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Caricatures in Innovation: Teacher Adaptation to an Investigation-Oriented Middle School Mathematics Curriculum

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Recent recommendations from the mathematics education community espouse new and different mathematics content, ways of teaching, and assessment methods. The National Council of Teachers of Mathematics (NCTM) has launched a major reform by publishing standards documents on curriculum, teaching, and assessment. *The Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) recommends work in Grades 5-8 go well beyond arithmetic and basic geometry to *expand students' knowledge of numbers, computation, estimation, measurement, geometry, statistics, probability, patterns and functions, and the fundamental concepts of algebra* (pp. 65-66). NCTM proposes major methodological changes as well. Teachers must relinquish much authority and encourage students to formulate and verify mathematical conjectures for themselves rather than rely on teachers or texts as primary sources of knowledge according to recommendations of the *Professional Standards for Teaching Mathematics* (NCTM, 1991). Assessment is also undergoing radical changes. The *Assessment Standards for School Mathematics* (NCTM, 1993) emphasize the need for a balance of evidence from multiple sources including types of assessment traditionally unheard of in mathematics classrooms such as journals, portfolios, and group projects. If teachers took all the NCTM recommendations to heart, many would have to alter their practice dramatically.

Wood, Cobb, and Yackel (1991) contend that studying *the manner in which practicing teachers learn and change is... crucial* (p. 589). We agree, and we also believe it important to respond to calls for descriptions of process, conditions, and circumstances for the design, implementation, and evaluation of new curricula (Lappan & Ferrini-Mundy, 1993). In our work, we examined how teachers who agreed to field test an innovative middle school mathematics curriculum—a curriculum aligned with the new NCTM content, teaching, and assessment standards—would react to the considerable expectations for change placed upon them. We were particularly interested in identifying difficulties teachers have teaching new content, sharing authority with students, and using nontraditional assessment techniques. How much would they struggle with mathematics content, given that many of them have limited mathematics backgrounds (see Ball, 1991)? To what extent would they struggle with adopting new methods of teaching as they attempt to create learning environments most have rarely, if ever, experienced themselves (Little, 1993)? Would new forms of assessment, often time consuming and difficult to translate into grades, be the most difficult adjustment? We designed our study of these questions to inform the teacher education community of the types of assistance mathematics teachers may require to adapt to reform.

Teachers in the study responded very differently to field testing the new curriculum. Some found the innovation a close match to their personal philosophy and made very smooth transitions. Others found teaching new content or using new methods quite difficult, although they found the experience rewarding as a whole. Still others struggled, questioned the commitment required, and never fully implemented the curriculum. We identified three very different reactions to innovation. In this article we present composite descriptions of three salient teacher types by combining information from all the project teachers.

Background: The Change Process

Change is generally slow and difficult; teacher change is no exception. Duffy and Roehler

(1986) note that teachers *particularly resist complex, conceptual, longitudinal changes (as opposed to changes in management routines, or temporary changes)* (p. 55). Because much of a teacher's self-perception may come from his or her professional activity, changing teaching practice is a highly personal process (Rogus, 1988). Teacher change often involves admitting that prior practice was problematic, perhaps harmful to students (Sikes, 1992). One experienced teacher in Duffy and Roehler's (1986) work described the agony of attempting to change his *entire approach to teaching... it's like taking away half of you. You've done it for 20 years and you know how, and all of a sudden, you find out, hey, there's a better way. And it's really painful* (p. 57).

Some teachers, perhaps uncomfortable with the state of their profession, embrace change and call for reform. Others may be less strident but still open to the idea of change. Still others take a wait-and-see attitude, willing to participate in change if it can be shown to have potential to increase student learning or interest.

No matter how enthusiastic or cautious teachers are about change, they generally adapt (rather than adopt) innovations according to their individual needs and beliefs (Doyle & Ponder, 1977). There is often a *great gulf between rhetoric and reality, between what is intended by the authors of the change and how the change actually turns out* (Sikes, 1992, p. 38). Duffy and Roehler (1986) theorize that four factors affect adaptation of a teaching innovation: understanding of content, concept of instruction, environmental constraints, and desire for a smoothly flowing school day. These factors may conflict with each other; a teacher's sense of how best to teach a subject may conflict with ideas about how to teach and maintain control in the easiest manner (Richardson, 1990). Tobin (1987) speculates that a teacher's beliefs about how students learn, often based on how the teacher learns, and what students ought to learn are often the greatest factors in how that teacher adapts an innovation. Thompson (1984), acknowledging the vital influence of teacher beliefs on reform efforts, writes that *failure to recognize the role that the teachers' conceptions might play in shaping their behavior is likely to result in misguided efforts to improve the quality of mathematics instruction in the schools* (p. 106).

The Project

In response to the NCTM standards recommendations, the Connected Mathematics Project (CMP) of Michigan State University, with funding from the National Science Foundation (NSF), is developing a complete mathematics curriculum for Grades 6, 7, and 8. Writing and field testing of the CMP materials began in 1991-1992 and will continue through 1996-1997. In this article we report on data collected during trials of the sixth grade materials in 1992-1993 and 1993-1994.

Teachers and students using the CMP materials engage in teaching and learning quite different from the traditional transmission and reception mode. CMP is developing materials that engage students in learning mathematics through contextualized investigations, activities involving groups of students with mathematical concepts and applications, and in reflective writing and discourse about these concepts and applications. Because much CMP content is nontraditional, teachers find they must adjust to more than merely new methods of instruction. For example, CMP de-emphasizes computation, a comfortable topic for most experienced teachers, whereas it emphasizes probability and statistics, generally unfamiliar to students and teachers. CMP utilizes nontraditional methods of assessment: more realistic, contextualized mathematical tasks and frequent writing assignments.

We are the external evaluators for the CMP project, assigned to collect CMP evaluation data from classrooms in San Diego, California; Portland, Oregon; Flint, Portland, Shepherd, and Waverly, Michigan; Pittsburgh, Pennsylvania; Queens, New York; and Chapel Hill, North Carolina. The teachers and students using the CMP materials represent varied geographic locations and diverse academic abilities from learning disabled to gifted; socioeconomic levels from upper middle class to poor; and ethnic backgrounds including large representations of African Americans, Latinos, Asians, and nonnative English speakers at some sites. Although volunteers, CMP teachers are involved in the project for a variety of reasons: the influence of someone they respect such as a university professor or a district mathematics consultant or of someone to whom they must answer such as a principal or department head, enjoyment in being involved in innovation, or perks in being a part of this project. The teachers bring varying measures of skepticism and commitment to the project.

Methodology

Our work involved documenting use of the curriculum materials, providing feedback to the authors of the materials, describing changes in classroom and professional culture, and learning the kinds of support teachers require to use the materials as intended. In this article we report on complete data collected from 34 teachers and additional, incomplete, information from 10 other teachers who used the sixth grade CMP materials.

Questionnaires, including both Likert-scale items and open-ended questions, are the primary sources of information. Each teacher filled out two forms before beginning to use project materials: a teacher information form (background, education, inservice experiences) and a classroom practice questionnaire (teacher's style of teaching before teaching CMP, including use of lecture, group work, writing, technology, and assessment). In order that we could compare their approach to teaching with CMP with their prior practice, teachers at midyear completed a second classroom practice questionnaire and one on their reaction to the materials. At the end of the year, we administered the same two instruments again. Teachers also filled out feedback forms for each unit they taught, giving their ratings and suggestions for the unit and noting supplemental activities they used. The questionnaire demands were extensive, but most of the teachers thoroughly completed the several pages.

Probably even more important than the self-report data we obtained from teachers are reports from on-site recorders, individuals hired to provide in-depth documentation of curriculum use by the teachers. Most recorders were experienced mathematics teachers or graduate students in education including a college teacher educator, a doctoral student with considerable experience in conducting professional development, a lead teacher/administrator, and an educator with leadership experience in a similar mathematics project. The recorders attended a 2-day orientation in summer 1992 during which we introduced them to the project, described our evaluation goals, and provided assistance in developing a plan for their work. We met with the recorders for 2-day sessions on three occasions during each year to discuss their observations and impressions of teaching and learning at the sites. We used part of each meeting to strengthen skills in writing vignettes, conducting interviews, and observing in classrooms.

Recorders observed weekly in teachers' classrooms, administered questionnaires to teachers, administered questionnaires to students three times during the school year, and conducted periodic interviews with target teachers and a subset of their students. They also collected archival data including teacher plans, teacher supplemental activities and quizzes, and student work. They wrote profiles of target teachers and students and vignettes describing interesting or important classroom events. In this article we focus primarily on target teachers' reactions during their first year of using the sixth grade CMP curriculum.

Although concerned about expecting teachers to implement such sweeping reform without significant assistance, we generally agree with the spirit of mathematics reform articulated by the NCTM and the CMP project. The materials were still under development, and the teachers testing the CMP materials received little to no inservice training in using the materials. Teachers' support networks (number of teachers involved, level of administrative support, and availability of site director or recorders to answer questions and smooth over difficulties) varied according to site.

Our earliest plan for this article was to present case studies of successful and unsuccessful teachers in the CMP field testing. We planned to write these cases around themes uncovered by a careful triangulation of all the data we had collected: the observational, interview, and archival data from the recorders; the questionnaire data; and information from evaluator site visits. However, as we examined our data and analyzed anecdotal reports from the recorders, we observed commonalities among teachers we could not adequately describe by writing about individuals. We noted that mathematics background, teaching methods, and sources of classroom authority seemed important, but differentiating, dimensions in our efforts to describe teachers' adaptation to the CMP curriculum. Three main classifications of teachers emerged from our analyses; thus we adopted the method of describing findings via caricatures that Noss and Hoyles (1993) suggest. At one of our recorder meetings, we presented our caricatures to the recorders and were gratified to have them validate our efforts. They concurred with our typology, independently validated our typing of key teachers from their sites, and provided us with additional data for our descriptions.

We wrote each of the three caricatures as if describing an individual teacher, but each is actually a composite description emphasizing the salient characteristics of the group of teachers it represents (see Donmoyer, 1987). The first caricature (the Frustrated Methodologist) represents five teachers with relatively strong math backgrounds resistant to the changes in their teaching methods the CMP curriculum requires. The second caricature (the Teacher on the Grow) is from seven teachers whose weak backgrounds in mathematics presented difficulties in teaching certain CMP investigations, but who nonetheless readily adopted new methods of teaching and seem to be developing gradually, but steadily, into confident and effective CMP teachers. The third caricature is the Standards Bearer, and it represents the most successful group we have encountered. These four teachers, with strong backgrounds both in content and pedagogy, have found a match between their educational philosophies and that of the CMP curriculum and embraced it wholeheartedly and successfully.

Other of the 34 teachers appear to fit into one of the three composites, but we did not use them to develop the caricatures. Our caricatures are still evolving as we continue gathering data on CMP teachers. In 1993-1994, both sixth and seventh grade teachers tested CMP materials. In 1994-1995, teachers are testing eighth grade materials. We hope to note additional characteristics of successful and problematic adaptations to the CMP curriculum and remain open to identifying and describing additional composite teacher types.

The Frustrated Methodologist

Billie Duncan, a Frustrated Methodologist, has been teaching for 9 years. A mathematics education major in college, she has taught junior high mathematics for the past 7 years. During this time, she has developed comfortable classroom routines that were also generally acceptable to students and administrators. Because her mathematical background is broad, she encountered very little in the sixth grade CMP materials new to her. Billie believes a good mathematics teacher should be clear, enthusiastic, and strong in interpersonal skills. Her comments and practice indicate that she values a controlled classroom featuring a careful mathematics presentation delivered by the teacher. On her teacher information form she wrote, *I feel that the most important thing in teaching math is motivation. If you present the material in a way that is fun and relevant to your students then they will work at it and if they are working and involved they will not cause problems.*

Billie worries about making her class too frustrating. She is quick to alleviate any evidence of student confusion, despite the recommendation of the *Professional Standards for Teaching Mathematics (NCTM, 1991)* that teachers foster in students *a tolerance for getting stuck or sidetracked* (p. 21). She is also uncomfortable about leaving a topic until certain the majority of students have mastered it.

Although Billie claims that she uses the discovery method, classroom observations indicate otherwise. Most of her classes are very teacher directed, as the following discourse occurring after Billie wrote 2/4 = 1/2 on the overhead illustrates.

Billie: *What is the name of the top number of the fraction? [Billie pointed to the fraction 1/2.]*
Morgan: *One.*
Billie: *Please raise your hand to answer.*
Julio: *Numerator.*
Billie: *Mark, what is the name for the bottom number?*
Mark: *Denuminator.*
Billie: *What did you say? Try it again.*
Mark: *Denominator*
Billie: *Now if 2/4 is equal to 1/2, what could we say about the numerator of the one fraction in relation to the numerator of the other fraction?*
Tiffany: *It's a pattern. The bottom number is a 2 and the top number is a 1. You went up one on the numerator and two on the denominator.*
Billie: *Natosha?*
Natosha: *You can multiply both by the same number and get the second.*
Billie: *Yes. What did we multiply by?*

This brief excerpt illustrates several characteristics of Billie's teaching style: tight control over discussions, discouragement or ignoring of most statements that may be incorrect or that could lead to confusion (such as Tiffany's), and more concern with procedural facility than with conceptual understanding. Billie demonstrates many of the methodological characteristics of Jeanne in Thompson's (1984) case study, who *believed that it was her responsibility to direct and control all classroom activities... avoiding digressions to discuss students' difficulties and ideas* (p. 120).

Billie worries there is not enough review in the CMP materials, that she is not always able to stop at a place in the CMP activities where she can assign homework, and that her students' computational skills are deteriorating through lack of practice. She reports that her students are struggling with *basic computation without calculators* despite the project assumption that calculators are to be always available. Because of these concerns, she sometimes saves time and avoids student confusion by limiting student experience with manipulatives, generally preferring to demonstrate rather than having students handle materials at their seats. Among the data on Billie is a photograph of students gathered around to watch her conduct an intended student experiment. Later she commented on a questionnaire that she had opted for this approach because she was afraid that *sand would have been everywhere*. Billie allows students to work in pairs, but rarely in groups of three or four even though much of the CMP curriculum is designed for small-group investigation. It seems that Billie does not really trust that students working together will be on task. She has replaced the partner quizzes of the CMP assessment with her own teacher-made individual evaluations. Billie supplements the CMP curriculum with computational practice and occasionally gives a quiz or test without the use of calculators, although calculators are always available for nongraded activities. Further evidence of Billie's interest in computational practice comes from a reaction questionnaire, where she wrote that she would like to see *more concrete drill/practice (computation)* available in the CMP Teacher Edition.

To reserve classroom time she believes necessary for computational practice, Billie makes very limited use of student writing about mathematics, even though writing is a key component of the CMP curriculum. The recorder noted this lack of attention to writing; analysis of the writing of Billie's students on an end-of-year questionnaire further corroborated it. Students in Billie's class wrote extremely brief responses, less than 20% as long as those from Natalie the Standards Bearer's class where writing was emphasized. Billie's student responses were revealing in other ways. A student response to a question asking what he liked least about math evidences Billie's concern about computational skills: *flash math, where you just do strate [sic] problems*. Avoidance of student confusion and emphasis on teacher authority are key concepts in Billie's teaching. When asked *How do you know when you understand a math idea?* one of Billie's students wrote, *I understand when I'm not confused with the problem, and I've done it before with a teacher or adult with preview problems*. The CMP curriculum is designed to empower students to reflect on their own thinking and to serve as peer evaluators for each other's work, but this student, like many others in Billie's class, sees the teacher (or other adults) as the primary source of authority. Another student response further confirms Billie's teacher directedness. Asked what advice he would like to give to the CMP textbook writers, a student wrote, *Make it so we do more fun things and not just [sit] on our buts [sic] all day and listen to a teacher.* Billie commented on a questionnaire, *If the material is presented correctly, each child will learn.*

Generally reluctant to change her tried-and-true teaching methods, Billie is often frustrated by the inevitable incongruence of trying to teach a curriculum not matching her teaching style. Nevertheless, we observed changing aspects of Billie's teaching. In the second half of the year, she began letting go of some routines she had used for years, like using the first 10-15 minutes of each class for computational or problem-solving warm-ups. She began tolerating some confusion in her classroom; her wait time in questioning became longer than earlier in the year. When asked what she planned to do differently next year, she stated she wanted *less lecture time and more time with cooperative learning groups*.

Billie does many things casual classroom observers would classify as good teaching, and her fellow teachers appreciate her secure knowledge of mathematics. One commented on the help Billie has provided her, writing on a reaction questionnaire that other than attending CMP inservice workshops *working with [Billie] is the next best thing for me*. However, we note a constant tension or mismatch between the intentions of the CMP curriculum and Billie's routine practice. Billie may be at Hord, Rutherford, Huling-Austin, and Hall's

(1987) mechanical level of use of an innovation, a level characterized by disjointed often superficial use of curriculum materials. Perhaps, Billie's minimal changes in practice have not yet been accompanied by a related change in beliefs (see Fullan & Hargreaves, 1992). In such cases, the disjointedness of old and new practices and beliefs leads to the frustration of being torn between two philosophies of teaching—hence Billie's moniker, the Frustrated Methodologist.

The Teacher on the Grow

Darcy Sparrow, a Teacher on the Grow, has been teaching for 10 years. She has a degree in elementary education, but for the last 4 years has been teaching middle school mathematics. Darcy characterizes the first 7 years of her teaching as very traditional but says that during the past 3 years she has attended workshops and met people who opened doors for her. Darcy's background in mathematics is not strong; she had only 9 hours of mathematics in college and openly admits this weakness, claiming *If I had a better background in mathematics I would be a better teacher.* On a recent questionnaire, she volunteered, *I need a better mathematical foundation. These last two years have taught me that I must have more knowledge to know if my students are headed in the right direction, mathematically. I have changed my thinking—the way I think mathematically, thanks to CMP's units.* As Fennema and Franke (1992) point out, the lack of mathematical knowledge can be influential in a teacher's instructional decision making.

We agree Darcy needs help in understanding the mathematics of the sixth grade curriculum at times, but we also see her as willing to learn and take risks in exploring uncharted territory. Her approach to teaching allows students to explore and discuss ideas and take responsibility for their own learning. These explorations occasionally lead to unanticipated dilemmas but more often provide occasions for learning. For example, a recorder described the classroom interactions of a group of boys in Darcy's class. *They are not afraid or embarrassed to ask each other or an adult a question. If they come up with different solutions, each person will argue his case. If any one person in the group doesn't understand a question or how to get a solution, someone else in the group will explain it.... They explain concepts to each other until the person understands.*

Darcy is strongly committed to being a learner. After the unit on area and perimeter, she wrote, *This is the first time I really understood how to find the actual area of a circle.* Darcy is also learning new methods of teaching. Toward the end of the year, the recorder observed, *[Darcy] now tries to create a classroom environment that promotes and encourages student involvement in class activities. Instead of presenting a math concept first and illustrating that idea by working several problems to practice on, she now investigates a series of problems with interactions between her and the students to develop mathematical concepts. [Darcy] wants her students to be able to articulate some of the mathematical concepts that were introduced to them.*

Not all Darcy's teaching episodes turn out as the writers of the CMP curriculum had envisioned. Sometimes difficulties are due to Darcy's limited mathematical background. She once confused the class for an entire lesson by mistakenly telling them that adjacent angles were consecutive angles in a polygon. On other occasions Darcy gets so involved in the creative aspects of a student activity that she overlooks mathematical errors. For example, an activity in the CMP unit on rational numbers asks students to lay out a garden with different fractional parts designated for each vegetable. Darcy had students illustrate their selections by gluing seeds to miniature gardens drawn on pieces of cardboard. Some of the gardens were quite creative. However, in grading these colorful projects, Darcy failed to notice that some gardens showed 12/10 or 15/10 of the garden planted. On other occasions, she spent much more time than the authors on a particular investigation, perhaps because she was comfortable with that content but not as sure of the content to follow.

Student responses to questionnaires further illustrate various aspects of Darcy's teaching. When writing about what he liked least about math class, a student stated, *I hate when they mess up the teacher book because [my teacher] doesn't know what she's talking about and it get[s] me aggravated.* This illustrates, from the student point of view, what the recorder noted on several occasions (in a vignette on probability, in feedback to the authors, and at recorder meetings): The slightest of errors in the materials can confuse Darcy and the class. However, Darcy's students seemed comfortable with their teacher not being the sole authority and with their responsibility for active involvement. In response to the questionnaire item asking how students know when a math idea is understood, one student wrote, *If I can explain the idea to myself or someone else, I know I understand.* When asked what she liked most about math, another student wrote, *I liked not having to do simple computation from a text book. We could also find many ways to solve a problem. I liked the hands on experiments we did.*

We have noted considerable growth in Darcy's teaching from the beginning of last school year to the present. The origin of her growth is a willingness to learn. In the write-up of Darcy's interview, the recorder wrote, *Due to the enormous changes in mathematics, [Darcy feels] that she needs to keep up with the changes and their possible impact on the classroom. She feels that teachers should be well-informed about current teaching methods and continue to learn through inservice how to implement them in their classrooms.*

Darcy has been learning about data analysis, area, and probability. She has tried journal writing to gain access to students' thoughts. Although at first rather reluctant, she now enthusiastically uses partner quizzes– *students are learning as they are doing them*– as a means of aligning her assessment with her instructional methods. Open to change and anxious to learn, Darcy is growing both in content knowledge and in pedagogical expertise.

The Standards Bearer

Natalie Cobb, a Standards Bearer, has been teaching for 13 years, with experience in both self-contained and departmentalized middle grades classes. Although her degree is in elementary education, she has taken a number of mathematics courses over the years, and her mathematics background (in terms of hours) is now the equivalent of a minor in mathematics. Natalie describes herself as having been *very good at teaching algorithms* during her early years of teaching: *I used concrete materials, broke down the skills, and felt quite successful.* After attending an NSF workshop several years ago, she reconsidered her thinking about teaching and sought inservice experiences. In the past several years, she has attended many workshops on mathematics teaching and methodology and is currently involved in field-testing CMP materials and in another project on alternative assessment. Natalie wants her students to be able to *talk, explain, probe, prove what they state, write, tackle a problem, never stop, problem solve, action plan, apply, and transfer concepts later in the year.* Her most common teaching approach is to pose a problem, have groups of students work on it, share their ideas with the whole class, explore related problems, and then return to the original problem.

Natalie had no difficulty adapting to the methods and mathematics of the CMP materials because her personal philosophy of teaching (e.g., *my goal is to empower the children—so they can function without me* and *early teaching of algorithms is harmful*) was already well aligned with the philosophy of the program. She quickly moved past the personal concerns many teachers must work through in implementing an innovative curriculum and focused her efforts on helping students adapt to the innovation. Natalie is particularly interested in students' views of assessment in this new curriculum. She writes, *Many are really hung up on assessment. They are concerned with the lack of grades in my gradebook. A few dislike the 'unfairness' of less able students doing well because they are working with a student who understands.*

The students in Natalie's class wrote much more on the end-of-year questionnaire than Billie's students. Many student comments were both lengthy and substantial. One student response to the question asking about the most interesting idea studied this year illustrates this: *I think one of the most interesting ideas in math class this year is having to explain our answer and show how we got it. I think that it helps us understand it better and know more of what we are doing. Also it helps other[s] understand it better because you are getting the information fully on how you get it. I also like working in groups and using calculators. When you work in groups you can work together and maybe help others out. The calculator sometimes helps you explain your answer.* Students and teacher in Natalie's class share authority for understanding a mathematical idea, as the following student response indicates: *I know if I understand a math idea if we start to talk about it and my teacher askes [sic] us to explain it and I answer. If I don't get it I just have a feeling that I don't get it and I go ask others in my group or the teacher.* Student inquiry is the predominant mode of learning in Natalie's class.

Students learn to expect help rather than answers from the teacher. One student wrote, *What I liked most about this year was working in groups and useing modles [using models] and having the teacher explain the question but not tell the ancer [answer].*

We believe Natalie has a comfortable command of both the mathematics she teaches and the appropriate techniques for facilitating student growth. Her content knowledge is strong enough that student questions extending beyond the content in the textbook do not threaten her; nor is she concerned when student conjectures are erroneous. Natalie is knowledgeable enough to know where to look for counter examples, as demonstrated in the following vignette. (Students had previously found the area of polygonal figures by superimposing clear centimeter grids and counting squares.)

Natalie: *Now, how do you measure the area of irregular shapes? What do you do with the pieces and parts? Pieces and parts seem to pose a problem. [Natalie draws a large 'bean-shaped' region on an overhead grid.] Who can tell me the area of this shape?*

Sam: *I put an x in all of the squares inside the bean. If it's almost a square, it gets an x too. Then I take a calculator and add. [Student is putting x's in all squares and 'almost' squares.] This would be .5, this one over here, .25. [When he reaches half a square and an even smaller partial square.]*

Natalie: *Other kids may be thinking of those as fractional parts of the square, but Sam doesn't want to add fractions, so he put it in decimal form. Renaldo, do you want to share your strategy? [Silence, then Renaldo nods his head. He comes forward, carefully places a piece of string around the perimeter of the 'bean' and then stretches the measured length of string into a square. Natalie demonstrates to the class with hand gestures.] OK. What did you get?*

Renaldo: *200.*

Natalie: *[Referring to an earlier lesson.] Remember the polygon we found with area of 14 and perimeter of 30? We changed it so that the perimeter stayed the same, but the area changed?*

Carla: *The perimeter is the same, but the area is different, that's confusing! [Natalie gives the students some time to try out 'Renaldo's Theory' of finding the area of irregular shapes by comparing the results obtained (a) by tracing around their open hands and figuring an approximate area by counting squares versus (b) by wrapping a piece of string around the figure, making the measured string into a square, and figuring its area. Then the class comes back together.]*

Thomas: *My square is going off the paper. Renaldo, your theory is wrong!*

Natalie: *Renaldo, can you tell us your theory?*

Renaldo: *You take the perimeter and you make a regular polygon, then you measure the square.*

Janelle: *Your theory is wrong!*

Natalie: *[To Janelle] Why?*

Janelle: *I don't know, it's just wrong.*

Natalie: *How many found that the square had a greater area? [Many hands] I just wanted to say that this is what mathematics is, coming up with a theory and testing it out. Renaldo is acting like a mathematician.*

This vignette captures the essence of the Standards Bearer. Natalie builds classroom discourse around students' ideas, whether right or wrong. Renaldo has come up with a seemingly logical but incorrect method for finding area, and Natalie has encouraged the class to explore the conjecture. She could have stopped this session with the first student's suggestion of how to find the area, and Renaldo might have continued to wonder about his approach to finding area. The other students would have missed the opportunity to test a theory and show by counter example its weakness. This classroom episode was made possible because Natalie is confident enough of her mathematical background to allow students to make and test mathematical conjectures. She is also willing to risk letting students assume some control over what happens in the classroom, realizing that students may experience momentary confusion when they share ideas, but that such discussions may lead to greater student learning opportunities.

Discussion

We speculate how Billie and Darcy might react to the situation in Natalie's class. Billie, in her concern to remove all potential confusion, might ignore or quickly correct Renaldo. Darcy, due to her limited mathematics background, might accept his incorrect method as correct and praise him for his creativity, especially if his estimate for the bean-shaped figure proved at all reasonable. In either case, a valuable learning opportunity would be lost. Billie might squander a chance for the class to do real mathematics. Darcy might perpetuate a misconception, both for her and her students.

Our three caricatures are simplifications and exaggerations. In practice, teachers may not fall neatly into one category or the other all the time. A teacher might conceivably be a Standards Bearer for a unit of instruction on factors and multiples (a topic with which she is experienced and confident), and a Teacher on the Grow for another, less familiar, unit (perhaps data analysis or probability). Our caricatures are not representative of any linear progression. We have no data to indicate whether Frustrated Methodologists or Teachers on the Grow might evolve into Standards Bearers. Although we are not convinced that such a transformation is very common, some evidence suggests that a teacher who contributed to the Frustrated Methodologist caricature has grown pedagogically in the second year of curriculum implementation. However, this teacher is the youngest and least experienced of the teachers contributing to the Frustrated Methodologist caricature.

The three caricatures do not represent an exhaustive taxonomy. We have studied only sixth-grade teachers, many of whom, because of their elementary training, have limited backgrounds in mathematics. A salient characteristic of our Teacher on the Grow is her weak mathematics background. We can imagine a different kind of Teacher on the Grow, one with a strong mathematics background who is slowly growing pedagogically. However, perhaps because of our limited sample, we have no data to support such a caricature, although at a recent recorder meeting there were indications that a teacher with such characteristics might exist among the CMP cohort. As our work continues and we begin studying seventh and eighth grade teachers, we may develop two subcategories of Teachers on the Grow (growing mathematically and growing pedagogically), or we may find that we can identify additional, different, composite caricatures.

As a result of our data collection thus far, we are confident that level of content knowledge is an important variable in successful implementation of the innovative CMP curriculum. Teachers with limited mathematical backgrounds suffer misconceptions, require considerable time to reach even a limited understanding of unfamiliar concepts, and often move more slowly than necessary through familiar material—perhaps as a means of delaying confrontation with the unfamiliar. Some teachers have partially offset a lack of mathematics background by the availability of someone with a richer understanding of mathematics (e.g., a fellow teacher or the project recorder). As one teacher put it, *I couldn't have made it through the unit without [the recorder].*

Degree of prior agreement with the methodological philosophy of the curriculum is another variable of interest. As one teacher wrote, *I believe the materials are designed to emphasize the approach to mathematics that I believe in. Wonderful!* For others the CMP approach is uncomfortable. Some teachers find allowing students to investigate ideas too time consuming: *I prefer to cover more material and use old textbooks*. Some teachers believe students working in groups produced too many discipline problems or that using an occasional partner quiz allows weaker students to benefit from stronger students. Yet when teachers attempt to use the CMP materials without employing the methodologies the authors suggest, they usually encounter considerable difficulties.

The preceding two issues, content knowledge and methodological philosophy, raise an interesting, important question. Which is the more difficult adaptation for teachers to make: Using and appreciating the power of unfamiliar methodologies (as Billie, the Frustrated Methodologist, must do) or recovering from lack of background when unfamiliar mathematics content is encountered in student materials (as Darcy, the Teacher on the Grow, must do)? From our caricatures, we believe that CMP teachers have had more difficulty changing long-standing methods than admitting they needed help in subject matter content. This is consistent with Brown and Borko (1992) who speculate, *growth in content knowledge appears to be easier for experienced teachers than growth in pedagogical content knowledge* (p. 221). Perhaps admitting that one's teaching methods are problematic is more painful and more personal than acknowledging a lack of knowledge. Teachers may be more easily convinced that their content knowledge is problematic than their methods are. For instance, there are methods that teachers *dis-value, things that they fear will not work or will make matters worse* (Fullan & Hargreaves, 1992, p. 5). Certainly, the content versus methods issue bears watching in future work.

Content knowledge is important. Teachers should have at least a minor in mathematics in order to be teaching at the middle school level. This education should be consistent with the vision outlined in *A Call to Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics* (Mathematical Association of America, 1991), which emphasizes a modeling approach to mathematical study, use of technology, communicating ideas, and the content standards of number, geometry, algebra, probability and statistics, and calculus. Ball (1991) stresses that teachers must have mathematical knowledge that is *correct* (they must be able to do mathematics), is *meaningful* to them (they must know why), and is *connected* (they must know the relatedness of ideas). Teachers already in the field require graduate level mathematics courses designed specifically for the middle school teacher needing growth in content knowledge. Most existing mathematics courses at the college level have little to offer sixth grade teachers with elementary education degrees, who need experience with topics such as probability, statistics, and geometry. Another option is to provide summer institutes where teachers do *real work rather than being 'talked at' and [have] an opportunity to consult with colleagues and experts* (Little, 1993, p. 137). For some teachers it may be sufficient to provide inservice programs or common planning periods with more knowledgeable colleagues.

Research indicates that most teachers teach how they were taught, not how their methods professors instructed them (Ball, 1988). For future teachers, the best course in methods would be to have them experience undergraduate mathematics instructed in a manner consistent with the reform effort. Changing methods for teachers in service may be even more difficult. Not only must these teachers overcome their education; they must rethink their practice and all the routines that have worked for them in the past. To facilitate such change, NCTM, state, and local organizations endeavor to create awareness and perhaps even perturbation. Assuming awareness and desire for change is created, support in the form of teacher inservice, collaboration with university personnel, and collaboration with colleagues may be necessary for worthwhile and lasting change. In addition to the above support, external pressure may be necessary. McLaughlin (1987) states *pressure is required in most settings to focus attention on a reform objective; support is needed to enable implementation* (p. 173).

Beyond new content and methods, assessment is the third and perhaps most challenging change for teachers in today's era of mathematics education reform. In part because the NCTM recommendations for assessment are the third of the standards documents written (published in draft form in 1993 with final publication to appear in 1995), progress in this area lags behind content and methods efforts. In the CMP project, assessment is one the last changes put in place. Assessment suggestions for teachers were unavailable to teachers testing early versions of the materials because teacher notes inevitably were written after the related student booklets. Thus many teachers in this study struggled alone in attempting to implement little understood and unfamiliar varieties of assessment. In the last year or so, however, we have observed the teachers making significant progress in becoming comfortable with more open-ended and subjective assessment forms. They have accomplished much of this progress by trying things and modifying them until they eventually became workable. Perhaps this is exactly as it should be. Much teacher education should occur during teachers' day-to-day work. Little (1993) comments that teachers must have the *opportunity to learn (and investigate, experiment, consult, or evaluate) embedded in the routine organization of [their] work-day and work year.... It requires that teachers and others with whom they work enjoy the latitude to invent local solutions—to discover and develop practices that embody central values and principles, rather than to implement, adopt, or demonstrate practices thought to be universally effective* (p. 133).

The three caricatures have started us thinking about numerous issues and raised more questions than answers. For instance, what percentages of teachers fall into each of our caricatures and other possible caricatures? How should this breakdown influence the types of teacher education activities that we recommend? After our first year of study, a best guess is 20% Frustrated Methodologist, 60% Teacher on the Grow, and 20% Standards Bearer. As our study of teachers involved in curricular innovation proceeds over the next several years, we will continue to formulate new conjectures and look for evidence to confirm or refute our claims. We hope that further study of the teachers who together comprised our caricatures of Billie, Darcy, and Natalie—along with additional information from teachers involved in the piloting of the seventh and eighth grade CMP materials—will shed light on many questions and issues in curricular innovation and teacher education.

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