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Problem Solving as a Means Toward Mathematics for All: A Look Through a Class Lens

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In this study, a researcher-teacher examines seventh-graders' experiences with a problem-centered curriculum and pedagogy. Analyses of interviews, surveys, teaching journal entries, and audio recordings focused on differences between lower- and higher-SES students' reactions to learning mathematics through problem solving. While higher-SES students displayed confidence and solved problems with an eye toward the intended mathematical ideas, the lower-SES students preferred more external direction and sometimes approached problems in a way that allowed them to miss their intended, mathematical point. The lower-SES students more often became "stuck" in the open and contextualized nature of the problems. An examination of sociological literature revealed ways in which these patterns in the data could be related to more than individual differences in temperament or achievement between the children. This study suggests that class cultural differences could relate to students' approaches to learning mathematics through solving open, contextualized problems. This article discusses equity-related challenges we might face, as well as interventions that could be helpful, in our attempts to center mathematics instruction around problem solving.

Problem Solving as a Means Toward Mathematics for All: A Look Through a Class Lens

The National Council of Teachers of Mathematics (NCTM) argues that problem solving should become "the focus" of mathematics in school (1989, p. 6). According to NCTM (1989; 1991), centering mathematics instruction around problem solving can help all students learn key concepts and skills in motivating contexts. In contrast with previous emphases on problem solving as an end in itself (e.g., focusing on heuristics), problem solving is now promoted as a means to learning mathematical content and processes.

This article focuses on problem-solving experiences of students of lower- and higher-socio-economic status (SES) in a classroom aligned with the NCTM Standards (1989; 1991; 1995). This discussion will center around two key aspects of NCTM-inspired problems. First, the problems are "open" — they have no obvious solution and allow students to approach them in a variety of ways, requiring creative and complex work. Some problems have no single right answer and could take "hours, days and even weeks to solve" (NCTM, 1989, p. 6). Second, the problems are "contextualized" in some way — they arise out of a motivating situation that is often "real-world," but might also be strictly mathematical or fictional.

THE PROMISE OF OPEN, CONTEXTUALIZED PROBLEMS

The use of open, contextualized problems seems sensible at many levels. Instead of students completing meaningless exercises and memorizing what the teacher tells them, why not have students come to understand and apply key mathematical ideas while solving interesting problems? Not only do these ideas seem sensible for "all students," there are ways in which instruction centered around open, contextualized problems seems particularly promising for lower-SES students.

For example, some argue that lower-SES students tend to receive more than their share of rote learning and low-level exercises from teachers with low expectations (Anyon, 1981; Means & Knapp, 1991). Hence, having teachers of lower-SES students move away from routine exercises toward more open, challenging problems would seem to address this concern.

Additionally, according to some scholars, lower-class families tend to be more oriented toward contextualized language and meanings. Bernstein (1975) argues that linguistic codes (or the underlying principles of speech, as opposed to surface features, such as dialect) are affected by the class system. The more privileged classes, who have power and tend to be individualistic, are socialized in a way that develops high-status knowledge and the language of control and innovation. Because of the emphasis on the individual, meanings are not assumed to be shared with others. Hence, middle-class families use what he calls "elaborated codes," or language with meaning that is more explicit and less tied to local contexts. Lower-status families use "restricted codes," or language with implicit and context-dependent meanings. This language makes sense in contexts in which an emphasis is placed on community and in which common knowledge and values are assumed to be shared. Additionally, Holland (1981) found that middle-class children tended to categorize pictures in terms of trans-situational properties (e.g., grouping foods together that were made from milk or came from the sea), while working-class children tended to categorize pictures in terms of more personalized, context-dependent meanings (e.g., grouping foods they eat at Grandma's house). Holland did not conclude that children *could* not think differently, but that they had been raised with a particular orientation. If Bernstein and Holland are correct, then contextualized mathematics problems would seem to align nicely with lower-class students preferred ways of thinking.

Hence, in theory, the use of open, contextualized mathematics problems appears promising for promoting equity for lower-SES students. Yet, this study explores ways in which currently popular ideas could affect students from our lower classes.[1]

CLASS DISMISSED?

Since current reforms are intended to help "all students" gain mathematical power, it makes sense to consider how they impact the least powerful in our society — that is, lower-class children. It is particularly important for *mathematics* educators to consider class-related equity issues, since mathematics serves as a "critical filter" (Campbell, 1991b), with the potential to reward successful students with high occupational status and pay.

Yet, social class is rarely focal in current, educational studies.[2] After reviewing the literature, Secada (1992) noted the lack of serious attention given to social class in mathematics education:

> It is as if social class differences were inevitable or that, if we find them, the results are somehow explained. . . . While the research literature and mathematics-education reform documents (for example, NCTM, 1989; NRC, 1989) at least mention women and minorities, issues of poverty and social class are absent from their discussions. (p. 640)

Perhaps we tend to throw up our hands when confronted with class-based differences in mathematics achievement because many problems lower-class families face seem far beyond

[1] I use the term "SES" when referring to particular students, but use "class" when discussing larger, societal groups. SES can be thought of as an approximation for one's "class," which connotes more permanence, shared group values and beliefs about roles in society and relation to power (Secada, 1992).

[2] This void is not limited to *mathematics* education. For example, in a survey of all research on science learning and achievement from 1980-1986, out of 73 studies, four looked at race, twelve looked at gender, and seven looked at both. None of the studies examined class (McDowell, 1990).

the school's control. Yet, there are a variety of barriers that lower-SES students need to overcome to break out of the cycle of poverty, and some of these barriers arise within schools, including mathematics classrooms. We need to consider the possibility that changing mathematics curricula and pedagogy can remove or add new barriers for lower-SES students.

As Reyes and Stanic (1988) argue, we need to look carefully inside classrooms to try and understand the relationship between SES and math performance.

> Before quantifying classroom processes, more qualitative work is necessary to point out categories that may better capture the wholeness and richness of classroom life. . . . Within mathematics education research, relatively little work has been done on race-related differences and almost no work has been done on the relationship between SES and mathematics performance. (pp. 39-40)

Frankenstein (1987) agrees, arguing that we need to look at race and class on issues previously examined with the gender lens, such as attitudes about mathematics and types of pedagogies and curricula that are helpful or harmful for various groups.

Yet, class is difficult to study. In this time of celebrating the positive aspects of diversity, it is risky to discuss class differences and raise issues about potentially negative aspects of lower-class cultures. Additionally, the lack of agreement about definitions and indicators of class makes class particularly difficult to study (Duberman, 1976).

Despite these difficulties, this study focuses on class differences in students' experiences with one version of a reformed mathematics classroom. While the larger study gave attention to both curriculum and pedagogy, in this article I focus on findings related to students' experiences with the open, contextualized problems in the curriculum.[3]

METHOD

In this study, I played a dual role as both researcher and pilot teacher for a problem-centered curriculum development project. I now discuss key aspects of the study's methodology, including the school, the curriculum, the teacher-researcher role and my pedagogy, as well as data collection and analysis.

The School

This study was conducted in a socio-economically diverse school located in a medium-sized Midwestern city. The school had a socio-economic mix of students — a few upper-middle class students (e.g., with professional parents holding graduate degrees), some middle class students (e.g., with college-educated parents in professions, such as teaching or engineering), some working class students (e.g., with parents who work in factories or

[3] See Theule-Lubienski (1996) for more information.

service jobs) and some lower-class students (e.g., with parents who have very limited education, no steady job, and live below the poverty line). The school's 500 students were primarily white, with roughly 2% Asian, 3% Hispanic, and 11% African-American.

The school was a pilot site for the Connected Mathematics Project (CMP), and the students in this study had used the CMP trial materials during the year preceding this study. My role in the school across the year included piloting the trial materials with one class while serving as a CMP liaison and teaching "model" for other teachers in the school.

The Curriculum

The CMP is a middle school curriculum development project funded by the National Science Foundation to create problem-centered materials aligned with the NCTM *Standards*. In this study, CMP trial materials provided the mathematical focus of each class period, with students working on the problems both in and outside of the classroom each day. I refer to the materials as they appeared in a draft stage; this study cannot and does not attempt to make any claims about the final materials. This study is not a test of one curriculum, but an exploration of how currently popular ideas being implemented with various curricula might differentially affect lower- and higher-SES students.

Both the CMP authors and NCTM share an emphasis on learning mathematical content and processes through solving open, contextualized problems. The CMP authors describe their vision as follows:

> The curriculum is organized around rich problem settings . . . Students solve problems and in so doing they observe patterns and relationships; they conjecture, test, discuss, verbalize, and generalize these patterns and relationships. Through this process they discover the salient features of the pattern or relationship; construct understandings of concepts, processes, and relationships; develop a language to talk about the problem; and learn to integrate and discriminate among patterns or relationships. The students engage in making sense of the problems that are posed, and with the aide of the teacher, to abstract powerful mathematical ideas, problem solving strategies, and ways of thinking that are made accessible by the investigations. (CMP, 1995, p. 24)

Hence, the goal is not for students to simply learn about solving the individual problems, but to walk away from problem explorations having abstracted important mathematical ideas or processes. This abstraction occurs both because problems are carefully designed to require students to think about particular mathematical ideas and relationships, and because the teacher plays an active role in highlighting the intended ideas.

The seventh-grade CMP trial materials consisted of eight units, each containing around several "investigations." The one to four problems in each investigation were carefully constructed and sequenced to help students understand the intended, over-arching mathematical ideas of the unit. The problems were usually set in a "real-world" context (such as analyzing disaster data, starting a business, or designing a house), and they varied in the amount of time required to solve them from several minutes to several days. After many of the problems, there were follow-up "questions" to help students focus on key patterns and ideas. Each investigation concluded with a section of homework problems, which were mathematically similar to the problems in the investigation but generally set in different contexts. "Writing prompts" to help students summarize the mathematics in the unit were being added to the materials at this stage of development.

The Teacher-Researcher

Cochran-Smith and Lytle (1990) explain how teacher-researchers often ask questions that arise from working at the intersection between theory and practice. This was true for me, as it was during my CMP pilot teaching the year prior to this study that I began to wonder about a possible SES-related disparity in students' reactions to learning mathematics in ways aligned with current reforms. When I had the opportunity to teach in an even more socio-economically diverse school the following year, I decided to investigate my growing, yet still open and loosely focused questions about this issue.

These questions could have been addressed in a variety of ways, but in this study, being the teacher as well as the researcher allowed me to design the case to be studied (Ball, in preparation). There were other teachers who were piloting the CMP curriculum in the same school, but it was typical for pilot teachers (especially those working in urban schools) to struggle with implementing the curriculum in the ways the authors intended. Even if a teacher agreed with my interpretations of reform ideas and what an implementation should look like, other contextual issues could become problematic, such as the teacher's understanding of mathematics or her sensitivity to lower-SES students. Hence, my role as the teacher allowed me to play a large part in designing the site, which, (ironically) enabled me to focus more on the students' experiences and less on issues about the teaching.

Because I played such a major large role in this study, it is important to discuss the context provided by my own background. Coming from a working-class family, I brought to this study an interest in the potential of mathematics education to perpetuate or break the cycle of poverty. I also held expectations that lower-SES students *can* succeed in mathematics, as I had.

At the time of this study, I held a Master's degree in mathematics, as well as a secondary mathematics teaching certificate. I was completing my doctoral program, in which I had studied with key figures in the NCTM reform movement and learned much about the theories behind the reforms. I had the opportunity to put these theories into practice in working with the CMP in both writing and piloting trial materials. My mathematics background and deep familiarity with NCTM and the goals of the CMP curriculum, helped me guide students' explorations of the problems and our discussions afterward.

It feels a little embarrassing to discuss my background, but I do so because my ability to create a reasonable interpretation of a "reformed" classroom is an important contextual factor in this study. While I certainly have more to learn as a mathematics teacher, I contend that I had at least an average chance of effectively helping students learn mathematics through problem solving, as envisioned by the CMP authors and the NCTM *Standards* (1989; 1991).

Pedagogy

As advocated by the CMP, I usually structured my lessons using a "Launch, Explore, Summarize" model. In a typical lesson (which could take more or less than one class period) , I "launched" a problem with the class, and then students worked in groups to "explore" and solve the problem. Finally, I facilitated a whole-class discussion to "summarize" students' explorations. During these discussions, I asked students to explain how they solved the problems, encouraged students to compare ideas shared by their classmates, and posed questions to highlight key mathematical ideas.

Overall, I viewed my pedagogy as reasonably consistent with the NCTM Standards — I facilitated students' exploration, discussion and sense-making of important mathematical ideas. Evidence from surveys and interviews indicated that students shared my perspective about key aspects of my pedagogy. For example, I intended to guide students' problem solving, prompting their explorations in fruitful directions when they were stuck, as opposed to giving them the "right answer." On a multiple-choice survey question about my response to students who were stuck on a math problem, the majority of students chose, "Our teacher encourages us to figure it out for ourselves," while no student indicated, "Our teacher tells us the answer." Similarly, students confirmed that I "usually" encouraged the consideration of different problem-solving methods, and that students worked in groups and used calculators in our math class at least half the time.

Data Collection and Analysis

I began this study unsure of what I would find or even what I was looking for, except that I wanted to understand how lower- and higher-SES students experienced the CMP trial curriculum and my pedagogy. I suspected that perhaps the contexts of the problems would be more appealing to the middle-class students, since a middle-class group of curriculum developers had chosen the settings. Or perhaps I would find that the middle-class students would get more help at home on their non-traditional homework. I found little evidence to support these hypothesis, but my data collection and analyses methods were open enough to allow other trends to surface.

I used three sets of interviews, a variety of surveys, student work, teaching journal entries, and daily audio recordings to document students' experiences with the curriculum across the school year, including their struggles and successes with problems, what they thought they were learning, and what they found helpful or hindering.

To get a sense of students' SES backgrounds, I surveyed parents about their occupation, education, income, number of books and computers in the home, and newspapers read regularly. These are commonly used SES indicators (e.g., see Duberman, 1976; Kohr, Coldiron, Skiffington, Masters, & Blust, 1991). I used these data to place the students into two, admittedly rough, categories: lower and higher SES. The lower-SES students were primarily working-class, but a few of them could be considered lower-class. The higher-SES students were what most Americans would call middle-class, with some families bordering on upper-middle class. I ultimately gained permission to include 22 students, 18 of whom provided clear SES data that allowed me to categorize them as lower- or higher-SES (see Table 1).[4] Note that I use one-syllable pseudonyms to refer to lower-SES students, and three-syllable pseudonyms to refer to higher-SES students. I use two-syllable pseudonyms to refer to students who were not categorizable due to missing or ambiguous SES data.

Table 1
Participating Students Categorized by Gender and SES

Lower-SES Females	Lower-SES Males	Higher-SES Females	Higher-SES Males
Rose	Carl	Samantha	Benjamin
Anne	James	Rebecca	Timothy
Dawn	Nick	Guinevere	Christopher
Sue	Mark	Andrea	Harrison
Lynn			Samuel

I collected homework and survey data from all participating students and interviewed them at the end of the year. I also followed a smaller group of "target students" more closely, interviewing them at the beginning of the year, and having colleagues interview them in the middle of the year. In selecting the target students, I tried to include a low- and high-achieving male and female from each SES group to help me distinguish SES from achievement (measured by students' initial performance in the class, including the quality of their quizzes, homework and participation).[5]

[4] All but two of the eighteen students were Caucasian; James was African-American and Rose was Mexican-American (yet her family had lived here for several generations, and her English had not even a trace of an accent).

[5] For a variety of reasons — including fear of attrition, the desire of some students to be heard, and wanting to fill gaps due to diversity within the categories — I interviewed more than eight students. For example, I added Sue to my pool of interviewees because she requested the opportunity to be interviewed, and she added

Table 2
Separating Achievement from SES in Selecting Target Students

	Lower-SES		Higher-SES	
Low-Achievement	Female	Male	Female	Male
High-Achievement	Female	Male	Female	Male

Survey and interview questions focused on students' experiences with and reactions to the CMP curriculum and my pedagogy. Questions in later interviews asked students to consider how their opinions about the class and curriculum might be changing and why.

Students also completed CMP surveys regarding the pedagogy and environment in our classroom. Additionally, CMP-designed "Show What You Know" surveys asked students to describe their experiences with particular units, including which mathematical ideas were most interesting and important and what activities helped students learn the ideas.[6]

Analyses of the data focused on similarities and differences of lower- and higher-SES students' experiences, also considered interactions with gender.[7] With a primarily Caucasian sample, I was able to focus on gender and class without much variation in race within those categories.

After completion of the school year, formal analysis began with a systematic examination of my teaching journal as well as tables containing all survey and interview data organized by question. I referred to audio recordings and student work when relevant to specific questions that arose from my analyses of the surveys, interviews and my journal. Through these initial analyses, I developed roughly sixty questions or mini-themes.[8] For each of these themes I created a table in which I recorded all relevant survey or interview data for each student, categorized by SES and gender. I wrote summaries of the data pertaining to each theme, being careful to note conflicting evidence for individual students, SES or gender groups, as well as across related themes. I paid particular attention to data on high-achieving, low-SES students and the low-achieving, high-SES students, as they helped me sort out differences that seemed more aligned with achievement than SES; when I

some dimensions that her fellow lower-SES females did not (she was only mid-achieving, though she tried very hard, and she raised some gender issues that seemed important, because she was often ridiculed by the boys in the class). Twelve students participated in the first round of interviews, fourteen participated in the second round, and eighteen students participated in the final round.

[6] The CMP instruments were administered to all students in CMP pilot sites to inform the curriculum development.

[7] Scholars have pointed out the dangers of studying the variables of race, class and gender in isolation (e.g., Campbell, 1991b).

[8]Examples include: Reactions to being frustrated on problems, views on whether feelings are hurt in class discussions, and views on which type of math helps them learn/think more.

saw patterns that seemed related to SES, yet these students differed from others in their SES group, I was quick to consider achievement as a confounding variable.

Because many recurring themes were related to students' experiences in whole-class discussion, I also systematically examined some of these discussions to compare students' participation with their reported experiences in the discussions. I randomly selected two days from each of the seven curricular units used throughout the year, and I analyzed the audio tapes of the whole-class discussions from those days. I coded each student contribution to discussions (a total of almost 300 contributions over the 14 days) using twenty categories designed to capture the content, problem context, social context, reasoning, visual/tactile references, tone, correctness, insightfulness, mathematical relevance and difficulty level associated with each contribution. I looked across the results of each day's coding for patterns in students' participation by gender and SES.

In addition to the analyses of the data for all participating students, I wrote cases of the female target students. Looking across the larger data set helped me see trends in SES differences; looking closely at individuals helped me understand the trends and how they interacted to shape the experiences of individual students.

RESULTS

During the year, I enjoyed watching some successes of the curriculum unfold, such as seeing the most seemingly apathetic students become engaged in problem explorations. Yet, in considering which students seemed to experience and benefit from the curriculum in ways we authors intended, some SES-related trends emerged that relate to two key aspects of the curricular problems — their "openness" and their contextualized nature. In the first several sections below, I present data relating to students' experiences that relate primarily to the open nature of the curricular problems, including students' appreciation of the open problems in relation to more computation-oriented curricula, students' struggles and motivations to make sense of and solve the problems, and what students' thought they were learning. In the final section, I focus directly on the *contextualized* nature of the problems and how this might have differentially affected students.

General Feelings About Traditional Versus CMP Curricula

The survey and interview evidence relating to students' curricular preferences indicated that more higher-SES students preferred the CMP trial materials over the more typical math books they had experienced through fifth grade . Many students expressed a mixture of opinions about the curriculum, but the four students who consistently expressed preference for CMP were all higher-SES. Four of the six students who consistently said they preferred typical math to CMP were lower-SES.

The CMP asks students to think harder and differently than before, so it is not surprising that many students reacted negatively to the new expectations. Yet, their complaints were not all the same. The predominant theme among the lower-SES students was that the problems were frustrating because they were too confusing or hard (a theme for eight out of the nine lower-SES students). For example, Sue said the books were "confusing [because the] questions are too long and complicated." Dawn declared, "I don't like this math book because it doesn't explain EXACTLY!" Moreover, six lower-SES students specifically said they were better at math the old way. For example, Sue said, "I used to do really good in math," and James explained, "I'm worse (now), 'cause I used to could do the work, but here I don't understand it." When pushed to explain what exactly was hard or confusing, the lower-SES students would primarily talk about being unable to figure out what they were supposed to do with the problems, and they blamed this on the words and general sentence structures used, as well as the lack of specific directions for how to solve the problems. Since SES correlated with achievement, it is important to give attention to those students who were of low-SES and high achieving, as well as students who were of high-SES and low achieving. Although both Rose and Lynn were high-achieving students in all school subjects, they shared their lower-SES peers' attitudes about the difficulty of the curriculum. Rose consistently said the CMP was harder for her because of the lack of specific direction. She explained, "These books are bad because they are so confusing. We are told to do a page as homework and the page gives directions but it doesn't explain how to do it." Lynn said, "I'm better at number problems than problem solving."

Some higher-SES students also complained about the books being confusing, but their complaints were usually voiced toward the beginning of the year (when it was "cool" to complain about this) and not as passionate or personalized, often offering a specific suggestion or pointing to one problem or word that was unclear. For example, Guinevere suggested that the CMP authors include a glossary, and Samantha recalled that the CMP's use of the word "corresponding" confused her until she learned what it meant. These specific complaints were quite different from those of the lower-SES students, who conveyed the feeling of having no idea how to proceed on the problems.

While no lower-SES students said that the CMP curriculum was easier for them than typical curricula, several higher-SES students made comments about CMP problems being easier for them than computation. Guinevere explained that CMP problems were "a lot easier" for her because "I guess our family's just — we are word problem kind of people." Similarly, Christopher explained that CMP is easier for him because, "I'm pretty good at problem solving." Benjamin encouraged the CMP authors to make their problems "more challenging." Additionally, in an interview Rebecca explained:

> This year we're doing stuff that I like. Two years ago we did 20 x 4, I hated it because I wasn't good at it and I'm good at this. . . . [CMP is] easier. [Before] we just sat there with hundreds of problems on a page.
>
> . . . . *Why do you think it's easier for you (when others say it is harder)?*
>
> I don't know, it's just my abilities. . . .
>
> *Would you rather have the teacher tell you rules, or would you rather figure them out?*
>
> No. Learning about it like exploring how to do things is easier for me than sitting down and learning the rule.

I suspected that part of the lower-SES students' frustration might be due to feeling less than confident with the mathematical ideas assumed by the curriculum. James, who had just transferred in from another school, said that all of the material was new. Nick and Lynn said that most of it was new. Yet, all other lower-SES students said that at least half of it was familiar. So it seems that, at least from most students' point of view, if they were struggling, it was not the mathematics that posed the difficulty.

<u>Internal/External Direction and Motivation</u>

As one might guess from their comments about wanting clearer directions in the CMP trial materials, the lower-SES students preferred a more directive teacher role. When asked to rank various modes of working on problems, the lower-SES students, especially the girls, ranked having specific teacher direction higher. Also, the lower-SES girls tended to ask me, "Is this right?" more often. Only lower-SES students said they preferred having the teacher "tell them the rules." Three of these lower-SES students said it confused them to try and explore the problems and figure out "the rules," and two of them said that being told rules allowed them more time to work with and understand them. When the lower-SES students talked about aspects of my teaching that were "good," they focused on my ability to explain things well, particularly the CMP questions.

Teacher direction seemed less important to higher-SES students. For example, Andrea liked my "not too strict" style, and Benjamin said I was a good teacher because, "She doesn't give answers, but helps and is nice."

In the face of uncertainty the open problems presented, the lower-SES students seemed more passive, less confident about how to proceed. On the various surveys and interviews, lower-SES students tended to say they would become frustrated and give up when stuck, while more higher-SES students said they would think harder about the problem or just interpret it in a sensible way and get on with it. For example, Christopher explained his reaction to confusing problems as follows:

> I just, like, try to figure out what I was trying to do, and just go and do what I think it's trying to say. . . . I just try my best to figure out the directions, so if I get it wrong it's just because of directions and not because I did the problem wrong.

Hence, while lower-SES students seemed to prefer strong teacher direction, the higher-SES students displayed more confidence to delve into the problems.

The higher-SES students also displayed more intrinsic motivation to solve the problems and grapple with mathematical ideas. The four students who said they liked to figure problems out and really understand ideas were higher-SES. While there were several examples in my fieldnotes of higher-SES students showing intellectual curiosity and excitement about challenging mathematical problems, there were no such examples for lower-SES students. For example, Benjamin once became totally engaged in a context-free problem that asked him to find the dimensions of a cylinder with a volume of 1,000 cubic units. Although he asked me a few questions as he excitedly used various methods to get successively closer to 1,000, he made it clear he did not want me to tell him too much. When finished, he proudly said that this was the hardest thing he had ever done. Christopher also became very engaged in that problem and created an extension of the problem on his own, which he showed me the following day.

This is not to say that the lower-SES students did not ever engage in or enjoy the problems, but that they seemed to be motivated more by the activities involving fun, games, and contexts of interest to them (such as sports for Nick or dream houses for Rose and Sue) — it was not the mathematics that tended to draw them in or receive focus (I return to this later). Audio tapes of lower-SES students' group work revealed instances of them hurrying through problems but not wanting to appear to be finished for fear I might push them to re-think or discuss their solutions. My journal records several instances in which, the lower-SES students (especially the high-achieving females) seemed more concerned about getting the algorithm that would allow them to complete assigned work than grappling with or understanding mathematical ideas for their own sake.

Thus, more higher-SES students seemed to possess orientations and skills that allowed them to actively interpret the open problems, believe their interpretations were sensible, and follow their instincts in finding a solution. The lower-SES students seemed more concerned with having clear direction that enabled them to complete their work and were less apt to creatively venture toward a solution; they sometimes became stuck in the uncertainty of relatively open problems.

Thinking/Learning More

Students —both lower- and higher-SES — agreed that in their former math classes they learned "more basic skills," such as multiplication and division. Several students of both SES groups said the CMP made them think more, and most students said that CMP helped them see how math is connected to real life.

One difference in the way students talked about the benefits of CMP was that the higher-SES students more clearly stated that *they* were personally helped by the CMP, while the lower-SES students talked about the CMP's benefits from a more external standpoint — either saying what they thought they *should* be learning or what *others* said they were learning.

For example, Samantha explained that in CMP "I've learned new stuff and I'm able to think more . . . stuff that will help in real life in the future. . . . I can probably figure out a problem now, without having someone just tell me the rule — like if we're doing integers again, I could probably figure out a rule." Additionally, Andrea explained in her final interview that, in her former math classes, she would forget everything over the summer, but with CMP she remembers what she learns longer — "[CMP] sticks with you — it just stays with you."

As with the higher-SES students, most lower-SES students could articulate much of what the CMP was intending. For example, Rose explained, "CMP is kind of like real life stuff, so I think that maybe they want you to extend your brain. They aren't going to say here are the rules, they want you to figure it out yourself." When pushed to say whether the CMP worked for them like the authors intended, all higher-SES students (except two who gave mixed reviews) said "yes." But the lower-SES students, especially the girls, tended to be much more hesitant, saying "I don't know," or "kind of." The majority of lower-SES students talked about their difficulties with the curriculum getting in the way of their learning. Lynn (known by her teachers as a very motivated, high-achieving student) articulated views shared by many of her lower-SES (especially female) peers, as indicated by their survey and interviews throughout the year:

> I usually just try to remember it [rules] and do the problems. I don't ask how or why it works. I think sometimes it confuses me more, and sometimes I'm not interested, I just want to know how to do the problems or something. . . . Like when we were doing the, um, the negatives and positives, adding and all that stuff. For a while there you tried to have us figure out the rules, and then when Miss Mattel [their "regular" classroom teacher who substituted for me while I was away] taught us, she just told us the division and multiplication laws, and I liked it when she told us so we could just do 'em. and I didn't have to sit and try to figure them out. 'Cause I think when I didn't know the rules, I got em wrong, and now that I know the rules I get most of em right now.
>
> . . . . *Why do you think we [the CMP and I] want you to figure out the rules?*

So you can, like, learn how they do it. Or try to, um, so you can just like — so you can, um, I don't know why really, but I know it's a good reason.

Why do you think it's a good reason if you don't know it?

'Cause if you can figure em out, then maybe you're learning more; if you can figure out how they do it or how the rules go, maybe you understand it more or something.

But you prefer not to do that?

Yeah, cause it confuses me . . . 'cause when I try to figure things out, I like the rule I get, and I stick to it even though its not right and when we get the real one it confuses me.

Lynn provides a summary of many of the issues discussed above. Most lower-SES students (especially the females) preferred having the teacher tell them "the rule" so they could get "the right answer" to problems. Lynn did not seem to view learning to work through ambiguities of problems as an important curricular goal — the ambiguities were simply confusing obstacles to knowing the right rule to use to obtain the correct answer. Like many other lower-SES students, Lynn talked in the third person about the curriculum being helpful. She thought maybe the CMP and I had a "good reason" for wanting students to figure out the rules themselves, but it did not work very well for her, because the lack of clear direction and rules was too confusing for her. In the end, Lynn did state that she thought that her experience with CMP had improved over time, and she attributed this to having a teacher who understood the problems and could explain things (or simply restate the problem) in plain English. For example, she once asked me, "Why don't they [CMP authors] write it like you say it?. . . . When I figure out what I'm supposed to do, I can do it, it just takes me longer."

Much of what Lynn expressed difficulty with and has been the focus of the data presented thus far is the open nature of the problems in the CMP trial materials. One final aspect to be discussed is the problems' contextualized nature.

Contextualization

One might expect that, if lower-SES students tend to have a contextualized orientation to ideas, they would benefit from contextualized problems. Yet, the data from this study raise questions about this supposition.

Data from this study suggest that the lower-SES students were, indeed, more contextualized in their orientation toward ideas. As is published elsewhere (Lubienski, 1997), I interviewed the students about their interpretations of mathematical claims presented in the media (e.g., magazine advertisements, newspaper articles). The lower-SES students were more likely to completely mistrust and ignore the data provided, and to reason in personalized and "common sense" ways, such as referring to pictures or offering stories about friends and family that tried various products. Higher-SES students tended to scrutinize given mathematical information to find a "loophole." Their reasoning was not necessarily more "correct" than that of the lower-SES students, but it was more mathematically focused and impersonal.

Additionally, the type of language and proof used by students in their contributions to class discussions (on the fourteen randomly selected days) suggest at least a moderately more contextualized orientation among the lower-SES students.

I coded whether students used generalized or contextualized language.[9] In order to avoid exaggerating or masking differences, I coded contributions that were not clearly generalized or contextualized as "in-between." According to the data, roughly two-thirds of each group's contributions were "in-between." Still, there were patterns in how the remaining contributions fell. The lower-SES males (16% of their contributions) and females (23%) used contextualized language more than the higher-SES males (3%) and females (10%). The higher-SES males (38%) and females (24%) used more generalized language than the lower-SES males (11%) and females (6%).

I also developed six categories of proof: proof by pattern, common sense, deference to rule, proof by one example, general proof, or "in-between".[10] Again, when in doubt, I coded the contribution as "in-between." The majority of students' contributions were "in-between," ranging from 52% (lower-SES females) to 76% (higher-SES females). The higher-SES students contributed eight of the ten general proofs offered. Proof by one example was used twice, both by lower-SES girls. The lower-SES girls gave seven of the nine common sense proofs. The lower-SES students deferred to rules more often than higher-SES students, providing sixteen of twenty four instances (about one-fourth of lower-SES students' contributions were in this category — twice the average of the higher-SES students).

Might these differences be simply attributable to achievement differences between the SES groups? Rose's case is a counter-example to this hypothesis. Rose was a very bright, high-achieving student, and yet she sometimes drew conclusions from one example and

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[9]For example, in a problem about differences in prices between stores, I would record the language of someone who constantly referred to the objects, the dollars, and the stores as contextualized, and the language of one who only referred to the numbers without any contextual attachment as generalized.

[10]A proof by pattern involved arguing that something is true because it follows a predictable sequence. A common sense proof offered a non-mathematical (in the traditional sense) rationale that relates to every-day living, while deference to rules involved arguing that something is true because of a rule learned previously. A proof by one example argued a general statement was true because it held in one case, and a general proof was what might be considered a typical, deductive proof — an abstract argument that logically derives a general (i.e., not tied to the problem at hand) conclusion from previous conclusions. An "in-between" proof involved giving a general explanation of some sort using the problem context at hand — hence, a proof that was somewhere in between a general proof and a proof by one example.

seemed to have difficulty distinguishing between that and a more general proof. For example, I noted the following incident in my journal:

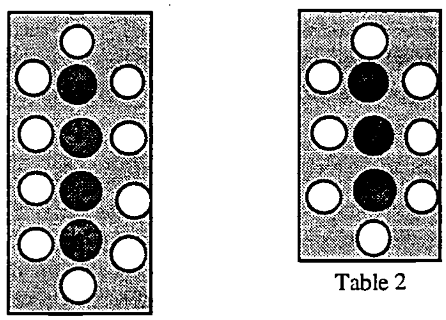
> Benjamin was very insistent about his (correct) theory that the area increases by the square of the scale factor. I was asking for explanations as to *why* this happens. Again, Rose chimed in with, "Well, we know that the area is 18, so it has to be multiplied by 3", and . . . Benjamin said "But WHY does it happen? — If you didn't know what it would be, how could you figure it out?" Rose has a very difficult time with this — this is the second or third time this exact situation has come up.

Rose also had some difficulty distinguishing between an opinion-based question versus one that could be mathematically analyzed. For example, on a probability question about where a spinner is most likely to land, she said that since different people have different guesses, it is just an opinion question. I also recorded several examples in which Rose's "real world, common sense" reasoning seemed to take precedence over finding or realizing the usefulness of the intended mathematical solutions to problems. For example, in response to a question about data stating that men are killed in car accidents more often than women, Rose said, "Maybe men were in the wrong place at the wrong time." As another example, a CMP problem asked students to compare the volumes and prices of three popcorn containers sold at a movie theater. Rose used solid "common sense" reasoning to argue that, since the prices went roughly in order of size, we should just choose which size we really needed — "It depends on how much popcorn you want." Although Rose's reasoning was very sensible, she approached the problem with a more "common sense" orientation than the authors expected, and, therefore, did not gain the intended experience of working with volumes and comparing unit prices.

Rose was typical of many of the lower-SES students who approached ideas in a more contextualized manner. As the above evidence suggests, this orientation could sometimes hinder understanding of intended ideas.

As an extended example, I offer the following data surrounding a problem about dividing up pizza. This is an example in which both lower- and higher- SES students were actively engaged with the curriculum and discussion. But in looking beyond that similarity, we can see some differences between the thinking and reasoning of the higher- and lower-SES students.

Imagine that you entered a pizza parlor and saw pizzas being served at two tables of your friends, one table with 10 people and the other with 8 people. Friends at each of the tables call out to you to pull up a chair and share their pizzas. You could choose the table with fewer friends or the one with more friends. Or you might choose the table with the most pizza. But is this the best way to make the decision? Are there other more helpful ways that we can use mathematics to *compare* the two situations?



Problem 1.2: If you like the two groups of friends equally well, which table would you join and why?

Figure 1. Problem from trial version of *Comparing and Scaling*, Investigation 1: Making Comparisons

The authors intended the problem presented in Figure 1 to help students learn to create and compare ratios. As I launched this problem, I clarified that students should assume that they want to go to the table at which they can eat the most pizza. Students worked on this problem in groups for about fifteen minutes, and then Rose began our whole-class discussion by sharing the work she had done in her group.

Rose	Um, you'd think there would be equal if they were divided up into 4, I don't -- anyway, if they were divided up into 4 —
STL	Into 4 pieces each you mean?
Rose	Yeah, at Table 1 there would be 16 pieces.
STL	OK, 16 pieces, alright. *(I'm writing her information on the board as she talks. My "OK's" signal when I have it down.)*
Rose	And on table 2 there'd be 12. . . And so, um, there'd be 4 people who wouldn't have seconds on table 2 (pause as she waits for me to record her information on the board) because that would be 8 and 8 is 16 (pause) And then the same on Table 1.

STL	Four people without seconds, and four people without seconds. (pause) Does anyone want to ask them anything? . . . (pause) Sue?
Sue	OK um, you don't know how much the, the, the people at the table who already ate, and (pause) (*She tended to mumble toward the ends of her contributions, and I had difficulty understanding her.*)
STL	You don't know — I'm sorry —
Sue	You don't know, like say you came five minutes after they served everyone and everything, and say like two pizzas were gone at like both tables, and then there's only two on both of them.
STL	OK, so if, so you don't, OK, you don't know how much is left at each table, is that--?
Sue	Yeah! You don't, you -- I don't know! (She mumbles something I can't hear.)
STL	(Pause) OK, let's just assume -- they don't say this explicitly -- but let's assume they just got the pizzas and they haven't started eating yet.
Student	It says that.
STL	It does say that? OK. . . . (*I checked -- the problem did say that.*) Um, Samantha you've had your hand up a long time
Samantha	Um, I want to take the people -- um, there's four people without seconds at each thing, but the table 1 has more people, so, um, um, those people without seconds on table 2 that's half the people, but the people without seconds on table 1, that's um, less than one half, so you have a *better chance* of getting seconds at table one than at table two. (*We had recently finished a probability unit, and Samantha was able to use those ideas here.*)
STL	OK, so you would say table one is better. So you like this idea of getting seconds --
Samantha	--I have another idea
STL	Go ahead
Samantha	OK, I got the answer by dividing by um, dividing how many pizzas there are by the number of people, and-- (*Getting seconds was not the original way she solved it. But she had listened to their argument and understood it's mathematical flaw and tried to address it.*)
STL	OK, (*I'm writing on the board again.*)
Samantha	So I took four divided by 11 because you have to add more people if you're going to join the table.
STL	Because you're going to be there too, so you're saying there's 11 people and --
Samantha	And you get 36% of the pizza

At this point, I pushed a bit on what the 36% was a portion of — one pizza or all the pizza. While many students seemed to understand Samantha's approach and answer, we ran out of time to really pursue the differences in Rose's and Samantha's approaches during this class period.

As the bell was ringing and students were leaving, Rose approached me for help in understanding how to proceed on the first homework problem. It asked which park was most crowded, given the areas and number of children playing in each park. This problem is mathematically similar but contextually very different than the pizza problem.

In looking closely at their homework from that night, the SES patterns were striking. Most of the higher-SES students made good sense of the park problem and their solutions to it. Their answers involved ratios such as ".087 kids per square meter," or "11.4 square meters per person" — quite abstract ideas. Most lower-SES students performed some computation with the given numbers to arrive at an answer, but they could not make sense of their answers when they finished. For example, Rose divided some numbers, but could not interpret what they meant and, therefore, could not determine which park was most crowded. She wrote, "I divided the area by the number of children playing. This found the percent of people on each playground."

Although stronger teacher intervention might have helped students "pull out" the intended mathematics after their group work on the problems, the issue still remains that it was the lower-SES students who seemed to have more difficulty learning the intended mathematical ideas from the pizza problem. Instead of exploring the problem in a way that allowed them to learn about generalizable methods of comparing numbers using division or ratios, Sue and Rose's approaches to the problem seemed heavily influenced by real-world concerns, such as getting seconds on pizza or arriving late to dinner. Hence, these students did not solve the problem in a way that helped them learn the powerful, generalizable methods of using division or ratios to make comparisons, as was intended. As Samantha demonstrated, Rose's approach with "getting seconds" could have allowed her to reach the right answer, in which case she might have left class confident that she understood what was intended. But Rose would not have learned the intended ideas that would have helped her solve the mathematically similar homework problem she had that night.

There is other evidence to suggest that the lower-SES students tended to focus more on individual problems without seeing the mathematical ideas connecting various problems. Dawn said that she could never figure out what she was supposed to be learning until she took the test. Rose complained that she had difficulty seeing how the problems we did in class related to the assigned homework problems. Rose also did not see connections between units — according to her, once we finished with an idea, we never revisited it. In contrast, several higher-SES students (but no lower-SES students) noted that we hit the same mathematical ideas over and over again in various contexts.

A Simple Difference in Previous Achievement, Ability or Motivation?

It seems reasonable to assume that some differences in students' experiences and views might have been due, in part, to previous achievement differences, which correlated with SES. But a variety of forms of data point out the incompleteness of achievement as an explanation. When lower-SES students, such as Rose or Lynn, were known for being very bright, high achievers in their other, more typical classes (as I learned from their other teachers and parents), why were they struggling with particular aspects of my class? Why did the lower-SES students tend to say they used to understand math better before CMP? Why did some higher-SES students but no lower-SES students say that traditional math was more difficult for them than CMP math?[11]

Many of the differences in the data might also seem attributable to simple motivational differences. But my analyses of the data do not support that hypothesis, particularly when examining gender and SES together.

For example, Table 3 shows the students' average grades for the year. The first number for each student is the percent of assignments (homework and classwork) completed. This is a rough measure of their *effort*. The second number is their quizzes/test average, which

[11] I should note that students' perceptions were often confirmed by other students and comments made by parents. For example, Rebecca's mother supported Rebecca's claims that she found CMP math easier and more enjoyable than typical mathematics curricula.

indicates the degree to which students *understood* the intended mathematical ideas in a way that allowed them to apply the ideas to new situations.

Table 3
Students' Average Grades for the Year

Higher-SES Males	Higher-SES Females	Lower-SES Males	Lower-SES Females
Christopher: 96 W 95 Q&T	Rebecca: 99 W 95 Q&T	Mark: 82 W 84 Q&T	Rose: 97 W 87 Q&T
Samuel: 89 W 90 Q&T	Samantha: 98 W 96 Q&T	Nick: 78 W 87 Q&T	Anne: 94 W 88 Q&T
Timothy: 89 W 81 Q&T	Andrea: 91 W 86 Q&T	Carl: 69 W 61 Q&T	Lynn: 94 W 86 Q&T
Benjamin: 77 W 92 Q&T	Guinevere: 81 W 90 Q&T	James: 21 W 42 Q&T	Sue: 90 W 77 Q&T
Harrison: 70 W 69 Q&T			Dawn: 80 W 63 Q&T
84 W - 85 Q&T	92 W - 92 Q&T	76 W - 77 Q&T (w/o James) 63 W - 69 Q&T (w/ James)[12]	91 W - 80 Q&T

There were gender differences in terms of effort put forth on homework — the girls were more diligent, completing over 90% of assignments. Also notice that the work and test averages are very close for the higher-SES males (84 W - 85 Q&T) and females (92 W - 92 Q&T), as well as for the lower-SES males (76W - 77 Q&T). For these groups, the amount of effort put forth on assignments correlated closely with their quizzes and test scores. But the story is quite different for the lower-SES females, who showed the most frustration with the class throughout the year. These girls made a consistent effort, but they still did not understand the mathematics in a way that allowed them to do really well on tests. In other words, effort did not pay off for them in the way it did for the higher-SES girls.

There were also patterns in students' perceptions of their own mathematical abilities that seemed to go beyond actual differences in achievement or ability. In a survey at the end of

[12] Since James is an outlier for the low-SES males, I calculated the overall average both with and without his grades.

the year, I asked students to name the top three math students in the class. Table 4 contains the tallies of those named.

Table 4
Those Mentioned in Response to "Who are the Best Three Math Students?"

Higher-SES Males	Higher-SES Females	Lower-SES Males	Lower-SES Females
Benjamin* - 18	Samantha* - 20	Carl - 0	Rose - 9
Timothy* - 2	Rebecca* - 4	James - 0	Anne - 2
Christopher* - 2	Guinevere* - 1	Nick - 0	Dawn - 0
Samuel* - 1	Andrea - 0	Mark - 0	Sue - 0
Harrison -			Lynn - 0

Students with an asterisk named themselves as one of the top three math students. Notice that *no* lower-SES student ranked herself among the top three — even Rose, who was considered by nine other students to be a top student. Meanwhile, every higher-SES student mentioned by anyone also mentioned themselves. Even Samuel and Guinevere, who were not mentioned by anyone else, named themselves. According to their homework and test grades, Rose and Anne had as much cause to feel mathematically confident as Timothy, Guinevere, or Samuel. And yet, they did not.

DISCUSSION

In addition to achievement, there are other potentially confounding factors that need to be addressed. First, one might wonder if the CMP trial materials or my pedagogy were simply ineffective. Yet, the point is that lower- and higher-SES students were *differentially* affected by the open, contextualized nature of the problems (and the less directive nature of my pedagogy). Others might wonder if differences in students' reactions were rooted in their previous school experiences, but since the students were all in the same classroom and the majority had been in the same school system since kindergarten, this does not seem a plausible explanation.

Due to the nature of this qualitative study, I cannot draw conclusions from the data about the likelihood of differential outcomes for all higher- and lower-SES students in other classrooms aligned with current reforms, and I cannot say what would happen if the students experienced a reform-inspired curriculum and pedagogy for many years. Additionally, with such a small sample, it is possible that the patterns in the data are due to individual differences that happened to fall along class lines, or to other confounding factors, such as teacher/researcher bias. Still, a review of relevant literature suggests it is very plausible that the patterns in the data are, indeed, linked to class cultural differences.

Given the context the literature provides, this study raises awareness of ways in which the use of open, contextualized problems can play out differently for lower- and higher-SES students. I discuss two key differences below, along with relevant literature that sheds light on these differences and links them to class cultures.

Perseverance and Direction in Problem Solving

The relatively open nature of the CMP trial curriculum required students to take initiative in interpreting and exploring problems, as opposed to following step-by-step rules given at the top of the page. The higher-SES students were generally able to explore the open problems in this way, without becoming overly frustrated. In fact, many higher-SES students voiced appreciation for their increased confidence and abilities in mathematical problem solving due to the CMP curriculum. But the lower-SES students, especially the females, more consistently complained of feeling completely confused about what to do with the problems, and asked (often passionately) for more teacher direction and a return to typical drill and practice problems.

In Heath's (1983) famous study of middle-class and black and white working-class communities, she found differences in parenting practices. In teaching their children, the middle-class parents emphasized reasoning and discussing. Through interactions with their parents, the children "developed ways of decontextualizing and surrounding with explanatory prose the knowledge gained from selective attention to objects" (p. 56). Meanwhile, the white, working-class parents emphasized conformity, giving their children follow-the-number coloring books, for example.[13] They told their children, "Do it like this," while demonstrating a skill (such as swinging a baseball bat), instead of discussing or explaining the features of the skill or the principles behind it. The white working-class children tried to mimic their parents' actions. When frustrated, the children often tried to "find a way of diverting attention" from the task" (p. 62). These children became passive knowledge receivers and did not learn to decontextualize knowledge and then shift it into other contexts or frames. These students did well in early grades, but when they hit more advanced activities that required more creativity and independence, they frequently got stuck and asked the teacher, "What do I do here?"

Similarly, Hess and Shipman (1965) found that middle-class mothers asked questions to help focus children's attention to key features of a problem, which taught the children generalizable problem-solving strategies. Working-class mothers tended to explicitly tell their children how to solve a problem, often solving it for them.

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13 In contrast, the black, working-class families emphasized creative story telling. Like Delpit (1986), Heath describes the children in these families as linguistically fluent and argues that they need to learn more decontextualized, factual and explanatory means of reasoning and communicating for success in school.

Other studies describe middle-class families as stressing initiative, curiosity, reflection and self-confidence; they describe working-class families as emphasizing obedience to authority and believing they have little control over their own fate; hence, middle-class children are taught to take initiative and to enjoy learning for learning's sake, while working-class children are more oriented toward receiving knowledge from those in authority (Banks, 1988; Duberman, 1976; Terrell, Durken, and Wiesley, 1959; Zigler and DeLabry, 1962).

These comparisons are likely to make many people nervous (including myself). Bruner (1975), after surveying the literature on class cultural differences concluded, "It's not a simple matter of deficit" (p. 41). But although he could see strengths and weaknesses in the culture of both the middle and lower classes, Bruner was particularly concerned about feelings of helplessness and hopelessness that seem more pervasive in the culture of the lower classes. He concludes:

> I am *not* arguing that middle-class culture is good for all or even good for the middle-class. Indeed, its denial of the problems of dispossession, poverty, and privilege make it contemptible in the eyes of even compassionate critics. . . . But, in effect, insofar as a subculture represents a reaction to defeat and insofar as it is caught by a sense of powerlessness, it [lower-class culture] suppresses the potential of those who grow up under its sway by *discouraging problem solving*. The source of powerlessness that such a subculture generates, no matter how moving its by-products produces instability in the society and unfulfilled promise in human beings (p. 42, emphasis added).

While class is the primary focus here, gender seems to be an interactive variable on issues surrounding problem solving. Studies have found that girls (especially those with low self-esteem) are more likely than boys to internalize their frustrations and failures as evidence of their incompetence (AAUW, 1992; Covington & Omelich, 1979). These findings might explain why the lower-SES students in this study, especially the females, voiced such strong preferences for a more traditional curriculum. The lower-SES students seemed to have lower self-esteem in the area of their math performance (e.g., recall their rankings).[14] The lower-SES females made strong, consistent efforts to succeed, and yet they struggled. The lower-SES females became the most frustrated with the open nature of the problems (and my pedagogy, as discussed in Theule-Lubienski, 1996), and this makes sense, according to the literature, because these are the students who were most likely to internalize their "failure."

Hence, in contrast with the reformers' rhetoric of "mathematical empowerment," some of my students reacted to the more open, challenging mathematics problems by becoming

[14] Additionally, Kohr et al (1988) found that SES correlates with students' general self-esteem in school (more so than race or gender).

overly frustrated and feeling increasingly mathematically disempowered.[15] The lower-SES students seemed to prefer more external direction from the textbook and teacher. The lower-SES students, particularly the females, seemed to internalize their struggles and "shut down," preferring a more traditional, directive role from the teacher and text. These students longed to return to the days in which they could see a more direct payoff for their efforts — e.g., 48 out of 50 correct on the day's worksheet.

Abstraction from Contexts

Since the "open" problems could be explored in a variety of ways, they left room for students to approach the problem in unexpected ways. While this "openness" is not necessarily problematic, this study suggests that, when combined with the lower-SES students' orientation to contextualized meanings, some complications can arise.

Many of the CMP problems were set in realistic situations, and these contexts were often effective motivators, prompting students to delve into the problems. While the higher-SES students seemed more able and inclined to pull back from the context and analyze the intended mathematical ideas involved, the lower-SES students seemed to focus more on the real-world constraints involved with the contexts as they solved the problems, thereby missing some of the intended mathematical ideas. Usually the lower-SES students' thinking about these real world constraints was very sensible, and I (and the CMP authors) did want students to be able to think about mathematical ideas in the messy, real-world contexts in which they are often embedded. But these contextualized problems were primarily supposed to be a means of learning more general mathematical ideas that could then be applied in other contexts. The tendency for the lower-SES students to focus on the immediate context, as well as their desire for more specific teacher direction for their mathematical thinking and less intrinsic interest in understanding the mathematics for its own sake, contributed to the lower-SES students' tendency to becoming "stuck" in the contexts.[16]

Hence, while it might seem sensible that students with more of a contextualized orientation toward meaning will gain more from contextualized mathematics problems, this

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[15] Again, this study says nothing about the published versions of the CMP curriculum. The CMP problems gained clarity with each revision, and, therefore, it is likely that all students' struggles with the open nature of the problems would have been diminished to some degree if the published CMP materials were used. The issue raised in this study is SES-related *differences* in students' reactions to open, contextualized curricular problems, in general.

[16] While some might take issue with the negative connotation the word "stuck" carries, I think it fits here. "Stuck" indicates that the students' thinking could become so heavily immersed in the real-world constraints of the problem that they missed some important mathematical ideas. Again, this is not to say that the lower-SES students' thinking was less sophisticated than the higher-SES students' thinking, but their approaches did not always allow them to reap the intended mathematical benefits of the problems.

study raises questions about possible drawbacks of contextualized problems in the curriculum. A recent study raises similar questions about the fairness of contextualized mathematics assessment items. In comparing British working- and middle-class students' approaches to standardized test items, Cooper, Dunne & Rodgers (1997) found that class differences were greater on questions involving realistic situations. In examining these differences, they discovered that the contexts were an obstacle for working-class students, who approached the problems in heavily context-laden ways unintended by test writers.

While students need to become able and inclined to critically analyze real-world problems, particularly those involving inequities, perhaps those problems are not equitable means of building the mathematical understandings necessary for such critical analyses. Evidence from my classroom raises the possibility that, although contextualized problems can be powerful motivators, the lower-SES students might have more difficulty learning abstract, mathematical principles when taught in contexts.[17]

IMPLICATIONS

This study raises the possibility of some unintended consequences of using open, contextualized problems as a means to learning mathematics; perhaps learning mathematics in this way does not come as "naturally" for all students as has been presumed.

Still, my conclusion is not that we should return to simple, one-step computational problems. Students learning to take initiative in mathematical problem solving is an important goal. In some ways, this study suggests that lower-SES students have the *most* to gain from problem solving instruction. Still, this study raises questions about using problem solving as a *means* to learning other mathematical ideas, as well as questions about possible pedagogical interventions.

Two mathematics projects known to be "successful" with disadvantaged students, suggest some instructional variations that could address issues raised by this study. First, Bob Moses' "Algebra Project" (1989) is known to be successful in helping disadvantaged middle-school students learn algebra. Moses found that his students had particular difficulty in moving from the concrete, arithmetic question, "How many?" to more abstract, algebraic questions (p. 422). Moses developed a five-step plan to help students avert frustration and move "from physical events to a symbolic representation of those events" (p.

[17] Ball (1995) raises additional equity issues surrounding the use of realistic contexts. She suggests that teaching mathematics through real-world problems can pose difficulties because of differences in students' interpretations and approaches, and because of uneven access to relevant knowledge that some children have. In her classroom experience, abstract mathematical contexts often seemed more inclusive of all students, giving them a sense of common understanding and purpose. When her students explored real-world problems, they "were distracted, or confused, or the differences among them were accentuated in ways that diminished the sense of collective purpose and joint work" (p. 672).

433). Moses advocates teaching students' problem-solving skills explicitly and helping them learn, in non-threatening ways, how to be more self-reliant learners of mathematics, including how to generalize from concrete situations. Additionally, Project SEED (Phillips & Ebrahimi, 1993) aims to help low-income and minority elementary and middle-school students learn abstract mathematics in order to promote the study of more advanced mathematics later. Project SEED students actively engage in mathematical thinking and problem exploration, but there are two relevant differences between SEED's methods and those advocated by NCTM. First, SEED students do not explore open problems independently, but instead the teacher leads the entire class through the exploration, using focusing questions. Second, there is no emphasis on contextualized problems — abstract ideas are taught in the abstract.

Considerations of how to adapt instruction to meet lower-SES students' needs, might contain inherent dilemmas about what types of instruction and goals are intrinsically more valuable yet also likely to increase the gap between lower- and higher-SES students' mathematics performance. This study points to the need for further research to determine how we can help lower-SES students become more effective problem-solvers. While this study explored a variety of issues that arose in one classroom, more focused studies with larger numbers of students are needed to address questions raised here (such as the differential impact of more or less open, abstract problems versus more or less open, contextualized problems).

Hopefully the issues raised here can deepen our thinking about complexities involved with the "mathematical power for all" agenda, particularly as the NCTM *Standards* are revised. This study reminds us to keep equity at the forefront of our discussions regarding curriculum and pedagogy, since methods that are promising for many students could be a hindrance to the students who most need mathematical empowerment.

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