# Mathematics and the World: What do Teachers Recognize as Mathematics in Real World Practice

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Abstract
Elementary school teachers are encouraged to better integrate appropriate mathematics pedagogy with deeper, more relevant mathematics content. However, many teach a mathematics they do not fully understand to students who see, recognize, and use less mathematics than ever before. Both teachers and students struggle to articulate the role mathematics plays in society as mathematics becomes more embedded into our technology. In this study, we asked teachers to record the mathematics they used on a daily basis during a 1-week period. Their responses indicate that they do not recognize that mathematics plays any important role in technological and professional practices. This negatively impacts their ability to effectively teach mathematics in the elementary classroom because they cannot make connections between classroom practices and real-world uses of mathematics.

Keywords: mathematical beliefs; mathematics pedagogy; mathematics content; mathematical literacy; pre-service teacher education; real world mathematics

**Introduction**

As American society becomes more technologically reliant, the actual, day-to-day use of mathematics diminishes (Noss, 2001; Skovsmose, 2005). The application of mathematics is less obvious (Skovsmose, 2005) and less understood (Friedman, 2005; Schiesel, 2005) by K-8 classroom teachers and their students. Thus, many teachers teach a mathematics they do not fully understand to students who see, recognize and use less mathematics in their lives than ever before (Hastings, 2007, February 2).

"School mathematics" (Gerofsky, 2004) is defined as a interconnected set of content knowledge (including numbers and operations, algebra, geometry, measurement, and data analysis)

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and cognitive process skills (including the ability to use content knowledge and conceptual understanding to reason, solve routine problems, develop proofs, and effectively communicate, represent, and model mathematical ideas) (Mulls, Martin, Gonzalez, & Chrostowski, 2004; National Council of Teachers of Mathematics, 2000; 2006). In practice, mathematics curricula stress the importance of linking school mathematics, often presented as a static, predetermined body of knowledge, to the flexible and changing realities of students' daily lives, as a way of connecting academic mathematics to contextual and/or practical realties and understandings (Desimone, Smith, Baker, & Ueno, 2005; Graeber, 1999; Hannaford, 1998; Nasser, 2005; National Council of Teachers of Mathematics, 2000; 2006). K-6 teachers try to explicitly tie mathematics to the world of their students (Delpit, 2006; National Council of Teachers of Mathematics, 2000; Reys, Lindquist, Lambdin, & Smith, 2007) as they look to make realistic connections between mathematical rules and algorithms and the events children participate in on a daily basis.

Yet teachers often struggle to respond to students' (and even some parents') frustrations that they rarely, if ever, use the mathematics they learn in school. The assumption that mathematics is fixed body of knowledge that offers clear-cut answers to numerically-based problems precludes recognition that mathematics is a creative and experimental tool that explicitly informs planning, organizing, and ethical decision making within specific constructs (Bakalar, 2006; Bishop, Clarke, Corrigan, & Gunstone, 2006; Delpit, 2006; National Council of Teachers of Mathematics, 2000). Formal mathematics is associated with scientific, technological, and engineering practices and there is little understanding that important mathematics is embedded in many professions not usually associated with mathematical understanding (Barton & Frank, 2001; Lesser & Nordenhaug, 2004; Masingila, 1996; Mewborn, 1999; Nicol, 2002; Rauff, 1996; Sithole, 2004; Zlotnik & Galambos, 2004). Therefore, many teachers do not appreciate the practical utility of many topics they teach (FitzSimons, 2002; Gutstein, 2006; Mukhopadhuyay & Greer, 2007) and are ambivalent about the necessity of teaching mathematics (Mewborn, 1999): teachers neither understand how mathematics serves professional practices nor do they recognize that the ability to conceptualize mathematical thinking outside of the classroom is an important skill for their students (Gainsburg, 2006). Thus, the students themselves have a limited appreciation of the intersection of mathematical understanding and ability with the other areas of curriculum or real-world tasks (Iverson, 2006; Mudaly, 2007).

**Mathematics in Society**

Certainly, the role of mathematics in society is changing. The more that technology impacts and influences our daily lives, the less mathematics is visible (Iverson, 2006; Noss, 2001; Oers, 2001; Skovsmose, 2005). While mathematicians, scientists, and engineers recognize that technological advances require a deep understanding of mathematics (Tate & Malancharuvil-Berkes, 2006), societally, we do not explicitly "see" the mathematics nor do we perceive when mathematics is used on a daily basis (Bishop et al., 2006; Empson, 2002; Gainsburg, 2006; Mudaly, 2007). The implicit use of mathematics is ubiquitous in the United States (e.g., bar codes that monitor inventory, global positioning systems, fast food restaurant cashier counters that display pictures of food items instead of numerals), yet these embedded uses of mathematics obscure explicit uses of mathematics. Even the recent NCTM *Curriculum Focal Points* (National Council of Teachers of Mathematics, 2006) fails to directly address this. While calculator and computer use is encouraged, to help students visualize, explore, and manipulate a variety of mathematical ideas and representations, there is no discussion regarding helping students recognize the important mathematics that underlies the design, development, and maintenance of the technological supports they are using. Therefore, it becomes difficult to explain to children (and, often, to teachers themselves) that the mathematics that is responsible for innovations, advances, and creative technological practices depends on the elementary concepts and building blocks of basic mathematics and arithmetic (Hastings, 2007, February 2). Additionally,even when mathematics is explicitly used professionally or vocationally, the mathematics taught in the K-8 classroom ("school math") often does not mirror the math used in occupational practices (Gerofsky, 2006; Masingila, 1996; Shockey, 2006; Tate & Malancharuvil-Berkes, 2006). Oers (2001) suggests that school mathematics is the activity of participating in a mathematical practice. What happens, then, when students and their teachers do not recognize that they are participating in mathematical practices?

The goal of mathematics education for pre-service teachers focuses on ensuring that they understand the basic mathematics concepts they will teach (Dahl, 2005; Graeber, 1999; Hagedorn, Siadat, Fogel, Amaury, & Pascarella, 1999; Hannaford, 1998; Hill, Rowan, & Ball, 2005) and have access to developmentally appropriate pedagogy and practices (Dahl, 2005; Donnell & Harper, 2005; Gerofsky, 2004). Additionally, it is hoped that they recognize connections between "school math" and daily practices (e.g., calculating unit cost or interpreting a graph or chart in the newspaper) (National Council of Teachers of Mathematics, 2006). Yet little attention is paid to ensure that educators acknowledge implicit and/or embedded mathematical practices that are part of daily life, professional practices, and technological underpinnings beyond the connections made in textbooks (Reys et al., 2007; Sheffield & Cruikshank, 2005).

It is recognized that equitable societies ensure that all students have appropriate, high level mathematical knowledge (Empson, 2002; Hannaford, 1998) because it is this knowledge that allows citizens to participate effectively in the democratic, decision-making process that guides the future of the nation (National Council of Teachers of Mathematics, 2006). Also, students need an explicit mathematical vocabulary and a philosophical framework within which mathematical knowledge can be questioned and understood in order for the mathematics to have deep meaning (Iverson, 2006; National Council of Teachers of Mathematics, 2006). In the United States, some curricula have been developed that tie classroom mathematics to social justice issues (National Council of Teachers of Mathematics, 2006) and concerns that reflect the lives of students, their families, and their communities (Braver et al., 2005; Gutstein, 2006; Gutstein & Peterson, 2005; National Council of Teachers of Mathematics, 2006); these are to be applauded. These curricula and lesson plans illustrate how mathematics is embedded into the political and economic fabric of our society, such as issues that perpetuate social injustices in terms of immigration policy, inequitable taxation, and gentrification of inner-city neighborhoods (Grant, Kline, & Weinhold, 2002; Gutstein, 2006; Gutstein & Peterson, 2005; Lesser & Nordenhaug, 2004; Mukhopadhuyay & Greer, 2007). However, they do not routinely explore the "hidden" mathematics included in, for example, computer design and architecture, product standardization, advertising graphics, organizing seasonal game schedules for a sports leagues, and health policy decision-making. While social justice education in the mathematics classroom helps students consider vocational and professional options, neither students nor most teachers are able to articulate how the "school mathematics" taught in elementary and middle school translates into important, implicit, and embedded mathematical knowledge that is used in professional practice in technical and non-technical fields. Yet, when teachers are able to make these connections, there is evidence that students 1). begin to recognize the role of mathematics in technology, innovation, planning, and decision-making (FitzSimons, 2002; Hannaford, 1998); 2). recognize the social justice impacts of mathematical knowledge (Braver et al., 2005); and 3). understand that mathematics is more than just a "right answer" (Gerofsky, 2004; Gutstein, 2006; Mudaly, 2007; Mukhopadhuyay & Greer, 2007).

Thus, K-6 teachers may limit or omit discussions of embedded mathematics because 1). they may be unable to recognize these implicit practices; 2). they may not even be aware that such mathematical practices exist; 3). their teacher preparation programs did not stress these connections; 4). they may be mirroring the practices of their own K-6 mathematics education; and/or 5). the textbooks they use in their classrooms do not focus on these connections. Yet if the teachers themselves were able to reflect on implicit or embedded uses of mathematics, whether or not they fully understand how the mathematics is implemented, it is arguable that they could discuss the breadth of usage of mathematics in our society. If teachers do not recognize the many ways that mathematics is embedded into our daily lives, then, regardless of the depth of their mathematical content knowledge, they may be unable to help students make connections between school mathematics and the reasons for studying the mathematics.

While much literature has addressed teachers' mathematics content knowledge (Empson, 2002; Gerofsky, 2006; Graeber, 1999; Hill et al., 2005) and their understanding and utilization of appropriate pedagogical practices (Iverson, 2006; Lesser & Nordenhaug, 2004; Mewborn, 1999), little if any work has explicitly explored what mathematics K-6 teachers recognize as inherently mathematical outside of the K-6 classroom. While several reports have speculated about teachers' inability to connect classwork to actual practice (e.g., FitzSimons, 2002; Gerofksy, 2004; Gutstein, 2006), there is no empirical evidence supporting this contention. This study addressed those concerns directly in an initial attempt to understand what teachers recognize as mathematics. Specifically, preservice and practicing teachers (collectively referred to as "teachers" in this paper) were asked to identify and articulate their recognition of mathematics usage in their daily lives in a typical week. This analysis of the mathematics they reported addresses the main areas of their mathematical recognition and acknowledgment: how much and what types of implicit or embedded (not readily visible) mathematics they acknowledge; and what does their recognition of specific types of mathematics implies about their understanding of the need for and utilty of mathematics in the K-6 mathematics classroom.

**Methods and Data Sources**

*Participants:*

Participants were teachers (n=28) enrolled in one of two Introduction to Research courses as part of a graduate-level Masters of Education program at a regional university in the northeastern United States during the Spring of 2006. Eleven students were licensed and certified teachers and had been or currently were elementary school teachers; seventeen were completing initial licensure and certification. All held a Bachelors degree in Social Science (n=16), Science or Engineering (n=6), Education (n=4) or Accounting (n=2). Twenty-three had completed three years of high school math, including Algebra, Geometry, Trigonometry and Advanced Algebra. Sixteen had continued their high school mathematics for another year to include pre-calculus or calculus. Only two reported no high school coursework in mathematics. Fifteen completed college level calculus courses (n=9) or algebra/statistics courses (n=6). One calculus student and one algebra student also completed a mathematics methods course designed for prospective K-6 mathematics specialists. Four others completed at least one of two mathematics content courses designed for prospective teachers during which they developed an understanding of the NCTM mathematics curriculum.

*Data Collection:*

We began with an in-class discussion of overt, explicit, covert, implicit, and embedded mathematics that we use on a daily basis to ensure that all participants shared a common understanding of "mathematics" and "mathematical encounter." Teachers shared examples of the explicit and overt mathematics they used and recognized, such as balancing checkbooks and measuring recipe quantities. They also discussed how mathematics is implicit and embedded in much of today's technology. Many straightforward uses of technology were identified (e.g., how computers translate bar codes and magnetic stripes to digital and electronic pulses that are recognized by electronic circuitry). Teachers also recognized less common uses of mathematics embedded in modern technology. These included traffic management protocols, digital communication optimization, and many manufacturing techniques. The conversation also included discussion of the content and process standards that are incorporated in school mathematics (National Council of Teachers of Mathematics, 2000). These examples were not meant to be inclusive; teachers were encouraged to use these examples as models and exemplars to guide their identification and recognition of mathematical practices. Thus, "mathematical encounters" were defined as any recognized, concrete, mathematical event that the teacher participated in (e.g., preparing a budget) or observed (e.g., watching a cashier make change or a carpenter review a blueprint). Teachers were asked to also report their own thoughts and questions about mathematics and mathematical practices. Both the concrete events and the mathematical speculations were defined as "mathematical encounters." Teachers were asked to carry a notebook and record all mathematical encounters, including repetitive mathematical events, during the data collection period.

Using the classroom discussion as a starting point, the teachers spent seven days monitoring their recognition, practice, and use of mathematics. This allowed them to report the mathematics used on their jobs as well as mathematics that they identified during their personal time, as well. They were able to capture mathematics used professionally, vocationally, and avocationally, as well as mathematics used to maintain their household and mathematics used during leisure time activities. It was recognized that students' daily lives and activities were different and would not produce similar lists of mathematical encounters. To control for these possibilities, the researchers examined the individual scenarios presented by the teachers in their journals to identify what other mathematics could have been reported in the individual scenario. For example, a student discussed the gas pump at the gas station that keeps track of the gallons pumped and the total cost of the gas yet did not mention the pumps capacity to maintain a constant inventory or the ability of the pump to monitor the flow of the gas to the car.

*Data Analysis*:

This study was a qualitative analysis of the mathematics that the practicing and preservice teachers recognized and recorded in their journals. We explored the following questions:

1. What types of mathematics did the practicing and preservice teachers recognize and/or use in their daily lives?
2. What types of mathematics were not recognized and/or acknowledged?
3. What are the implications of teacher mathematical recognition for K-6 teacher education?

Journals were collected and entered into a data base that allowed us to manipulate and categorized their thoughts and ideas utilizing NVIVO (QSR International, 2006). Constant comparison, as a basis for theory development, was employed to identify core properties of mathematical descriptors and mathematical understanding (Charmaz, 2006; Creswell, 2007) to allow us to create matrix that illustrates teachers' understanding of the interplay between school mathematics and real world practices.

Within each journal entry, individual mathematical items identifying content and/or process were identified and entered into the database as individual records. Entries that illustrated similar ideas were collected into *topic groups*. Topic groups were sorted and organized into one of nine shared *categories*. Categories were classified into one of four overarching *classes*. Topic groups, categories, and classes were all generated from the journal entry data and were not pre-identified or pre-conceived.

**Results**

In order to articulate a coherent model of teacher understanding of the connection between K-6 mathematics teaching expectations and mathematical practices in real world contexts, a multilayered data structure was employed (Bazeley, 2007; Charmaz, 2006). Individual mathematics encounters were organized into 30 different *topic groups*; each topic group described similar events and observations, such as driving (distance, speed, mileage), price comparisons, and budgeting, spatial relationships. Topic groups were collected into nine *categories*. Members of each category shared an underlying utilization of mathematics in practice (e.g., use of algorithms, decision making). Finally, four *classes* were developed from the categories, reflecting a hierarchical model of mathematics use and recognition (see Table 1). All individual mathematical encounters reported in the journals were included in the analyses. Mathematical encounters that reflected more than one mathematical encounters were placed in the "highest" level of mathematics reported.

Table 1
Categories and Classes of Mathematics

| CLASS | Non-Mathematics | Counting and Calculation | Estimation and Planning | Embedded (Implicit) Mathematics |
|---|---|---|---|---|
| CATEGORIES | 1. Number Recognition<br>2. Dialing Telephone | 1. Counting<br>2. Algorithms<br>3. Allocation (Budgeting) | 1. Comparisons and Decision Making<br>2. Logistics (including Spatial Relationships) | 1. Mathematics /Technology Interactions<br>2. Pattern Recognition |

*Identification of Mathematics:*

Student journals included bulleted lists, individual sentences, or short paragraphs that outlined a mathematical description or speculation about mathematical practices. These constituted the individual "mathematical encounters" that were categorized. In the seven-day period during which teachers recorded their recognition of mathematics-related phenomenon, based on the definition of mathematics that they developed in their class, 27 teachers ($N_{(male)} = 9$, $N_{(female)} = 18$, one student did not complete the mathematics diary)) identified 695 mathematical encounters (Table 2). Women reported 2.3 times as many mathematical encounters as men, which is consistent with the fact that twice as many women as men participated in this study.

Table 2
Mathematical Encounters

| | **Male**<br>**# of reference (%)** | **Female**<br>**# of references (%)** | **Total**<br>**# of reference (%)** |
|---|---|---|---|
| • **Non Mathematics** | 16 (7.6%) | 44 (9.1%) | 60 (8.6%) |
| • **Explicit Mathematical Relationships** (including Calculations and Algorithms; Implicit Mathematics; and Embedded Mathematics | 194 (92.4%) | 441 (90.9%) | 635 (91.4%) |
| TOTAL | 210 (100%) | 485 (100%) | 695 (100%) |

Non-mathematical encounters were defined as purely nominative uses of numbers. Examples of nominative mathematics include dialing telephone numbers, identifying a room number, or tracking a basketball player by his jersey number. While this type of use is technically related to mathematical ideas, they were identified by teachers as mathematical because, as one student stated "numbers means you're dealing with mathematics." However, for the purposes of this study, nominative identification of numbers, which constituted less than 9% of the reported mathematical encounters, were omitted from the final analysis.

Explicit mathematical encounters (n=635) were recognized in all spheres of life activities, including work (accounting, allied medical services, business, teaching), home (budget and planning, cooking, scheduling, child care activities, transportation), and recreation (sports, interactive gaming). Most of the reported mathematics included explicit use of numbers or formulas, although many of the journal entries reflected uses of mathematics as a tool for logic and decision-making that was not reliant on explicit calculations. Very few entries reflected or described implicit or embedded uses of mathematics that were not readily visible, such as traffic signal efficiency or automatic inventory control associated with self-checkout counters at supermarkets.

Explicit mathematical encounters (Table 3) are defined as activities that require use of mathematical strategizing beyond the simple recognition of numbers. Explicit mathematical relationships often involved numbers (e.g., budget planning, bill paying, calculating sports statistics) but were not limited to the numeric manipulations (e.g., reading maps, choreographing a dance).

Table 3
Explicit Mathematical Relationships

| | **Male**<br>**# of reference (%)** | **Female**<br>**# of references (%)** | **Total**<br>**# of reference (%)** |
|---|---|---|---|
| • **Measurement, Calculations and Algorithms** | 143<br>73.7% | 329<br>(74.6%) | 472<br>(74.3%) |
| • **Estimation and Planning** | 48<br>(24.7%) | 109<br>(24.7%) | 157<br>(24.7%) |
| • **Embedded Math (Implicit Mathematics)** | 3<br>(1.5%) | 3<br>( 0.7%) | 6<br>(0.9%) |
| TOTAL | 194<br>99.9% | 442<br>100.1% | 635<br>100.1% |

Measurement, Calculations and Algorithms, which account for over 70% of the mathematical encounters, represent the most straightforward uses of mathematics. Teachers recognized this type of mathematics both at home and at work, for recreational, administrative, and professional purposes. This type of mathematical enterprise closely mirrored school uses of mathematics to solve problems that were easily described. Nearly 70% of these explicit calculations involved home and work finances, including bill paying, making change, and calculating tips (n=172, 37.8%), and calculations of elapsed time, expected time constraints, and time-distance calculations (n=138, 30.3%).

> Purchased the carpet and provided the figures to the sales person and made the purchase. Purchased groceries while in Auburn. Kept track of selected items in my head to be sure that I had enough cash for the purchase as I do not like to use a credit card for this type of purchase. Again this is math as I used addition and subtraction. I did this while I was in the grocery store [Male 21]

> Considered if I could drive to work (number of miles) on the amount of gas (% of tank, fraction of gas in tank). Considered cost of gas vs. cost of running out of gas. Decided to get gas later. [Female 4]

> Filling out my tax forms- I add up my yearly income at various jobs I've held. I subtract the sale price from the buying price of stocks I've sold this year (these calculations were done on a calculator, and are very practical for life). [Male 18]

Other calculations reported included revising recipes to increase or decrease serving sizes and calculating room areas to buy paint and carpeting. Several teachers discussed how mathematics is used to calculate scores during sports and games (n=10, 2.2%): Six teachers reported calculating scores while playing games or watching sports, four reported using mathematics to calculate gambling odds or payouts.

> I used math last night while watching the season's finale of *The Gauntlet II* on MTV because the team of 8 won 250, 000 to be divided equally. Worked out to be $ 31,250.00 each. At first I estimated the amount to be $ 30,000 something each and then to be exact I used a calculator. [Female 12]

Almost 25% of the reported uses of mathematics recognized the mathematics as a tool for estimation and planning. Within this category, formulae and algorithms were not explicitly discussed. Logical understandings described nearly half of the reported entries in this category (n=73, 46.5%) and were invoked to make purchases ("Mentally calculated how much wood we'd need to make a bookshelf at home depot" [Female 6]), plan a project ("Create a portfolio at a glance. Must estimate how much information I will need to fill a tri-fold brochure" [Female 4]) and drink tea:

> I sip tea- this is the first time I realized that I use math when I drink or eat something hot! I realize that, subconsciously, I feel the radiant heat on my lips of a hot beverage or food. Depending n how far away it is before I feel its heat, I can judge how hot it is. Based on the temperature of the air surrounding me, I make a judgment of how much time it needs to cool off enough so that I won't burn myself [Male 18].

Logical understandings of mathematics also included the use of spatial relationships. These were recognized in sports, driving, and art:

> Played racquetball at local YMCA; this sport is all about math. Reading angles of the ball to know where it is going to go. If you do not read the angle of the shot and just try to react, you will generally be too slow. It's not an exact math, but an estimation done in my head. [Male 25]

> Driving anywhere – distance needed to pull out in front of car or to make a u-turn or k-turn, Find a parking space, keeping speed constant, increasing pressure on gas to go up a hill, decreasing when going down. [Female 2]

> Creating formations for dancers to stand- dancers have to be a safe distance apart while looking visually appealing and symmetrical [Female 11]

Mathematics as a decision making tool accounted for the other half of journal entries in the Estimation and Planning category (n=84, 53.5%). This was described in terms of approximation, comparing/contrasting, and probabilistic estimation. Teachers described using mathematical ideas to interpret charts and graphs, identify best value for money, and make game and gambling decisions.

> Figured the cost of moving the trailer and deck from Union Springs to Dexter (Watertown) myself or having someone move it for me. I received a quote from the person who moved the trailer a few years ago and determined that I will move it myself. This is relevant due to the cost of gas and labor involved and I now have a vehicle that I can move it with. All of the figures I used if I move the trailer myself were estimates and the final figure was quite a bit lower if we complete the move on our own. [Male 21]

> Playing games: I have a group of friends that I play some obscure games with, but all of them involve some math. First is Bonanza, which involves a lot of probability. Knowing the number of each type of card that is left and playing the odds is an important part of the game. It is math that is done in my head, but can be difficult to

track because there are different amounts of each type of card and the more rare they are the more they are worth. [Male 25]

During their week of data collection, teachers were especially encouraged to identify embedded mathematics, such as implicit uses of technology and hidden mathematics, in their daily mathematics encounters. Based on the in-class discussion prior to data collection, teachers acknowledged many implicit uses of mathematics, including bar-code technology, traffic management, and manufacturing. However, less than 1% of the responses identified such embedded or implicit mathematics. Of the six responses in this category, half discussed how a computer translates keypad instructions to electronic impulses:

> I use a computer. When I use a computer, I press a symbol on the keypad. The computer uses binary math (ones and zeros) to perform a specific operation and display an output (mathematics is being used here because the computer does not have the ability to speak English, rather each symbol on the keypad has its own mathematical formula understood by the computer [Male 18].

The other three responses focused on issues of pattern recognition and encryption (e.g., "Open door with code" [Female 9]) with limited discussion of the connection between the mathematics involved in the technological enterprise.

## Discussion

This study has important implications in light of the mathematics education offered to preservice K-6 teachers. While pedagogy and content knowledge are important, this work suggests that K-6 teachers may not value the mathematics they teach. They fail to connect the mathematics and mathematical thinking they teach to mathematical practices outside their classrooms, from explicit calculations to logical and organized thought to the modeling protocols that inform and influence technological design and decision-making. While this disconnection may be acceptable for a layperson, it is worrying when observed in a teacher population. Thus, teachers need support in identifying where mathematical is located and how it is used in society, beyond superficial and explicit calculations and algorithms. As teachers become better able to identify and articulate mathematical thinking in non-mathematical contexts (National Council of Teachers of Mathematics, 2006) they will be better able to help students recognize mathematics across the curriculum,(i.e., cartographic understanding in social studies, mixing paint in art class). Mathematics education for preservice teachers must incorporate the exploration of professional, vocational, and avocations contexts of mathematics into the discussion of pedagogy and content in order to ensure that K-6 teachers can introduce students to true mathematical contexts outside of the mathematics classroom.

Teachers did overtly acknowledge that mathematical ideas underlie much of the technology that they encounter, however they did not report such embedded mathematics. While not mentioning the implicit mathematics of technology is not the same as not recognizing this mathematics, the lack of such mentions is disturbing, given that teachers were specifically asked to mention any mathematics they did recognize. Responses in a variety of areas (e.g., choreography, logical decision making, planning) suggest that teachers do identify less visible, less common uses of mathematical ideas and practices. Thus, the lack of technology related mathematical encounters suggests that such encounters were, indeed, unidentified. In fact, Fitzsimons (2002) contends that except in specific technologically-based vocational education classrooms, most teachers, educators, and students fail to grasp such connections. The thrust of K-6 teachers' practice in the mathematics classroom focuses on algorithmically-based mathematics and logical strategies to solve explicit problems and make straight-forward decisions (National Council of Teachers of Mathematics, 2006; Reys et al., 2007; van de Walle, 2001). Calculating distance traveled per gallon gas used, making change, and scheduling and organizing events were seen as mathematical because the teachers recognized that mathematics embodies both algorithmic understanding and logical planning and organization. However, less tangible uses of mathematics and mathematical ideas that are not easily visible – such as the mathematics that underlies the technology that is used daily or mathematical modeling protocols to compare and contrast solutions and to explore the possible impacts of various decisions – were rarely mentioned. Several teachers described buying gas and paying for it, recognizing that the calculations of miles per gallon and the cost of the gas were mathematical. None mentioned the mathematics involved in maintaining the embedded computer in the gas pump that monitors the fuel flow from the nozzle to the car tank, automatically shuts off the pumping mechanism if problems arise, displays the gallons sold and the price to be paid, transmits that information to the clerk at another cash register, and tracks the total gas inventory of the gas station.

Similarly, the mathematics identified reflected the teachers' ambivalence about mathematics. When the mathematics they attempted to describe veered away from common and/or recognizable calculations and/or explicit organization and planning routines, they often wondered if what they were doing was mathematical at all or just common sense. Others teachers questioned whether they should include mathematics when they observed things they tended to take for granted, such as the geometrical shapes and sizes of buildings or the choreography of a dance routine. This suggests that the teachers are not accustomed to thinking broadly about mathematics and reflects Iverson's (2006) suggestion that mathematical curriculum infused with philosophical discussion would give teachers and students a vocabulary with which to speculate about mathematics use outside of the classroom environment. Simultaneously, teachers' journals also indicated a lack of confidence in their knowledge of what is mathematics and what should be labeled as mathematics in daily life. Teachers recognize mathematics as important, in that on its most basic level, as an algorithmic tool, mathematics is used on a daily basis. On a somewhat more theoretical level, mathematics as an instrument for logical, organized thinking and planning is also part of teachers' daily lexicon. Yet teachers are unable to fully articulate more complex uses of mathematics, which models possible, theoretical, and creative solutions to problems, responds to a variety of real-time variables, and anticipates that which may be imagined.

In-class conversation suggested that the teachers could articulate broad mathematical recognition. However, the mathematics that the teachers reported verified and corroborated this "school mathematics" perspective. This is troubling because sixteen of the teachers had completed advanced mathematics in high school and/or college level mathematics, and had been exposed to more abstract understandings of mathematical thought, yet they did not appear to have internalized this understanding as inherently "mathematical."

This failure to give mathematical credence to the underlying technologies and implicit uses of mathematics in their daily lives raises questions about what is valued about mathematical understanding and utilization. It is not clear that these teachers recognize that the basic mathematics taught in most K-6 classrooms, as suggested and defined by the NCTM (2000, 2006) standards, is an important precursor to the implicit mathematics that governs the technology that we rely on and the political, economic, social, and technological decision making that impacts our lives. . Perhaps teachers' inability to explain the mathematics embedded in technology (for example) may also make them shy away from acknowledging it. If that is not recognized, their ability to teach this mathematics with meaning and understanding may be compromised. Although nearly everyone reported using calculators to complete various calculations, very few people recognized that the calculator itself relied on mathematical algorithms translated into a mathematically-based computer processing language that allows communication between people and the machines. Similarly, although several people reported using computer programs to calculate budgets and prepare tax returns, no one mentioned the mathematical-logical processes required to write the software itself or the mathematically-based computer architecture design decisions that allowed the computer itself to run the program and solve the problems. As Mewborn (1999) suggested, this raises questions about what should we expect teachers (and students) to recognize, understand, and value in terms of mathematics and mathematics education. If technology – be it a calculator, computer, automatic teller machine, or set of switching relays monitoring traffic patterns – solves problems accurately and efficiently, why should teachers and students try to solve those problems manually? If technology does the job well, what is the value of understanding how the machine "does it?" Or, more philosophically, how can teachers and students acknowledge and value the underlying mathematics if they do not recognize, acknowledge, and/or understand that mathematics exists in these locations?

This is the question that must be faced in mathematics education today. Formal definitions of mathematics (Mulls et al., 2004; National Council of Teachers of Mathematics, 2000; 2006) strive to help teachers create a classroom environment that allows students to explore mathematics itself. What is missing, however, is the link that helps teachers and students connect the important mathematics that is part of the K-12 curriculum to the less visible mathematics that undergirds the technological supports of our society. Ultimately, this is to our disadvantage: fewer students are studying mathematics at the university level (National Center for Education Statistics, 2005). As a nation, we are not supporting the mathematical background needed to maintain the structure of our current technology nor the development of needed technologies or new uses of existing technologies.

If we are teaching mathematics as an arcane set of skills that helps students hone their abilities to think, organize, and solve straightforward problems, then the mathematics curriculum we are teaching today may be appropriate. However, we must clearly articulate to teachers and students that that is the goal of mathematics education. Many have suggested, however, that mathematical understanding is the key to creating the future that we envision (Empson, 2002; FitzSimons, 2002; Gutstein, 2006; Hannaford, 1998; Lesser & Nordenhaug, 2004; Mukhopadhuyay & Greer, 2007; Nicol, 2002; Noss, 2001). If teachers do not recognize the many uses of mathematics in our lives, then they cannot be expected to prepare students for using mathematics to build a viable tomorrow.

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