenging algebra problem. They are considering evidence from the video to try to evaluate the "strategic competence" of each of the at-risk students using a rubric developed by the project leadership.

"They weren't very open to each others' explanation which caused the confrontation," asserted one 5th grade teacher about the initial interactions of the four 8th graders. Regarding another student in the group, a high school teacher concluded, "he bounces ideas off the group. You could see from his end product that he knew what was going on. He uses the group as a springboard for independent work, taking what people are saying, but also developing his own thoughts."

Video analysis of teaching and learning is becoming almost routine as an element of professional development in secondary mathematics in Delaware. In the course of this work, teachers design and apply student-to-student discourse rubrics and discuss the status of student understanding and how best to intervene to support more effective learning. NSF-sponsored curriculum projects are the rule rather than the exception in middle grades classrooms throughout the state and nearly all of the school districts in Delaware have invested in one or more mathematics specialists to support fidelity of implementation of these challenging curricula. Delaware has come a considerable distance in institutionalizing the reform of teaching and learning in middle school mathematics. How has this promising state of affairs come about?

This is the story of our secondary mathematics Local Systemic Change (LSC), the Delaware (6–12) Exemplary Mathematics Curriculum Implementation project, which was built on the foundation of a number of large-scale reform efforts that had preceded it. DEMCI began as a collaboration of the University of Delaware, the Delaware Department of Education, 17 of Delaware's 20 public school districts, and 2 charter schools. The stated goal of the initiative was to dramatically improve the teaching of mathematics in middle and high schools throughout Delaware by providing 130 hours or more of professional development for at least 70 percent of Delaware's teachers of 6–12 mathematics. DEMCI professional development was to feature the related foci of content, pedagogy, and curricular knowledge. We believed that as communities of teachers were supported in their reflection upon the use of these novel curriculum materials, they would reassess deeply-held assumptions about best practice and improve their instruction accordingly.

First Stirrings in the First State

Consequent upon the seminal event of the publication of the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards for School Mathematics* (1989) and then gathering momentum after the *Professional Standards for Teaching Mathematics* (1991) took a first stab at codifying an essentially constructivist pedagogy, the modern era of "the reform movement" was in full swing by the mid-nineties. These currents of reform were felt in Delaware as in the rest of the nation.

The choice of the initial vehicle of the reform in Delaware speaks volumes about the issue of scale that is the most notable thing about the context of our state. In 1991, the state mathematics supervisor convened a two-day conference, called Project 301 in testimony to the number of distinct school entities in Delaware at that time. Each of these schools was challenged to send a pair of teachers to the conference with the understanding that they were to take back an idea or a lesson illustrating the new *NCTM Standards* to implement in their classroom. Ultimately, taken under the wing of the Delaware Council of Teachers of Mathematics, Project 301 was held each spring for nearly a decade; it is regarded by many teachers in Delaware as their introduction to the ideas espoused in the *Standards* and, perhaps more importantly, as the venue in which they first met and over time became affiliated with like-minded colleagues from across the state. Fledgling networks were begun at these early meetings that forged links that have endured to this day.

This grassroots approach to school reform was replaced in mid-decade by a comprehensive self-consciously systemic program funded in part by a Statewide Systemic Initiative grant from the National Science Foundation and fueled by aggressive inputs from the Delaware corporate community. The systemic nature of this initiative was expressed in a new collaboration between the University of Delaware and the Delaware Department of Public Instruction. State standards were put in place over the next three years and an assessment system tightly linked to the standards became operational in spring 1996. The SSI worked on three fronts: mathematics reform, science reform, and school change.

From SSI to LSC: University as an Axis of Reform

The University of Delaware became a locus of reform in mathematics and science education during the decade preceding the funding of our LSC. With assistance from University faculty, specialists in mathematics and science education were charged with working with K–12 teachers in public schools across the state in order to help "Delaware's K–12 mathematics and science teachers implement new content and performance standards in their classrooms." Eisenhower grants were secured, for example, to support the implementation of standards-based mathematics curriculum materials—principally *Investigations in Number, Data & Space* and *Math Trailblazer*—in elementary schools throughout Delaware. In another early initiative dubbed Del-Core Plus, private funding was obtained to pilot the implementation of *Core-Plus Mathematics* in classrooms containing a high proportion of at-risk students. It was in this context that our Local Systemic Change initiative was developed, the grant proposal written by University faculty and

staff in concert with colleagues from the Delaware Department of Education and a consortium of districts from around the state.

While the era of the Delaware SSI may be characterized in retrospect as a period of experimentation with new standards and novel curriculum units—a "replacement unit" strategy was the one most often employed—the LSC represented an opportunity to move to scale with curriculum-driven instructional reform. Linked through the mediation of the school change component within the SSI, the mathematics and science reform efforts were to go their separate ways as the SSI apparatus morphed into separate centers and sought subsequent sources of funding on their own. The school change component found a home with the Delaware State Education Association and received a substantial grant to continue its work in promoting site-based reform of school culture.

The science reform effort incubated within the SSI took on new leadership and found a home within the reorganized Delaware Department of Education, with significant funding through a major LSC grant for elementary science. (See Case by John Collette.) Not only were they now housed in different locations, but Delaware's mathematics and science LSCs chose to follow distinctly different tacks with regard to both methods and goals. The DEMCI LSC was narrowly focused on secondary mathematics curriculum implementation. The Delaware science community, on the other hand, undertook a very ambitious program of curriculum *development* in which large-scale instructional units were either developed locally from scratch or adapted from materials that had been developed with NSF support. The science LSC crafted, in sum, a common curriculum for use by all districts in K–5 science.

The Delaware mathematics community, on the other hand, felt that the tradition of curricular local control dictated another approach. Therefore, we promised to support the implementation of "standards-based" materials with our LSC and made recommendations about those emerging curricula that seemed to best align with both the substance and the spirit of the new Delaware content standards. This forced-choice strategy worked from the start as district supervisors and middle school mathematics teachers joined University mathematics educators in evaluating curricular alternatives. By the time our mathematics LSC was finally funded—our first application was, with good reason, denied—all participating districts had made considered decisions about their middle school mathematics curriculum and about half of them had adopted high school materials as well. Of the 14 K–12 districts initially in our LSC, 8 decided to adopt the *Connected Mathematics Project* materials as their middle grades mathematics program while the remaining six opted for *Mathematics in Context.* Fourteen districts, including our three vocational-technical high schools chose initially to implement *Contemporary Mathematics in Context* (*Core-Plus Mathematics*) within at least some of their high school mathematics classrooms, while two opted to adopt another NSF-funded curriculum, *Mathematics Connections.* In a number of cases, this was the residual impact of the Del-Core Plus initiative; it was a first venture into the use of reform mathematics curriculum at the high school level.

Multiple Drivers: The Perfect Storm

Timing is everything, and the Delaware reform effort benefited from the convergence of multiple "drivers" as our LSC hit its stride in 1999. Perhaps the factor that most immediately commanded the attention of our district partners was the accountability attached to the new Delaware Student Testing Program. The testing program was quickly coming on line and promised to go beyond routine multiple-choice questions to include constructed response items of both brief and extended nature; the test blueprint called for 40 percent of the items to measure conceptual knowledge, 40 percent to evaluate procedural fluency, and fully 20 percent to assess aspects of problem solving. This was not your basic skills large-scale assessment, and district supervisors were fully aware of the dangers inherent in the new comprehensive assessment system. They also understood that the leadership from the SSI, and now the LSC, were involved in the design and development of the new assessment system and that this arrangement suggested the possibility of a productive alignment between instruction and assessment for a long time to come.

Our LSC was also perfectly timed with regard to the release of many of the middle and secondary NSF-funded mathematics curriculum projects. While we had managed to negotiate with several of the materials developers for access to pre-publication versions of many of their curriculum units during the years of the Delaware SSI, by the time our LSC was funded, first editions of these new materials were commercially available at all grade levels, making adoption decisions less perilous for participating school districts. Because the curriculum development efforts were, in most cases, only recently completed, many of these curriculum projects had residual staff that were in a position to provide support for new adopters. In fact, personal contacts that endured for years were forged at this time between Delaware leaders and curriculum project personal.

A third factor that augured well for the timing of our LSC was an emergent network of district, University, and Department of Education leadership in the mathematics education community. Many of the principal players in the Delaware mathematics reform had first gotten to know one another within the context of the Project 301 annual meetings. Another early collaborative effort initiated by mathematicians and mathematics educators at the University of Delaware and funded by an NSF grant from 1992–96, the Delaware Teacher Enhancement Partnership was devoted primarily to teacher leadership development and nurtured key teacher leaders within four target districts. It also had the salutary effect of establishing long-lasting ties between University of Delaware faculty and teachers within those districts. More than a decade out, teachers from the Teacher Enhancement project have assumed key roles of curriculum supervision and support within the partner districts and beyond.

Buying Buy-In: Top Down *and* Bottom Up

How best to prepare the system for radical curricular change? Our initial tactics of engagement might best be described as more "top down" than "bottom up" with a great deal of time and energy spent convincing district leadership to support the goals of the LSC. Our experience with the Delaware SSI suggested that unless one impacts district policy, changes in practice will be

limited to isolated teachers and always susceptible to changes in personnel or the whims of building administrators. Our "Memo of Understanding," personally endorsed by district superintendents included provisions through which the participating district agreed to "support and endorse the National Science Foundation's policy requiring *all* mathematics teachers in designated DEMCI schools to participate in DEMCI professional development activities." Districts also agreed to support teacher attendance at week-long academies through four summers, bimonthly dinner meetings, and biweekly school meetings. The pecuniary responsibilities shouldered by participating districts included "district purchase of textbooks, materials and appropriate technology to support the implementation of standards-based mathematics curricula in grades 6–12" as well as supplements of participant stipends for summer and evening professional development activities "according to district procedures."

Although we did not recruit participation on a teacher-by-teacher basis when designing the DEMCI rollout plan, we had already established a productive working relationship with at least some teachers from most of the participating districts and we believed that this would prove an effective bridge to a wider engagement of Delaware's secondary mathematics teachers. We also hoped that the daily stipend would be sufficient to encourage a large turnout for our summer professional development academies. The fact that some teachers *were* familiar with the NSF curricula and had used them on at least a replacement unit basis provided a general awareness and at least some local momentum for the LSC at the outset.

In hindsight, however, our expectation that a significant number of teachers would immediately rally to the cause of a major re-formation of their practice was overly optimistic, and our assumptions that teacher leadership would emerge naturally at the school level were a bit naïve. One year into the LSC, we met with representatives from the Delaware State Education Association (DSEA) to ask for their public backing of our program of Local Systemic Change. We were surprised to learn that they would not go on record as supporting either the goals or methods of the LSC even though they acknowledged in private that they personally agreed with them and wished us luck in our endeavor. The DSEA rebuff was based, they said, upon their perception that we had not garnered sufficient support for the LSC on the ground *before* submitting the original proposal. Fostering and maintaining this grass roots support, often teacher-by-teacher, was to be a continuing challenge during the LSC. As the program matured, and especially beginning with our third year, differentiated development addressed the needs of teachers at very different levels of project experience. We came to think of teacher readiness in terms of a Concerns-Based Adoption Model and modified our professional development accordingly. By the project's end, we were to appreciate more fully the need to cultivate teacher leadership quite explicitly in order to support the intended reform.

Capacity, Capacity, Capacity: Breadth Before Depth

While going to scale became an important watchword for the "systemic change" family of initiatives, ways to build to this obviously desirable outcome have been hotly contested. Mathematicians and mathematics educators may be inclined to conceive of scaling up as some sort of orderly geometric or even exponential progression in which full scale deployment is

Rather than begin the reform in one school or even a small number of district loci, we chose to initiate the implementation in *all* of our target districts and schools at the same time. A metaphor that might capture the wisdom of this is that of a long line of cars stopped at a traffic light. If, upon the light turning green, the driver of the each car waits for the car in front to move before hitting the gas pedal, then there is a certain incremental delay occasioned by each successive car in line so that the driver of the n^{th} car must wait through n-1 delays before starting to move. A more efficient if somewhat hazardous strategy would be for each driver to *watch the traffic light* rather than the car in front. In such a scenario, all cars would begin to accelerate together upon the light turning green and far more cars could pass through the intersection in the time allotted. This simultaneous implementation strategy was chosen by our LSC. This approach appeared at the time and seems even more so today a wise strategy for prompting systemic change across schools and districts. All enter the arena with a more-or-less equal status. There are neither leader nor follower districts hence no motivation to be first adopters or to try something different in order to get a hand up on the competition. Partner districts can thereby make common cause of curricular improvement in spite of any perceived need to equal or best one another in student outcomes.

To be sure, there were a few renegade administrations that opted out of the LSC when met by teacher resistance or organized push back. In another instance, a school principal severely compromised the integrity of the implementation of *Mathematics in Context* in her school, and ultimately in her district, when she was convinced by an educational entrepreneur that an expensive online assessment program would help her tailor a more "balanced" mathematics curriculum to the particular needs of her student population. For the most part, however, school and district administrators stood by their promise to support the purpose and progress of our LSC. Today, we see a landscape in which the use of standards-based materials is the norm in middle school mathematics in Delaware. Teachers have embraced the use of these materials as well as the underlying pedagogical imperatives in far more cases than not.

Our choice of an accelerated implementation—three full years plus a fourth summer—carried with it potential advantages but also profound risks. While one might, with planning, luck, and perseverance, achieve breadth of implementation in relatively short order, one will almost certainly do so at the cost of depth. In fact, this may well be an inverse function of sorts. We had tried an intensive school-based implementation within our SSI, focusing on issues of school culture and teacher buy-in at a few sites around the state, and had achieved mixed results. Instead of once again investing all of our capital in a small number of schools and districts as we had several years before, we opted for a profoundly democratic approach. Rather than judging the readiness of any given school or district context, we welcomed all of them; resources were to be spread as thinly as necessary in order to achieve our grand design.

First Signs of Pushback

Pushback was not long in manifesting itself in response to our first year rollout. We perceived it initially in the form of individual teacher resistance, sometimes vocal, often passive. This was, no doubt, a reaction to both the scale and the speed of the change we had set in motion as well as the unusual timbre of these new materials. Rather than introduce the new curricula incrementally, most districts had opted for an all-at-once approach, all units at all grade levels, no teacher nor student to be left behind.

The primary mechanism for establishing best practice at the school level was to be the biweekly school meetings described in the Memo of Understanding as follows:

> *During the first school year, DEMCI will provide all professional development activities in collaboration with the team of school mathematics teacher participants. During the second and third school years, the school team will gradually take on more responsibility for these meetings, so that these collaborative, reflective team meetings will be an integral part of the school culture extending beyond the duration of the DEMCI.*

We were, however, not properly mindful either of the limitations of our own capacity for providing this quantity of professional facilitation on a biweekly basis or of the vicissitudes of depending upon an emergent school-based leadership. In the first place, our six Secondary Mathematics Specialists were logistically challenged in trying to attend the plethora of school-based meetings described in our proposal. We obviously had not done the math! Furthermore, issues around the establishment and then transfer of leadership for these meetings were never properly resolved. While many school faculty were quiescent enough when we offered to "facilitate" these meetings during the initial year of the project, this quiescence had an obvious price in that leadership seemed vested in outsiders and never properly invested within the faculty itself.

The focus of these first school-based meetings seemed simple enough—a discussion of the opportunities and challenges of the lessons currently being taught from the standards-based materials. This idea, too, proved more complicated than we had at first imagined; our plan to focus on a single lesson or series of lessons at any one grade level or even a series of lessons within a curriculum unit was often frustrated by the range of teachers of various grade levels in attendance. Too often, in fact, these sessions became opportunities for reluctant teachers to air their grievances about the new materials, and this dynamic created rather than dissipated friction in the implementation.

In fact, we came to rely upon our large-scale bimonthly evening meetings as a rallying point for the curricular reform. We attempted to utilize these occasions to illuminate aspects of the new instructional paradigm embodied by the materials. We also came to appreciate the salutary effects of having teachers from across schools and districts meet on neutral territory in common cause. School and even district politics were left behind, or at least held in check, in these forums. Principles of curriculum and instruction could be examined, we believed, at a safe distance from the actual site of instruction.

In a similar manner, the summer institutes served to aggregate teachers into within-grade and material-alike cells for deeper study of the curricula themselves. Although we had hoped to induct 50 percent of the target teachers into the first of three summer institutes the first year, and the remaining 50 percent the second year, we found that this two-cohort strategy was messier than we had hoped. We did finally manage to establish more-or-less similar cohorts based upon materials and number of years of implementation and this differentiated professional development was one of the most effective strategies we came to employ within our LSC. We recognized the desire of new adopters to develop initial familiarity with the materials and the even more pressing need for "experienced users" to be prompted into a deeper examination of the curriculum and the mathematics instantiated therein. By the third summer, we incorporated elements of vertical articulation into the professional development so that teachers at a given grade level could better understand the interaction of the mathematics in the units they taught with the conceptual development that came both before and after. We also aimed by this third and final year of summer institutes for a certain level of generalization of instructional principles.

Teacher resistance to the major reform of content and practice embodied in the new materials was a more serious threat to the integrity of our project's goals in some quarters than in others. High school teachers were, by and large, more willing to mount an active struggle to prevent or circumvent the adoption of the reform materials than were middle school teachers. They seemed more ready to play the content expert card with their local administrators. On several occasions, this active resistance required an act of intervention on the part of project principals, usually in the form of a presentation orchestrated for district-level administrators and mathematics faculty. In at least two instances, these interventions were successful in bolstering administrative support for the reform within those districts.

More numerous and frequently more damaging were the acts of passive resistance, e.g., when teachers would opt out of after-school curriculum meetings or otherwise stonewall with regard to their participation in curriculum implementation. Passive resistance tended to be most effective in stalling the reform in schools with relatively small mathematics faculties since, in these environments, a single senior faculty member could have maximum disruptive impact. Within larger faculties, the impact of a few resistors was often sufficiently diluted by the other teachers.

In a very few instances, faculty members worked collaboratively to block the reform in their school or district. This premeditated "push back" was perhaps most intense when the Secondary Mathematics Specialist assigned to facilitate the process of curriculum implementation was a former colleague of the resistant teachers. In these instances, the opposition could become quite personal. Once again, our usual proximal response was to send in senior project personnel as presenters or facilitators in an attempt to mediate the local dynamics. In at least one instance, the school district in question ultimately withdrew from the LSC as a consequence of a significant teacher resistance orchestrated by three veteran teachers who felt their leadership status as well as their considerable independence in curricular matters directly contested by the imperatives of the LSC. Before the reform had reached critical mass within their district, they managed to tip the balance back to the *status quo*. Only recently, following the retirement of the chief officer of this resistance movement, has this particular district returned to a gradual adoption of standards-based materials.

Another ongoing threat to our effort to go to scale within schools and districts was the large percentage of teachers who failed to secure professional development "on schedule," including cases where novice teachers were hired after the conclusion of the summer institute and just before school was set to begin. In response to this lower-than-budgeted attendance at previously scheduled summer institutes, we found ourselves offering identical sessions of professional development at more convenient times in more convenient locations. This fragmentation of the original PD plan did produce additional hours of professional development, more than 50,000 teacher hours within the original 40 months of the project, and may be seen as an increasingly flexible response to the ever-more real challenges of scaling up. On the other hand, certain aspects of a carefully designed program of professional development were lost in translation as training was provided *ad hoc* by colleagues in more disparate locations with less opportunity for common planning and implementation.

(In)Fidelity of Implementation

Given our determination to train 70 percent of the teaching force in participating districts within three academic years, it was perhaps inevitable that we would spread our resources too thinly to insure a truly generative learning organization for our LSC. For example, several members of our small cadre of Secondary Math Specialists were tasked with providing professional development across a half dozen districts, some in Delaware's northernmost county, others in the middle and southern counties, in the *Connected Mathematics* curriculum. Other Specialists were charged with providing training in *Mathematics in Context*, still others with introducing their high school colleagues across multiple districts to the *Core-Plus Mathematics* curriculum.

Although the cadre of Specialists met biweekly to share strategies and problem solve around emerging professional dilemmas, a corpus of wisdom of practice was never fully formed. In opting to disaggregate our functions in the service of efficiency—curriculum expertise being the most obvious arena of specialization—we failed to achieve a fully shared understanding of best practice in providing professional development. Lack of collegiality was never a serious problem for our project, but failure to communicate the lessons learned about project-based professional development most certainly was.

Not only did our trainers fail to develop the rich set of strategies that a more integrated approach might have achieved, but, in a significant number of instances, they began to feel isolated and, increasingly, the most proximal focus of the teacher push back that any aggressive large scale implementation will incur. Although personnel turnover was not especially high for a project of this kind, a number of our Specialists opted to return to classroom practice mid-project. We learned that, in order to mount an ambitious program of professional development, a project must develop a mechanism that enables project staff to learn collaboratively from challenges as they first emerge: the project must become *at least as adaptable* as the situation on the ground.

While we were able to deliver what seems upon recounting an incredible amount of professional development both in the form of summer institutes and in-year curriculum coursework, fidelity of implementation may have been an early casualty of the volume of activity. Perhaps ultimately more hazardous to our efforts than open rebellion or passive non-compliance, was a widespread

lack of fidelity in the initial implementations of the reform curricula. As our project progressed, our attention turned increasingly to issues of fidelity of implementation and strategies for promoting it.

From start to finish, our LSC staff guarded against willful adaptations of the curriculum materials. In biweekly meetings, the project leadership and Secondary Math Specialists devised strategies for both large-scale and school-based professional development and spent a good deal of time addressing problems of our own professional practice. How best to introduce the materials so that even initial use was purposeful rather than purely mechanical? How to make the pedagogy implicit in the curricula more explicit and sensible to teachers quite comfortable with a show-mimic-practice instructional regimen? Although we wrestled with these questions as a team and developed a shared understanding of the problems if not always the solutions, I think it is fair to conclude that we all believed and attempted to communicate our belief that the new user should "trust the materials" as written. Though this might sometimes be experienced as dogma by the teachers with whom we worked, it seemed an important article of faith that gave our project a common compass throughout the period of NSF-funding and beyond.

The Toll Taken upon Teachers-on-Special-Assignment

We invested quite purposively and heavily in authentic teacher leadership because we felt that: (a) it would be most immediately effective from the point of view of contextual credibility, and (b) it would contribute human elements to an emerging infrastructure of reform. We did not anticipate, however, how our new teacher leaders would suffer in this very challenging role.

Beyond the Principal Investigator and the handful of other faculty and staff at the University of Delaware who would dedicate considerable time and energy to the new project, we opted to recruit leadership for our LSC from the Delaware teacher corps, using the Teacher on Special Assignment model of project staffing. We chose this route for two reasons. Since the LSC was to be funded for 40 months, it made more sense to ask teachers to leave their teaching jobs for three academic years than to try to hire new staff at the University for such a short and uncertain term. More importantly, perhaps, we relied upon the power of pairing a University mathematics educator or mathematician with a public school practitioner. The first brought a deep knowledge of the subject to the work, the second a knowledge of and connection to the system.

Recruiting local leadership for mathematics education reform is, however, challenging across at least two dimensions. Most obviously is the issue of capacity—do we have enough experienced teachers of mathematics at the targeted grade levels who also have the skills and disposition to work with former and future colleagues? A related issue is less easy to quantify. Are our talented teachers willing to exit the classroom for a few years and position themselves as levers to drive that system toward pedagogical innovation with the likelihood that conflict with colleagues may result and that their credibility will be challenged the longer they are out of the classroom?

Given that high school teachers of mathematics were at a premium in our region, retiring or leaving the state at least as quickly as they were coming out of the university pipeline, there was

a good bit of teacher mobility from one district to another at the start of our LSC. This situation may, ultimately, have contributed to our ability to recruit high school and middle school teachers in equal parts as Secondary Mathematics Specialists in that these teachers were almost certain that they could return to their former positions, or find positions in other districts, at will.

We were also able to leverage a certain percentage of the efforts of several Teachers on Special Assignment who had been reassigned by their own district into "mathematics cadre" positions; there were now additional project staff on the ground and a sense that our project might actually have sufficient staff to go to scale. The challenge, however, was that those Secondary Mathematics Specialists who worked only part-time for our project regarded their district tasks as their primary responsibility whenever there was any ambiguity about how best to allocate their time and effort.

Given the intensity and the very real challenges of the LSC work—providing differentiated professional development for literally hundreds of middle and high school mathematics teachers over a 40-month span—we were quite fortunate that our staff suffered relatively little burnout or attrition. We did find ourselves faced with the loss of two Secondary Mathematics Specialists near the project's end because those specialists were offered permanent positions within Delaware districts. We were able to turn this loss to advantage, however, by spreading the funding for these two fulltime positions over a greater number of new part-time positions located in participating districts. In fact, one of the legacies of our project is that almost all participating districts currently now fund mathematics specialist positions as a routine part of their district budgets.

The Tipping Point: From Proselytizing to Professional Development

We spent a good bit of time, energy, and emotion during the first two years of our LSC selling and then defending the need to adopt standards-based materials. The idea that mathematics could be learned through the agency of a problem-based pedagogy seemed strange to many secondary mathematics teachers, and we had underestimated just how much teacher learning would be required. For the most part, our strategy was to use curriculum-embedded professional development to make our case. Our reasoning was that in learning to teach from these materials, teachers would come to appreciate the importance of the mathematics and the power of the pedagogy contained therein. We saw the introduction of the reform curriculum materials as a necessary condition for fundamental change in school mathematics. We hoped that it would prove sufficient as well.

While we devoted a great deal of time and effort to bringing teachers into curricular compliance, an important omission may have been our failure to invest significant resources in print or video media public relations. DEMCI's public footprint, save the occasional local newspaper article heralding "a new kind of mathematics," was relatively subdued. On a district-by-district basis we sponsored parent nights to promote local support for the curricular changes everywhere afoot, but even these were focused on the local situation rather than the project per se. In fact, perhaps unwittingly, in keeping the project in the background, we avoided any large-scale reaction to or

organized assault upon the reform itself. The so-called "math wars" were fought elsewhere with only minor skirmishes on Delaware soil.

Can we identify a particular tipping point around which juncture we knew that the reform had taken hold? Certainly we were not aware of such a point in the ebb and flow of the initiative itself nor is it obvious even now several years later when we are finally confident that significant change *has taken place* and will endure. In an annual report after the second year of NSF funding, I wrote with some enthusiasm that teacher change seemed more like a quantum leap than a linear or even recursive process:

> *Imagine that the professional development offered by our LSC represents energy input into a teacher's practice. It will take a certain critical quantum of carefully focused professional development to enable the teaching professional to leap to the next orbit or level of practice. Our current best guess is that two years of consistent coherent professional development are required to promote significant change in teacher practice.*

This statement now seems overly optimistic, but it may nevertheless contain more than a germ of truth with regard to the practice of individual teachers. What it does not speak to is the host of context variables that help determine the net effect and staying power of the reform writ large. What are all of the necessary ingredients of a profound shift in status quo? Need these factors be manipulated in the aggregate to produce the desired result? Or were we correct in our foundational assumption that if we could plant the reform in enough classrooms at once and at the same time nurture its growth through early perils, a coherent change in practice would likely result?

In order to move from initial largely mechanical use to deeper more substantive implementation, we did design differentiated professional development for our teacher cohorts for the second and third year summer institutes or their equivalent. So, for example, we tackled vertical articulation in our second year of professional development and the development of "best practices" rubrics in our third year. As teachers in "Level III" training studied, planned, presented and critiqued particular lessons, the pedagogy made explicit in those lessons came under intense but collegial scrutiny. Small groups of teachers were then challenged to develop their own rubric of professional practice. An example of one such rubric described four levels of attainment ("not trying," "emerging/growing," "proficient," "master") across the instructional attributes of questioning strategies, prerequisite knowledge, and curricular connections. For example, growth in questioning strategies was characterized as moving from "tells, does not use questions as a teaching tool" at the low end to "anticipates questions and plans a number of strategies to draw out student potential" at the other extreme. We take these artifacts as one source of evidence that these teachers at least were attempting to move beyond superficial implementation. They may even be regarded as indicators of substantial transformations of practice in some instances.

As I noted in another annual report:

> *There is some evidence, however, that teachers as individuals are beginning to reconceptualize their craft. For example, many of our Level III teachers are at least talking about the importance of "understanding student thinking." As Hiebert (private*

conversation) has argued, when teachers begin to think about how students might respond to a particular problem or prompt, they are applying a more powerful standard to their lessons. While our attempt to move Lesson Study to the fore in our LSC's professional development was not successful per se, the core activity of shifting the focus to student thinking does seem to be bearing fruit.

From Learners to Leaders

In assessing the legacy of our LSC, we may note that although professional development saturation targets were not realized in many cases, standards-based mathematics curricula were quickly put into place in middle schools throughout the state and in a smaller percentage of high school classrooms. Today, perhaps 7 out of every 10 middle school students in Delaware public schools experience either *Connected Mathematics* or *Mathematics in Context* as their primary middle grades mathematics curriculum. By and large, middle school classrooms offer a problem-based pedagogy at least some of the time, and the launch-explore-summarize model of instruction is familiar to most if not all middle grades mathematics teachers. At the high school level, NSF-supported curricula are the main stay of the grades 9–10 curriculum in the highest performing district in the state and at two of the three vocational school districts, although there has been considerable slippage in the other high school mathematics programs.

An intended legacy of the DEMCI LSC was to leave an enhanced infrastructure in its wake. This legacy has been accomplished in several regards. In the first place, all but the smallest of districts now has a Teacher on Special Assignment whose role is to support a high fidelity implementation of the district's mathematics curriculum. Created and supported by NSF funds during the first years of the grant as Secondary Math Specialists, these positions have since more than tripled in number and are now wholly district-funded. The University of Delaware continues to be the locus of learning for this community of mathematics specialists. Instantiated for the past three years as the Mathematics Specialist Team (MaST), this group meets on a semi-monthly basis for study, reflection, and support. For example, two years ago, the various members of MaST, now numbering almost 30 specialists, engaged in a book study of *Adding It Up*. Last year our group developed a set of transfer tasks to illustrate the revised Delaware mathematics standards, and this season we are engaged in an in-depth study of algebra learning utilizing multiple sources of evidence including video culled from local classrooms. In the MaST learning community as well as with our School-Based Teacher Learners-to-Leaders, we are modeling the idea that leaders must first and always be learners.

Another legacy of our work with partner districts during the Delaware mathematics LSC has been the development of strong relationships with curriculum supervisors in every one of the participating districts. These relationships have resulted, we believe, in strong and enduring district-level commitments to the project of reform in mathematics instruction. At the conclusion of our LSC, we sought, symbolically at least, to pass the baton of leadership in the mathematics reform movement to a collaborative of partner districts. This goal has finally been realized, just this past year, with the rebirth of the Delaware Mathematics Coalition whose mission is to "identify and endorse research-based best practices in mathematics instruction."

New Norms for New Forms

To re-form would seem to suggest that current forms are to be replaced by new forms, that hoary traditions are to be displaced by new ways of thinking, by a brand new "practice." An implication: really new forms require clearly new norms. This simple formulation ignores, however, the resilience of the familiar and slights the power of the former forms.

Traditions in school mathematics can prove to be deep and enduring, especially at the secondary level. In order to replace a student paradigm of watch-and-match with one of conjecture-and-consolidate and to promote a concomitant movement of teacher from explainer-verifier to facilitator-observer, both students and teachers must be inducted into their new roles. Fundamental goals of the learning must be re-examined and revised.

Can this reformation be achieved through successive approximations? Is the reform of teaching and learning a quantum phenomenon? Can a wholesale adoption of problem-based curricular materials with ongoing oversight and timely support result in an implementation of recursively enhanced fidelity?

At least in Delaware, the tentative answer to this set of questions is a not-so-cautious "yes." The reality on the ground seems to bear out our fundamental goals. The reform curricula seem to have taken hold in many places, and student outcomes as measured by the Delaware Student Testing Program continue to improve. Teachers often report that they do not wish to return to "traditional" materials and modes of instruction.

Most importantly, perhaps, we seem to have made some significant headway in promoting new norms in support of the new forms of practice. These norms include a commitment to continuous learning and a reinvigorated attention to student thinking involving a consideration of multiple forms of evidence. Learning Scene Investigation—LSI Delaware!--has become a standard feature of all of our professional development. Reflective replaces reflexive practice as the norm.

A final conundrum: Can these new forms and norms be "institutionalized?" We often say that we strive for "institutionalization of the reform" in order to guarantee its longevity. Is this a chimera? In what institutions is the reform of school mathematics to be permanently instantiated? How might this process of institutionalization occur? How will these institutions be different once the reform has been institutionalized?

Clearly, one institution that must change in order to accommodate and support a reformed practice in school mathematics is that institution most proximal to the site of that practice, i.e., the school itself. A major transformation of school *practice* probably assumes a roughly parallel shift in district *policy,* which in turn presumes guiding trends in state and federal policy as well as in academic theory. There will, of course, always be some discordant noise in the system, but some friction can be accommodated if the general momentum of the important institutions is roughly parallel and on course and not so loosely coupled as to result in a disruptive dance of

push-pull. In fact, a certain level of threat is probably useful in warding off the dangers of complacency in both policy and practice.

Have the institutions in Delaware been transformed in support of the mathematics reformation? I think the evidence presented in this case study suggests that in the main this has been the case. The University and State Department of Education have both accepted a leading role in promoting the reform and, though playing different parts, have done so in a clearly collaborative manner. School districts have responded to the leadership of the mathematics education community and have been, for the most part, steadfast in bringing their policy into line with the exigencies of the mathematics education reform. Teachers have, of course, shouldered the largest burden in re-forming what it means to learn and teach mathematics. Our School-Based Teacher Leaders have extended their grasp to reach for success for students who have always been at-risk in secondary mathematics. Clearly, significant progress has been made and our LSC was an important driver, in its turn, of that progress. Not certain that we will ever identify a closed-form solution to the problem of mathematics professional development, we can at the very least attest to the efficacy of recursion in reforming our own practice.

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