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# Mathematics for What?

## High School Students Reflect on Mathematics as a Tool for Social Inquiry

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**Abstract**

This study examines high school students' views of mathematics as a tool for social inquiry in light of their classroom experiences using mathematics to explore social issues. A critical theoretical perspective on mathematics literacy is used to ascertain the ways in which their views challenge or affirm the dominant image of mathematics in society. The study concludes that mathematics applications addressing social justice issues are promising vehicles for developing students' appreciation of mathematics as a social problem-solving tool, an awareness of its limitations, and a healthy skepticism toward its uses.

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## Introduction

U.S. SCHOOLS ARE under considerable pressure to get students to learn more mathematics. A mathematically literate populace is deemed essential for enhancing our country's economic competitiveness. Less frequently heard in discourse on education reform is the importance of mathematics literacy for informed and active democratic citizenship in technologically advanced countries such as our own where mathematics is increasingly used to characterize societal problems and formulate solutions to them. Without some mathematical competence, ordinary citizens are unlikely to comprehend, let alone influence, many of the decisions and actions of those in power in political, social, and economic institutions. This lack of agency by ordinary citizens undermines democracy (Apple, 1992; Bohl, 1998; Christiansen, 1996; Davis, 1993; Ernest, 1991; Frankenstein, 1983; Gellert, Jablonka, & Keitel, 2001; Skovsmose, 1994a; Tate, 1996).

Progressive educators have long viewed schooling as essential for developing the competencies and dispositions that are needed to create a more democratic and just society. Dewey envisioned classrooms as places where citizenship could be meaningfully practiced as students freely engaged in social inqury, grappling with the unresolved social issues of their time. In bringing disciplinary knowledge and democratic values to bear on deliberations of these issues, youth develop, in part, the capacities and dispositions needed for present and future participation in political life.

The insights that mathematics can contribute to an understanding of societal problems are lost on many U.S. high school students, however. "What good is this stuff?" is a question they too often ask their teachers about the mathematics they are learning (Research Advisory Committee [RAC], 2000). This is not surprising given that school mathematics is a subject that traditionally has been divorced from the problems of society (Frankenstein, 1989; Gutstein, 2003).

Two important documents for mathematics education address this issue—the National Council of Teachers of Mathematics' (NCTM) (2000) *Principles and Standards for School Mathematics*

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and the National Governors Association Center for Best Practices & Council of Chief State School Officers' (2010) *Common Core State Standards for School Mathematics*. The latter articulated a conception of mathematics proficiency for all students that includes the practice of mathematical modeling described as the ability to "apply the mathematics they [students] know to solve problems arising in . . . society" (p. 7). The former recommended engaging students with mathematics applications that address societal problems, which this study refers to as *socially relevant mathematics applications*.[1] NCTM asserted that "students should be able to use their knowledge to understand societal issues . . . [and] school experiences should include opportunities to learn mathematics by working on problems arising in contexts outside of mathematics" (pp. 65–66).

What do students think about mathematics as a tool for social inquiry when they have had opportunities to use it to investigate societal problems? The desire to answer this question led to my qualitative study of two high school mathematics classes.

## Conceptualizing Mathematics as a Tool for Social Inquiry

Perspectives on the purpose of schools, aims for mathematics education, and the nature of mathematics and society underlie conceptions of mathematics literacy (Ernest, 1991). Of interest to this study is a mathematics literacy rooted in critical theories of education that has been termed *critical mathematics literacy* (Frankenstein, 1990; Skovsmose, 1994a, 1994b). The capacity and disposition to use mathematics as a tool for social inquiry and the ability to reflect critically on its uses are central to this mathematics literacy. The notion of mathematics as both a "tool for critique" and an "object of critique" (Skovsmose & Nielsen, 1996, p. 1261) together with the notion of reflection in relation to mathematics applications (Skovsmose, 1994b; Christiansen, 1996; Gellert et al., 2001) frame this study's examination of students' views of mathematics.

## Mathematics: A Tool for Social Critique

Proponents of critical mathematics literacy argue that despite the social progress of the past few decades, a great deal remains to be done to achieve social justice in the United States and elsewhere. The resources and opportunities available to an individual throughout life and the ways in which others treat the individual continue to depend to a significant degree on the group(s) to which that individual belongs. These social groups exist within unequal, socially constructed hierarchies in which people experience differential access to power and to social goods (Bell, 1997; Young, 1990). Thus, individuals are oppressed or not on the basis of their social group status. The term *oppression* refers to the constraints that significantly influence a person's life chances and choices in an inequitable society.

Oppression in its various manifestations (e.g., racism, sexism, classicism) is systemic, operating through various social mechanisms in societal institutions and the mainstream culture through the actions of individuals. These mechanisms include policies, laws, norms, rituals, and language that disadvantage some groups and advantage others. Largely under the control of dominant groups, they are underpinned by dominant ideologies. In reference to social life, *ideology* refers to a system of ideas that describes and explains it—the way things are and the way they should be. Dominant ideologies appear to serve the interests of all, even as they are used to justify social arrangements favoring dominant groups and thereby, the status quo (Apple, 1990). To illustrate, a dominant ideology in the United States incorporates the belief that the United States is a meritocratic society—that is, upward social mobility with its attendant wealth, status, and power is available to all who work hard and acquire the requisite knowledge, skills, and attitudes. From a critical theoretical perspective, this ideology fails to adequately consider group privilege in explanations of "what is."

For critical theorists, the social mechanisms and ideologies that sustain social injustice are subjects for critique. By means of this critique and actions informed by it, it is possible to transform society in ways that empower the oppressed and improve the quality of their lives. Mathematics and other disciplines are seen as powerful tools for social critique, including "ideology-critique" (Burbules, 1995, p. 53), revealing the contradictions between social ideals and realities. Mathematical inquiries about social inequality can uncover evidence in support of arguments that many problems are due to inequitable social arrangements rather than individual failure (Apple, 1992; Bohl, 1998; Ernest, 1991; Frankenstein, 1990; Gutstein, 2003).

## Mathematics: A Subject for Social Critique

While mathematics is an invaluable tool for social critique, it must also be the subject of critique (Skovsmose, 1994b). Language is not a passive tool for describing social reality; it is also a tool by which social reality gets constructed (Freire, 1995; Giroux, 1997; Kincheloe & McLaren, 2005). The language of mathematics plays a similar role. It not only describes social phenomena but also constructs them (Keitel, 1993; Skovsmose, 1994b). How we view others will depend to a certain extent on the statistics we have read because they have become the language of politics and persuasion. Statistics and other mathematical representations reflect choices and are not "neutral" records of "what's out there" (Frankenstein, 1994, p. 27). This does not mean that they should be dismissed out of hand; rather, they need to be scrutinized. Scrutiny is needed because at times mathematics has functioned as a tool of oppression, used to support hegemonic structures and ideologies or societal myths (Frankenstein, 1994; Gutstein, 2003).

Critical mathematics education scholars posit that mathematics applications are insufficiently scrutinized in large part because of the dominant perception of mathematics as an infallible tool (Ernest, 1991). Borba and Skovsmose (1997) have argued that mathematics operates as an "ideology of certainty" (p. 17) in Western societies, which is to say that mathematics can be applied in virtually any situation, and its use attests to the certainty of solutions. Mathematics does not always provide solutions to real-world problems or results that are certain, however (Borba & Skovsmose, 1997).

Critical mathematics education scholars dispute other beliefs associated with the dominant view of mathematics. They argue that mathematics is not neutral, is value laden, and is not objective (insofar as objective is traditionally construed) in its applications to societal problems. A socially relevant mathematics application typically forces its creator to transform a complex and ambiguous situation into a simpler and more clearly defined mathematical model. It reflects numerous choices that are strongly influenced by disciplinary considerations but also factors in the larger context in which the application is developed and used. As a result, applications necessarily reflect sociopolitical values and agendas and relations of power (Christiansen, 1996; Frankenstein, 1995; Gellert et al., 2001; Skovsmose, 1994b; Tate, 1996). Apple (1992) has argued that mathematics applications in our society are largely dictated by the interests of the economic system in profits and the control of markets and products. They primarily benefit those who already have power in that system. When the attributes associated with the dominant image of mathematics are uncritically ascribed to mathematics applications, mathematics becomes mystified. This may impede a robust critique of mathematics applications by limiting the types of questions that are pursued (Apple, 1992; Davis, 1999; Gellert et al., 2001; Mellin-Olsen, 1987; Skovsmose, 1994b).

## Reflection on Mathematics

For Skovsmose (1994b), reflection on applications of mathematics to real-world problems entails scrutinizing their assumptions, processes, and effects. Applications inevitably embody both mathematical and nonmathematical assumptions. Reflection requires revealing what are often hidden assumptions and evaluating the reasonableness of assumptions and the basis for their selection (Bohl, 1998; Skovsmose, 1994b). Reflection also requires carefully examining the processes involved in an application's development. The mathematization of a problem situation—its transformation into a mathematical formulation—involves various processes. Reflection is needed due to the inherent "problems and uncertainties connected with the transitions" (Skovsmose, 1994b, p. 111) among processes due in part to the different languages they employ (e.g., everyday, mathematical). An ethical and sociopolitical evaluation of the consequences of mathematics' use to address a societal problem is also part of what it means to reflect critically on mathematics in its applications (Christiansen, 1996; Gellert et al., 2001; Skovsmose, 1994b).

In conceptualizing reflection on mathematics as a social problem-solving tool, Christiansen (1996) distinguished between what this study calls *technically oriented* and *critically oriented reflections* on mathematics. Technically oriented reflections focus on the connection between a mathematical application and the problem situation for which it was created. They address such points as whether the application's calculations focus on the right problem and have been performed correctly, the reasonableness of assumptions and methods in view of what was to be mathematized, and the reliability of results obtained. Critically oriented reflections view the mathematics application in a larger context: Whom does it benefit? Whom does it harm? Is it dehumanizing? How mathematics affects the perception of a problem, the purpose of using mathematics in a particular situation, and the functions it performs are also topics for critically oriented reflections (Christiansen, 1996; Gellert et al., 2001; Skovsmose, 1994a, 1994b).

For critical mathematics education scholars, both types of reflections on mathematics applications—technical and critical—are essential. They argue that critically-oriented reflections are frequently silenced or supplanted by technical concerns when mathematical applications are discussed (Christiansen, 1996; Gellert, et al., 2001; Skovsmose, 1994b).

## Research on Students Views of Mathematics as a Tool for Social Inquiry

Critical mathematics education scholars argue that mathematics applications that address societal problems, especially social injustices, are invaluable vehicles for social critique (Brantlinger, 2007; Frankenstein, 1995, 1997; Mukhopadhyay & Greer, 2001; Gutstein, 2000, 2003; Skovsmose, 1994a, 1994b; Tate, 1995; Turner, 2003). A significant finding across studies in the critical mathematics education research literature is that a positive change occurs in most students' perceptions of the utility of mathematics and importance of knowing it and using it as a tool for social justice when they have engaged in social inquiry with mathematics in the classroom (Alexander, 2001; Brantlinger, 2007; Christiansen, 1996; Frankenstein, 1995, 1997; Gutstein, 2003; Tate, 1995; Turner, 2003).

This study adds to this body of work a detailed description of high school students' views of mathematics as a tool for social inquiry in light of their mathematical investigations of societal problems, particularly social justice issues. Furthermore, characteristics of the study's participants set it apart from other settings in which critical mathematics literacy has been studied. Studies conducted in U.S. high school settings are rare (Brantlinger, 2007). In contrast to previous studies, the teachers in this study are not critically oriented researchers or teachers who collaborated with researchers (Brantlinger, 2007; Christiansen, 1996; Gutstein, 2003; Turner, 2003). Collectively, students in this study are more diverse with respect to race, ethnicity, social class, and mathematical achievement and interest than students in previous studies, who were largely from disadvantaged social groups (Brantlinger, 2007; Gutstein, 2003; Tate, 1995; Turner, 2003). The realization of a veritable democracy will require the participation of citizens from both historically advantaged and disadvantaged groups in efforts to achieve social justice (Goodman, 2001). Limiting the contexts in which critical mathematics literacy is promoted and studied marginalizes it as a tool for democratic citizenship.

## Methods

What do high school students think about mathematics as a tool for social inquiry in light of their experiences with socially relevant mathematics applications? To answer this question, qualitative research methods were used for data collection and analysis, as they enable a rich description of the "meaning-perspectives of participants" (Erickson, 1986, p. 121) engaged in educational practices.

A mathematics modeling class and a statistics class were the research sites. They were selected because their curricula included a wide range of applications with respect to mathematics and social content, and they afforded students multiple opportunities to use mathematics to explore societal issues.

## Research Sites

The setting for the mathematics modeling class was a high school located in a large Midwestern city. It is one of the city's elite public schools, located in the heart of the city amid high-rises, townhouses, a public housing project, and businesses. The school draws students from neighborhoods throughout the city. Admission is selective and highly competitive. Selection is based on grades, test scores on nationally normed tests, and race. The school is very diverse, racially and ethnically, less so socioeconomically.

The setting for the statistics class was a public high school in a small Midwestern city. The school was established as a university laboratory school. It draws students from a 40-mile radius within which are the university, several small towns, and rural areas. Although the school is very diverse culturally, the student body is far less diverse socioeconomically and racially. Admission is highly selective and competitive. Selection is based on grades and scores on a nationally normed test. The school is committed to a diverse student body, so race and other demographic factors are also considered in admitting students.

The teacher participants in this study were Ms. Jones, a biracial female (Black and White), who taught the mathematics modeling course, and Mr. Smith, a White male, who taught the statistics course. Both teachers have more than ten years of mathematics teaching experience and are very committed to incorporating socially relevant mathematics applications in their teaching. They developed the applications included in this study.

Student participants were high school juniors or seniors of diverse backgrounds and differing interest and achievement levels in mathematics. Table 1 contains summary information about the students in this study.

## Data Collection and Analysis

Data were gathered through classroom observations, interviews, and documents, including student work and curricular materials. I spent 50 days during the period of December 2003 through May 2004 observing classes during which time students engaged with seventeen socially relevant mathematics applications—nine in the mathematics modeling class and eight in the statistics class. These applications addressed a variety of issues[2] of either the students' or the teacher's choice and incorporated mathematics topics mainly from the advanced algebra and statistics curricula. Many applications dealt with social justice issues.

I conducted interviews with both teachers and all students who consented to be interviewed and were available for interviews: 93% of students (28 out of 30) in the modeling class and 82% of students (32 out of 39) in the statistics class. Interviews were semistructured, guided by a series of open-ended questions about topics of interest to this study. At the same time, they allowed for the pursuit of topics raised by participants. Each interview typically lasted 50 minutes. All interviews and classroom observations were audiotaped.

Student interviews were the primary source of data on students' views of mathematics. Interview data was triangulated with data from classroom observations, students' written work, and teacher interviews. For each mathematics application, students (a minimum of five) were interviewed individually or in groups and written work was gathered from them.

An inductive approach to data analysis, domain analysis (Spradley, 1980) was used to identify patterns in students'

**Table 1.** *Class Profiles*

| *Class Characteristics* | *Mathematics Modeling* | *Statistics* |
|---|---|---|
| Class size | 30 | 39 |
| Grade Level | Seniors | Seniors and juniors |
| Race/Ethnicity | | |
| White | 24% | 74% |
| Asian Pacific | 7% | 21% |
| Black | 33% | 5% |
| Hispanic | 23% | 0% |
| Biracial | 13% | 0% |
| Gender | | |
| Female | 37% | 49% |
| Male | 63% | 51% |
| SES | Mostly from poor and working-class families | Mostly from middle-class and upper-class well-educated families |
| Achievement/Interest | Mostly underachievers with little interest in mathematics | Mixed achievement levels and interest in mathematics; high-achieving students were also taking or had taken calculus |

descriptions of mathematics for each application and then across applications. Its analytic techniques were used to generate "categories of meaning" or "domains," as Spradley (1980, p. 88) referred to these categories. LeCompte and Schensul (1999) described domains as "classes of objects, things, ideas, or events in the real world, or at least in the world as people understand it and perceive it to be" (p. 71). Semantic relationships are used to place items, called *included terms*, in categories or domains that are named by *cover terms*. Thus, a domain incorporates included terms (items that belong to the domain) and a cover term (the name of the domain) linked by a semantic relationship (Spradley, 1980). Spradley (1980) has described several semantic relationships that are useful for categorizing data.[3]

Against the backdrop of this study's conceptualization of mathematics as a tool for social inquiry, the following overarching categories or domains were generated based on the data: (a) benefits of applying mathematics to societal issues; (b) shortcomings—limitations or the potential harm of a socially relevant mathematics application; and (c) evaluation—reasons for evaluating socially relevant mathematics applications and the components of an evaluation.[4] They incorporated students' ideas about mathematics and were generated using Spradley's (1980) semantic relationships—strict inclusion, rationale, and means-end. Table 2 contains examples of the ways in which these semantic relationships were used to create these domains. The included terms in the table are direct quotations from students or paraphrase what they said. I generated the cover terms in the examples.

The three domains and their subdomains (groups of related items within a domain) formed the basis of themes in students' descriptions of mathematics and constitute the study's findings. This study's conception of mathematics as a tool for social inquiry previously discussed allowed for inferences about the ways in which students' views incorporated elements of a critical theoretical perspective on mathematics.

As we turn to the study's findings, it is worth noting that quotations from students are abundant. This decision reflects my belief that the words of research participants are, as Erickson (1986) put it, "the essential core of a report of fieldwork research . . . Without it to instance and warrant one's key assertions, the reader must take the author's assertions on faith" (p. 149).

## Findings

What did students think of mathematics as a tool for social inquiry in light of their experiences with socially relevant mathematics applications in the classroom? All students found mathematics to be an indispensable tool for understanding societal issues. At the same time, they indicated that mathematical inquiries about these issues are inherently limited. Students also emphasized the importance of scrutinizing inquiries—their assumptions, methods, conclusions, and the motives underlying them. These overarching themes in students' views of mathematics are elaborated below.

### Mathematics: A Necessary Tool for Social Inquiry

The vast majority of students (approximately 86.7%) reported that applying mathematics to societal issues was a novel experience for them. We hear from Dominique on this point: "[Before this class] I certainly would've not had half a mind to look at some of the problems we've looked at, mathematically."

In describing the effects of their mathematical inquiries on their thinking about social issues, all students indicated that they expanded their awareness of what is going on in the world. They "opened my eyes" to problems, said Ernesto, while Sara B. remarked that they enabled her "to see what society is really like." Grace reflected that "I've been affected by the things we've studied dealing with affirmative action, racism, class divisions. . . . I appreciated having done it in class, because I got a better understanding [of them]."

Students said that many of the inquiries caused them to think about "what kinds of things constitute fairness" (Claire). Some students indicated that the inquiries confirmed their belief that there is still much about life in the United States that is unfair, while others like William found that the "facts" did not conform to their assumptions about the world:

> *Well, they [various inquiries] kind of leave me with a general feeling that a lot of things aren't fair that I always thought were. So you tend to question a lot more things that go on in life—you say . . . what's that doing to other people?*

Why did students find mathematical inquiries about social issues compelling? They proffered the following reasons, which are

**Table 2.** *Semantic Relationships in Student Descriptions of Mathematics*

| *Semantic Relationship* | *Included Terms* | *Form* | *Cover Term* |
|---|---|---|---|
| Strict Inclusion | Math is "objective" | Is a kind of | Benefit of applying mathematics to societal issues |
| Strict Inclusion | Math "oversimplifies" issues | Is a kind of | Shortcoming of applying mathematics to societal issues |
| Means-end | "Check any assumptions made" | Is a way to | Evaluate applications |
| Rationale | "If you just change what you do with the data, that same data can be used to make sometimes even opposing arguments" | Is a reason for | Evaluating applications |

discussed in turn: (a) mathematics furnishes evidence that supports (or challenges) assertions, (b) mathematics is an objective tool, and (c) mathematics provides a compelling justification for individual and societal beliefs and actions.

**Proof.** All students indicated that mathematics can help us see things in the world as they are. As Marcus stated, "With math you can actually see through things . . . to get to the truth." Mathematics provides the "hard facts" (Lilly) and thereby validates (or disconfirms) assertions about social issues. The following quotation from Alison illustrates this point:

> *When I can quantify something, that really helps me to see, "Wow, there really is a problem." You might have a vague sense that that's not right . . . , but when you have numbers to back that up and [can] say this is not what should be happening here, that really helps.*

The vast majority of students at both research sites (approximately 76.7%), used the words *evidence* or *proof* to describe the contribution of mathematics to social inquiry. Lilly's reflection on the class' inquiry about the death penalty was typical: The inquiry "prove[d] a point, that there's something wrong with the way the death penalty works." Students referred to their inquiries' findings as "concrete evidence" (Ming).

Notwithstanding their use of the words *proof*, *truth*, and *conclusive* to describe their mathematical inquiries, several students (approximately 38.3%) pointed out that one can never be certain that the conclusion of a mathematical inquiry about a social issue is true. Jay explained:

> *For all the procedures in statistics there's always a certain grain of uncertainty. You never can have no error in hypothesis testing, like a significance level of zero. So when we'll reach a conclusion, we always can say . . . most likely it's true, but we're never sure of anything.*

**Objectivity.** The majority of students interviewed (61.7%) used the word *objective* to describe mathematics, asserting that this attribute makes mathematics an essential tool for social inquiry. Students' interpretation of *objective* largely conformed to the everyday meaning of the word—that is to say, unbiased, impersonal, impartial, or unemotional. They noted that there is much about mathematical language that is beyond interpretation and debate, rendering mathematics objective in contrast to everyday language and other disciplinary languages. As Madison noted, "Two is two to everyone." All students indicated mathematics is "very structured" and has a clear-cut set of "rules" (Brooke) for determining what is true in mathematics and what is not. The rules rein in subjectivity, constraining the influence of personal preferences, biases, and emotions on mathematical outcomes. So, all who "do mathematics correctly" (Elena) will reach the same conclusion. When mathematics is properly applied, social inquiry is deemed impartial and its conclusions trustworthy.

Mathematics also offers precision. Students (approximately 13.3%) pointed out that having a sense of the magnitude of the problem is important for understanding it. "You get a better understanding of [the problem] when someone says, '95% of,' instead of 'most' or 'some'" (Sami). A few students (8.3%) pointed out that mathematics tells us the magnitude of the uncertainty of the results it provides. The margin of error, for example, gauges the seriousness of a random sampling error.

Several students (25%) indicated that one of the benefits of incorporating mathematics into social inquiry is that its powerful and versatile tools enable one to make sense of complex information. One of the tools mentioned was chi-square hypothesis testing, which Madison described as "kind of amazing." Blake explained how it "objectively" demonstrates the unfairness of the death penalty:

> *In the case of the death penalty, you would expect the victim distribution [by race] of the people executed for those murders to match the victim distribution [by race] of people murdered, and it doesn't. You can use the chi-square test to see how likely it is for the actual distribution to be that far away from the "fair" distribution.*

Finally, a few students (10%) identified another benefit to social inquiry that accrues from the objectivity of mathematics. Findings made public can be verified by anyone familiar with mathematical tools. As Gian noted, "Somebody will find the error if there is one."

**Basis for Beliefs.** All students indicated that the inquiries in their mathematics classes influenced or challenged, if not changed, their thinking about many of the societal issues explored. Students acknowledged that frequently their thinking about issues is based on "hunches" (Gian), "opinion" (William), or "what our parents think" (Lauren). Lauren echoed the sentiments of her peers in stating, "It's really nice to be able to look at statistics and have more of a, I guess, objective-as-possible way of looking at [a social issue]." Using mathematics to prove or disprove claims about social issues puts their viewpoints about them on firmer footing. Dominique's reflection on her class's inquiry about the location of toxic waste dumps in her city illustrates these points:

> *When I first heard about this toxic waste problem, my first instinct was to say, "I can answer this easily. Of course it's a racial thing. That's the only thing it can be." I think, the worst assumption I made was thinking that I could forget about the facts and the numbers.*

Students' descriptions of mathematics also evidence their awareness that mathematics is authoritative in our society. All students indicated that it is a powerful tool of persuasion, one that can be used to convince others (as well as oneself) of what to believe or do. A proposition is generally deemed more credible when it is supported by quantitative data. In Alison's words, "People are more likely to believe something if there are numbers to back it up. And I think that that is the biggest power that it has."

Students saw the value of using mathematical analysis as a basis for deliberations about societal problems. Noah's comment was typical: "You can't argue with correctly done math" because it provides a "solid piece of evidence" that a policy or law is or is not working. Students asserted that without quantitative data there is less likely to be consensus about the need to change or maintain a policy.

## Mathematics: An Insufficient Tool for Social Inquiry

Students indicated that mathematics is an inherently limited tool for social inquiry, even as it is a valuable tool as previously discussed. They proffered the following shortcomings of a mathematical inquiry about societal problems: (a) it is reductive and impersonal, (b) it provides inadequate explanations for problems, (c) it is irrelevant for moral arguments, and (d) it is inaccessible to the general public.

**Reductive and Impersonal.** In a mathematical inquiry, messy and complex societal issues are mathematized, transformed into simpler mathematical problems that can be solved. An issue is likely to be "oversimplified" (Alison) when mathematized. Therein lies an inquiry limitation. All students expressed doubt that a mathematical inquiry is capable of taking all relevant aspects of a social issue into account. In part, this is because, as Gabriel noted, "Not everything [about an issue] can be reduced to numbers."

Students acknowledged the difficulty of getting a mathematical inquiry right. For example, a rigorous examination of the fairness of the death penalty requires analyzing the complicated legal process that ensues between the commissions of murders and the executions of murderers. Students pointed out that the class's conclusions that the death penalty is a racially discriminatory practice would have been better substantiated had their inquiry incorporated additional factors. Students also acknowledged that a more comprehensive inquiry is likely to require more sophisticated mathematical tools than those taught in high school mathematics courses. Even so, students emphasized that it was unlikely that one inquiry could incorporate all relevant factors.

Additionally, many students (35%) indicated that a consequence of the application of mathematics to social problems is its simplification and objectification of human beings. An individual is reduced to a single statistic or a handful of attributes (e.g., race or gender) which William, among others, found worrisome: "People are so complicated. . . . You can't pick one thing to say represents a person. That's what makes it difficult for me."

Students (20%) indicated that the impersonal nature of mathematics can put us at a distance from social problems whereas personal stories help connect us to them. They spoke of the need to "leave the mathematics behind," as Zachariah put it, and reach out to individuals to hear their stories in order to better understand these problems.

**Inadequate Explanations.** For many students (approximately 38.3%), a mathematical inquiry about fairness lacks adequate explanatory power. Mathematics can help us identify social problems, but it cannot tell us why the problems exist, let alone what can be done to solve them. Noah made this point in reflecting on his investigation of the body image of students at his high school: "We found out that there is a positive trend of lots of dissatisfaction among girls, but that doesn't tell me why it is and that doesn't help me try to figure out how it could be reversed." In the following interview excerpt, Lauren indicated what other type of inquiry might be needed to help explain racial disparities in the special education classes in her town:

> *I really think that one of the things . . . would be to talk to a lot of people in that town . . . to try to understand what's going on behind that number. So while the statistics would still really be useful, it would just be a starting point.*

**Irrelevance for Moral Arguments.** Many students (46.7%) indicated that societal problems raise moral concerns and that mathematics is an irrelevant tool for addressing them. Some students challenged the implication of cost-benefit analyses that numbers should dictate actions commensurate with their magnitude or statistical significance. Why should some be denied care or resources because they are so few in number? Eric was one of these students:

> *When we were talking about [government-subsidized prenatal care], it would've been cheaper to just let the weak die, and then we wouldn't have to take care of 'em. But it's not very ethical. Math isn't ethical. It's just the hard facts . . . but as humans we're caring.*

Some students talked about the irrelevance of mathematics for what they perceived to be moral issues at the core of environmental policies and in social policies, such as the death penalty, which were the subject of their classroom inquiries. The following excerpt contains Noah's reflection on what he saw as an ethically questionable use of mathematics in the regulation of environmental hazards. He challenged the notion that the regulation of toxic substances is simply a matter of adopting levels pronounced safe by conventional scientific standards. In Noah's view, the risk of harm is too high.

> *The EPA has made this specific level, saying you can't have any more mercury than this. . . . If you're at 24 parts per million, you're OK, but if it's at 25 parts per million, you get arrested. . . . When you're talking about issues where morality is involved, if you use math, then it could become too easy to become disjointed from the subject and what's at stake. And if you do that then you can make mistakes that, while legally or mathematically sound, would be morally abhorrent.*

Students' reflections on the class's death penalty inquiry suggested that even if everyone agreed on the "facts" regarding the application of the death penalty in the United States (e.g., race is a factor in executions), the empirical evidence alone would not resolve the debate. One could always argue that the evidence suggests that the death penalty should be reformed, not abolished. Moreover, even if all the flaws in the administration of the death penalty were eliminated, one could still oppose or support the death penalty on other grounds, such as moral grounds. "None of the statistics would be relevant if you wanted to say, I think the death penalty is wrong because I just don't think you [the state] should kill people ever" (Blake). One could justify support of the death penalty on the grounds that "murderers deserve to die" (Sanjit) "to get justice for the murdered victims" (Emma), or because "death is a less cruel form of punishment than life in prison" (Gabriel).

**Inaccessibility.** Some students (15%) noted that mathematical arguments about equity issues are unlikely to be widely understood by or potentially convincing to all citizens. As a result, mathematics serves to constrain the participation of individuals in deliberations about social issues where these arguments are advanced. Most people have no choice except to rely on the critiques of experts.

## Judging Mathematics Applications

All students indicated that the conclusions of mathematical inquiries should not be accepted at "face value" (Madison). Rather, they ought to be accepted (or rejected) pursuant to one's "judgment" (Gerry) of the merits of the inquiry. Judgment is required because, in Elena's words, "there is not a set way to use mathematics to investigate a social problem." Furthermore, people can make choices that are self-serving, support their preconceived beliefs, or promote a political agenda.

Students identified the following five elements of mathematics applications as subjects for scrutiny. Representative comments about these elements and the percentage of students who mentioned an element are provided.

(a) Factors relevant to the social problem that are incorporated in the inquiry (100%).

Blake stated, "What things they were taking into account and what things they weren't taking into account. I think it's important to know these things."

(b) Definitions of concepts and their mathematical representations (approximately 71.7%).

A lesson learned from their inquiries was that opposite conclusions can be drawn from inquiries that incorporate different mathematical representations of concepts like fairness. Blake reflected on the class's death penalty inquiry:

> *You can conclude a situation is fair or not fair depending on how you define fair. . . . We showed that the death penalty was biased against African Americans when we compared the racial distribution of people on death row to that of the US population. However, we found that the death penalty was biased against Caucasians when we compared the racial distribution of people executed to that of people on death row. I find it interesting, and disturbing, that we could use two reasonable definitions of fairness to make radically different conclusions regarding the death penalty.*

(c) The data used and how it was collected and organized (approximately 78.3%).

In a joint interview, Adam and Matthew reflected on how data classification schemes can easily serve the agendas of those in power:

> *Because chi-square hypothesis testing and ANOVA statistics depend on the number of groups and the separation of numbers between groups, you can basically use the same number of people and classify them arbitrarily . . . to come up with whatever you want. (Adam)*
>
> *Historically, White people have been in power, and they classified people who weren't completely White as the "other" group. (Matthew)*

(d) The procedures used to analyze the data and their underlying assumptions (100%).

Brian noted that one needs to "make sure that the assumptions to use those methods are true." Milos reflected that "If you just change what you do with the data, that same data can be used to make sometimes even opposing arguments."

"There are definitely different ways of looking at the data and manipulating it to your argument," said Linh, who, like many of his peers, used words such as *manipulated* and *distorted* to describe the use of mathematics in this way.

(e) The conclusions and interpretations drawn by the inquirer (56.7%).

Students indicated that ignorance of mathematics or biases of the inquirer can influence the interpretation of inquiry results. Christopher reflected on how individuals could cherry-pick the findings of the class's mathematical inquiry about the death penalty to support the claim that there is no bias in its application:

> *White murderers were executed more often than Blacks. So, you could take that and say it's not really racist. But then when you look at the victims, it was the murderers of White victims who were more likely to be executed.*

Finally, all students indicated that mathematics can be used for good or ill. We hear from Ernesto on this point:

> *Some people are using their knowledge of math to inflict harm. They're creating weapons of mass destruction. Other people are saying, "I'm gonna use my knowledge to try to cure cancer." They're trying to use mathematics to do good. And it just shows that how math is used, all depends on the person.*

So, students argued, the motives and interests of developers or users of mathematics applications should be carefully examined to determine how (if at all) they stand to benefit from them and what we stand to benefit (or lose) from them.

## A Critical Perspective on Students' Views of Mathematics

Critical mathematics education scholars argue that mathematics is an essential tool for exposing social injustice because of the relevance of quantitative information to justifications of social policies and practices in contemporary society. All students reported seeing the value of thinking mathematically about social justice issues as a result of their classroom inquiries. They indicated that their inquiries uncovered compelling evidence of the differential effects of social policies and practices on various social groups. Critical mathematics education scholars argue that such evidence can indicate a systemic failure of our society to provide justice for all and that it implicates various forms of oppression as the underlying causes of these failures. Students largely agreed with this interpretation of group disparities revealed by their inquiries. Although they do not "prove" social injustice, students overwhelmingly (90%) said their inquiries clearly implicate racism, sexism, classicism and other forms of oppression as the causes of the disparities. Even students who did not agree with these implications indicated that their findings alert us to potential problems that ought to be investigated further.

Thinking critically about mathematics use as a tool for social inquiry entails thinking about mathematics in ways that challenge what Borba and Skovsmose (1997) referred to as an "ideology of certainty" (p. 17) about mathematics. Students' reflections on mathematics indicated that they contested many aspects of the dominant view of mathematics. Students challenged the belief that mathematics provides definitive answers to questions about the world. They noted that the certainty of conclusions of mathematical inquiries is frequently constrained by limits of confidence. They viewed their mathematical inquiries as an important beginning rather than an end to inquiry about the fairness of societal practices. While they expressed confidence in their conclusions, they saw them as provisional truths. They argued that because many social problems are very complex, they would probably need to weigh the evidence from several inquiries to obtain conclusive answers about them.

Students did not see mathematics as answering some important questions that might be asked about social practices. Although mathematics can tell us how the death penalty is working, it cannot in and of itself settle the larger question of whether we should have one, students said. Nor can mathematics tell us whether institutions should adopt affirmative action policies, whether wealth should be redistributed, or whether risks in the use of nuclear power are worth taking, and so forth. These students recognized that technical questions should not be conflated with sociopolitical and ethical questions in deliberations about societal problems.

Students problematized the objectivity of mathematics in its applications. They indicated that mathematical inquiries about social issues cannot be "entirely objective" (Gabriel) because people "put part of themselves in the math" (Matthew). All students reflected that there is often more than one way to mathematize problem situations. Furthermore, the transformation of many issues into a mathematics problem that can be solved is not unproblematic, as Dinesh reflected:

> *There's always an absolutely correct way to do things in math. That's what's really great about math. But then you have the problem of applying math to the world and then applying what you know about issues of fairness and social inequality to math. That's where things get muddled. . . . It's about that transition [between the real world and the math world] that you have to be careful of.*

His reflection embodies an element of Skovsmose's (1994b) rationale for reflecting on applications: the "problems and uncertainties connected with transitions" (p. 111) between the different languages involved in the processes used to develop the application.

Students demonstrated an awareness that mathematics applications incorporate the values and interests of their creators. As a result, they can be tailored to serve political or personal aims. A few students connected these aims to social groups and the larger sociopolitical context in which mathematics applications operate.

The questioning of mathematical knowledge and its uses is foundational to a mathematics literacy that is "critical." All students mentioned that their classroom experiences impressed upon them the importance of closely examining a mathematical inquiry before deciding whether to accept its claims as true. Alison's reflection was typical:

> *I never bothered to think about whether statistics I was told were accurate or not. You know, numbers can't lie. And now I realize that's not correct. You have to think about where these numbers are coming from and can we really trust them?*

In viewing people as the final judges of a social inquiry, students contested a dominant myth of mathematics as an "above-all referee . . . one that is above humans" (Borba & Skovsmose, 1997, p. 17). At the same time, they reflected that mathematical arguments are not likely to be understood by most citizens, echoing Skovsmose's concern that the use of mathematics limits the number of social critics of a mathematics application.

## Conclusions

This study contributes to the research literature a rich description of high school students' views of mathematics as a tool for social inquiry. It evidences that students who have multiple experiences applying mathematics to social justice issues find mathematics to be a compelling tool for social critique, albeit one with limitations. It also shows that students develop a less mystified view of mathematics. Students neither outright reject nor uncritically accept applications of mathematics to societal problems and the notion of mathematics' utility as a social problem solving tool. They recognize the importance of scrutinizing mathematics applications and demonstrate an understanding of what scrutiny requires.

This study has implications for a high school mathematics curriculum that aspires to promote conceptions of mathematics that will benefit students and society. More opportunities for students to express their views of mathematics in the classroom are needed. The students in this study clearly had ideas about mathematics that were grounded in their classroom experiences. While the students articulated them eloquently during interviews, these ideas seldom received an airing in the classroom. This is the norm in mathematics classrooms: The nature of mathematics is typically not something U.S. high school students are asked to reflect upon (Kloosterman, 2002). Teachers need to know their students' epistemic assumptions about mathematics in order to design activities that enrich their conceptions of mathematics and challenge any mystified views they may have.

If schools are truly places where students are prepared for citizenship, then mathematics classrooms must be places where students learn about the role of mathematics in society. Activities should engage them in reflection about the benefits and limitations of using mathematics to address societal problems and on the impact of mathematics applications on our lives. Engaging them in more activities where they experience the use of mathematics as an instrument of social change is another way to better prepare students for informed and active citizenship.

This study has limitations that suggest topics for future research. While it examined an important dimension of students' mathematics literacy—their views on mathematics as a tool for social inquiry—it did not examine other important aspects of mathematics literacy and their relationship to students' views. A topic for future research is whether socially relevant mathematics applications promote high mathematics achievement. This is an important question for secondary mathematics teachers who see the development of students' mathematics knowledge as their primary responsibility, particularly at a time of national concern about the underachievement of U.S. students. Another topic for research is a systematic examination of how socially relevant applications shape views of mathematics.

I believe that the classes in this study give us reason to be hopeful about the possibilities of socially relevant applications for mathematics education. So did the remarkable teacher participants in this study. I leave the last word to them.

> *I'm pleased with the extent to which . . . most of them would attempt to really understand what was going on in the problem as opposed to this pressure to just get the right answer, which is the pressure that they get from the test mentality everywhere else. I think they were genuinely curious about many of the things that we did during this year. (Ms. Jones)*

> *I think it made them a little bit more skeptical about reading an article or hearing a talking head on the radio . . . spouting off a statistic, that they are maybe a little more leery of accepting that. They began to ask questions about . . . why does it matter that this is unfair? What can be done about this injustice? Why doesn't somebody do something about it? I was pleased that they were doing that. (Mr. Smith)*

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## Notes

1. The term *socially relevant* is borrowed from Atkin, Kilpatrick, Bianchini, Helms, and Holthuis (1996), who use it to describe a type of pedagogy for mathematics and science. Their "socially relevant pedagogy" incorporates applications of mathematics and science to problems of society.

2. The issues explored include (but are not limited to) the death penalty, affirmative action, income distribution in the United States, toxic waste disposal, pollution, global warming, school funding, adolescent body images, community attitudes toward gay marriage, distribution of scarce resources, social service organizations' use of statistics, and social group disparities in special education.

3. Spradley's (1980, p. 93) nine semantic relationships for domain analysis are listed below. In each relationship, X represents an included term for a domain and Y the cover term for the domain:

Strict Inclusion: X is a kind of Y
Spatial: X is a place in Y
Cause-Effect: X is a result of Y
Rationale: X is a reason for doing Y
Location-for-action: X is a place for doing Y
Function: X is used for Y
Means-End: X is a way to do Y
Sequence: X is a step in Y
Attribution: X is a characteristic of Y

4. Dozens of domains incorporating students' descriptions of mathematics were generated during the initial phase of domain analysis. Several of Spradley's (1980) semantic relationships were used during this phase: strict inclusion, cause-effect, rationale, function, means-end, sequence, and attribution. Domain analysis continued with the goal of identifying fewer, more comprehensive categories. This involved searching for connections among the existing domains that would enable larger domains (extant or newly created) to subsume smaller domains. The creation of the study's three overarching domains during the final phrase of domain analysis was also informed by a comparison of included terms within domains with an eye on their differences.