EDITORIAL

In this issue I am very pleased to present the articles written by the XI Colloquium’s keynote Dr. Analucia Schliemann and several articles that demonstrate our graduate students’ research endeavor.

One of the major research interests of Dr. Schliemann is learning algebra in early grades. She is examining the questions: Can young students deal with algebra? How can algebra be taught in elementary school? Can elementary school teachers teach algebra? She has documented how children’s algebraic reasoning evolves when they study arithmetic and learn how to think about quantities. Dr. Schliemann asserts that given the proper conditions and activities, elementary school children can reason algebraically and use meaningfully the representational and computational tools of algebra.

Sharyn Gallagher, doctoral candidate at the Leadership and Schooling program, reviews the research related to the practice of ability grouping in 7th and 8th grades. Sharyn suggests that proponents of the ability grouping focus on common student needs within a classroom and on challenging students at their ability level to achieve appropriate educational goals. She says that critics of the ability grouping idea are concerned that students, mostly from disadvantaged backgrounds, may not have access to the same educational opportunities. Sharyn has found that most research supports ability grouping as one method that is likely to assist in improving student achievement.

Cynthia Jacobs, doctoral candidate at the Leadership and Schooling program, examines the literature on hopeful and resilient teachers. She asserts that social motivation, love for students, intellectual stimulation and meaningful contact with colleagues appear to be important common characteristics of these teachers. In high poverty communities, teachers face dispiriting prospects for their students who often fail to graduate, to pursue post-secondary education, and who are assessed as failures by increasingly weighty standardized achievement tests. She suggests that future research in this area could contribute to the improved practice of recruitment and retention of these teachers in communities where positive expectations for students are especially critical.

Charles Caragianes, doctoral candidate at the Leadership and Schooling program, is interested in the issues related to the urban public schools. He states that students of color currently constitute more than one-third of students in public schools in America and by the year 2035 will constitute more than half of total school enrollment nationwide. These students live in poverty at a disproportionate rate, and are disproportionately Limited English Proficient (LEP). In his paper he indicates about increasing rates of violence and decreasing opportunities for building social capital through internships, community programs, and extracurricular school based activities. Helping to reverse the trends of increasing urban violence and decreasing social capital, as experienced by students, are the goals that public schools must take on if our children are to be successful in the future.

Science teachers Andrew Nikonchuk, Patrick Kaplo and Michael Wall, are excited about technology application in science classroom. They claim that science educators are often among the first to employ emerging technologies in the classroom and laboratory. In their article they introduce a handheld computer, a portable electronic device which can serve to help organize and integrate electronic data into the mobile lifestyle of busy teachers and students. They assert that handheld computer is a terrific tool that has a great potential for applications in the classroom.

I am deeply grateful to all contributors to this issue and invite all to submit papers to the next volume of the journal.

R. Panasuk

Annual Colloquium Journal vol. XI, Spring 2006
GUIDELINES FOR SUBMISSION

The papers submitted for the Journal must discuss psychological and pedagogical issues and trends related to mathematics and science education.

WHEN SUBMITTING A PAPER, PLEASE USE THE FOLLOWING GUIDELINES:

1. Submit an electronic version of the paper and one hard copy, an abstract, approximately 150 words, and a biographical sketch, about 30 words. All pictures and diagrams must be submitted in a separate document.

2. Use double spacing with one-inch margins.

3. For references, tables, and figures follow the style described in the Publication Manual of the American Psychological Association (APA), Fifth Edition.

4. Paper length should not exceed 30 pages, including pictures, tables, figures, and list of references.

5. Paper must be received by November 15.

6. Authors will be notified about the status of their papers by January 15.

7. The Colloquium is scheduled in April.

SUGGESTIONS TO THE AUTHORS:

When preparing a research paper include:

a) a rationale and an identification of the research question(s)

b) a conceptual framework or brief statement of relationship to the literature

c) an identification of research methodology

d) a summary of the analytical technique(s)

e) a summary of preliminary findings

SUBMIT PAPERS AND CORRESPONDENCE TO:

Dr. Regina M. Panasuk
Professor of Mathematics Education
Graduate School of Education
University of Massachusetts Lowell
61 Wilder Street, O’ Leary 5th Floor
Lowell, MA 01854

Phone: (978) 934-4616
Fax: (978) 934-3005
# TABLE OF CONTENTS

The Evolution of Mathematical Reasoning: Everyday versus Idealized Understandings  
*Analúcia Schliemann, David Carraher* ................................................................. 1

Algebra in Elementary School  
*Analúcia Schliemann, David Carraher, Bárbara Brizuela, Anne Goodrow,*  
*Susanna Lara-Roth, Darrell Earnest, Irit Peled* .......................................................... 16

Ability Grouping in School Practice  
*Sharyn Gallagher* ........................................................................................................... 22

Finding Hope Where We Need It: Leading from the Gifts of Resilient Teachers  
*Cynthia Jacobs* .............................................................................................................. 32

The Real Challenges Facing Urban Public Schools in the 21st Century: Increasing Violence and Decreasing Social Capital  
*Charles Caragianes* ...................................................................................................... 36

## EDUCATIONAL RESOURCES

Handhelds as Assessment Tools in the High School Science Classroom  
*Andrew Nikonchuk*  
*Patrick Kaplo*  
*Michael Wall*  
*Michelle Scribner-MacLean* ............................................................................................ 41
CONTRIBUTORS

Dr. Analúcia D. Schliemann is a professor of psychology, Tufts University, and co-principal investigator of the TERC-Tufts Early Algebra Project.

Sharyn H. Gallagher teaches management and finance courses at the University of Massachusetts Lowell, Boston University and Merrimack College. She is pursuing her doctorate in Leadership in Schooling at UML and is currently writing her dissertation proposal.

Cynthia Jacobs is a doctoral student at the University of Massachusetts Lowell, Graduate School of Education, and an adjunct instructor in the Department of Psychology at UML.

Charles Caragianes is an Assistant Director of the Freshman Academy at Lowell High School. He is currently considering pursuing his Ed.D. in Leadership and Schooling where he has taken course work.

Andrew Nikonchuk is a biology and chemistry teacher at Central Catholic High School in Lawrence, MA, and a M.Ed. candidate at UML.

Patrick Kaplo, recent UML graduate, is in his second year teaching Physics and Physical Science at Campbell High School in Litchfield, NH.

Michael Wall, recent UML graduate, is a ninth grade physical science teacher at Dracut Senior High School in Dracut, MA.

Michelle Scribner-MacLean is a visiting assistant professor of science education. She received her doctorate from UML in 2000.

2005-2006 Academic Year
Mathematics and Science Education Program

DISSERTATION DEFENSE STAGE

Jeff Todd
Middle School Mathematics Teachers’ Use of Systematic Lesson Planning and Its Relationship to Student Mathematics Achievement in Low Performing Urban Schools

Rocco Perla
The Development and Validation of a Case Study in Science in the Context of a Non-Linear Model of Scientific Change

Scott Stanley
A Study of the Issues Related to the Development of Web-based Science Courses

Kathy Shea
Mentoring Alternatively and Traditionally Licensed First Year Science Teachers

Marsha Pease
Factors Affecting Mathematics Homework Completion and Achievement in Community College Remedial Mathematics Students

DISSERTATION PROPOSAL STAGE

Danielle Cross
Exploring the Relationship between Pre-Service Teachers’ Level of Knowledge in Mathematics History and Beliefs about Mathematics

Linda McAlpine
An Investigation of the Developmental Mathematics Community College Students’ Attitudes, Beliefs, and Perceptions Regarding Computer-Assisted Learning

Peggy LaBrosse
An Investigation of the High School Chemistry Students’ Understanding of Academic Language and Achievement

QUALIFYING PAPER STAGE

Jessica Devonis
Kate McLaughlin
Alex Ballantyne
Velerie Finnerty

Annual Colloquium Journal vol. XI, Spring 2006
The Evolution of Mathematical Reasoning: Everyday versus Idealized Understandings

Analúcia D. Schliemann, Tufts University
David W. Carraher, TERC

Developmental psychology lacks a theory of mathematical reasoning that accounts for how learners appropriate conventional symbol systems into their thinking. In this essay we attempt to consider how students’ mathematical thinking evolves not only as a result of their actions and everyday experiences but also from their increasing reliance on introduced mathematical principles and representations. First, we contrast how certain mathematical ideas are represented diversely in school and out of school. Then we exemplify, from our own research, how 8- to 10-year-old children’s personal representations come to face with (what for them are novel and for us are conventional) representations involving algebraic concepts. Finally we explore some implications for theories of instruction and long-term development of mathematical reasoning. © 2002 Elsevier Science (USA)

Mathematical understanding is both a personal and a cultural enterprise. It is personal insofar as it entails invention and rediscovery even when people are merely learning facts and conventions. It is cultural because it relies on conventional symbol systems and social contexts. Children construct a foundation for logical and mathematical thinking on the basis of their direct experience and reflection. But early on they draw from their experience in social contexts. Conventional representations and reasoning practices profoundly affect the course and possibly the very nature of their mathematical thought. Any theory of development runs into the fact that mathematical concepts and representations have a history of their own.

Developmental psychologists have striven to identify presumably universal, atemporal, and acultural characteristics of thinking and learning. In doing so they have tended to miss how development benefits from what has been collectively learned. Even though contemporary authors have begun to recognize the need to develop theories on the basis of individuals whose thought has been socialized almost from the moment of birth, much remains to be done. In the area of mathematical reasoning, we need to consider how particular external representational systems play a role in the evolution of thinking.

In this article we examine how students’ mathematical thinking evolves from their previous understandings and experiences out of school and from their participation in school activities as they become acquainted with formal mathematical principles and conventional mathematical notation. We (a) consider developmental psychology’s contributions to the study of mathematical reasoning; (b) contrast traditional mathematics instruction with informal mathematical practices and conceptions children develop on their own outside of formal schooling; and (c) provide examples from our classroom research in which formal instruction takes into account informal, everyday understandings. We argue that the understandings children develop outside of school are an essential prerequisite for any effective program of instruction. But there is more to mathematical understanding. Any analysis of how children develop mathematical knowledge must take into consideration the tools and representations they come to use and understand as they participate in formal mathematics instructional activities.

PSYCHOLOGY AND MATHEMATICAL LEARNING

Many issues of learning fall outside the purview of existing psychological theory, and as the child progresses, theories of development will have to cede ground to analyses of the particular mathematical issues learners confront (e.g., their notational peculiarities and their relations to mathematical content). What can we expect from psychological theory given that the development of mathematical understanding cannot be reduced to psychological processes?

ACTIONS, EVERYDAY CONTEXTS, AND MATHEMATICAL REASONING

Piaget’s proposal that human action and its internal representations provide a basis for thinking continues to offer a striking alternative to the empiricist premise that perception is the source of knowledge. In recent years this insight has inspired many discussions about the nature of mathematical knowledge, including the process–object tension (Sfard & Linchevsky, 1994) and the metaphorical thinking and body image schemes underlying mathematical concepts (Lakoff & Núñez, 2000). It has influenced our own work on everyday mathematics (e.g., mathematical operations as grounded in the actions of buying and selling, as studied by...
Nunes, Schliemann, & Carraher, 1993) as well as our more recent work on children’s early algebraic understanding—for example, the bodily displacements implicit in operations on number lines and in Cartesian graphs (Carraher, Brizuela, & Earnest, 2001; Schliemann, Goodrow, & Lara-Roth, 2001).

Even though Piaget acknowledged the contribution of sociocultural factors to the development of mathematical understanding, his theory almost exclusively emphasizes children’s own actions and reflections upon these actions as the source of mathematical understanding. Piaget largely ignored how mathematical procedures, notation, and formal contents may contribute to the development of mathematical thinking.

In recent years developmental psychology (or at least some of its researchers and theoreticians) moved away from the search of general, invariant cognitive development mechanisms as they sought to clarify the contextual nature of cognition. Neisser (1976) recognizes the contextual nature of cognition in his critique of models of memory processes based solely in the results of laboratory studies. Bronfenbrenner (1979) calls for studies of how settings and the ecological environment mediate cognitive processes. Ceci (1990, 1993) proposes a contextual model of intelligence where the potential for intellectual achievement develops as a result of one’s experience in specific contexts. Leontiev (1981), Luria (1976), Vygotsky (1978), and Cole (1988) emphasize the importance of social, historical, political, and economical changes for the organization and development of human cognition. Rogoff (1990) and Saxe (1991) attempt to reconcile the notion of individual cognitive development with sociocultural analysis and Lave (1988) argues for the dissolution of boundaries between the individual and the contexts where cognition takes place. It is now fairly widely accepted that specific contexts, far from being incidental, are essential to what is learned and thought.

Empirical studies show that cognitive performance may vary considerably across contexts. For example, children who fail in Piagetian conservation, class inclusion, or perspective-taking tasks demonstrate more advanced logical reasoning when interviewers ask the questions in slightly altered ways (see, among others, Donaldson, 1978; Light, Buckingham, & Robbins, 1979; McGarrigle & Donaldson, 1974). Children may also show different performance across contexts in multicausal reasoning (Ceci & Bronfenbrenner; see Ceci, 1990, 1993), syllogistic reasoning (Dias & Harris, 1988), and even microlevel cognitive strategies, such as the temporal calibration of one’s psychological clock (Ceci & Bronfenbrenner, 1985).

We find similar results in the case of mathematical reasoning. What children seem to be able to do in the classroom or in formal interview or testing contexts may be rather different from what they may do in informal, out-of-school contexts (Carraher, Carraher, & Schliemann, 1985). The contexts, social goals, and values associated with activities appear to highlight different relations and evoke different approaches and representations. Children draw from the particular social and physical activities in which they engage (buying and selling, comparing, measuring, computing and solving mathematical problems in and out of school, and so on). Their ways of conceiving and doing mathematics owe much to the specific representations and tools they learn to use such as abacus, weights and measures, quantities they deal with, notational systems, and so on. (Nunes, Schliemann, & Carraher, 1993; Hatano, 1982).

There are several rich topics of mathematics where one can expect clashes between schemes that have evolved out of school and the structure of knowledge being introduced. Consider physical quantities for example. Mathematics, at least modern mathematics, has lots to say about numbers but surprisingly little to say about quantities. (Granted, when quantities are measured or counted they are associated with numbers.) This raises enough issues to keep psychological theorists busy for decades. Do negative quantities exist? And how are they related to negative numbers? If the concept of division stems from the social act of sharing, why is division by zero undefined? Why does it not result in infinity, since the quotient approaches infinity as the divisor approaches zero?

Thinking about actions on quantities constitutes an important basis for many mathematical concepts, including number. Number words and activities involving numbers and quantities pervade a child’s environment from a very early age. Counting and sharing, buying and selling set foundations for future learning. The mathematics children come to use and understand in everyday situations may draw upon the same underlying properties they will learn about in school. However, these properties arise in very different systems of representation and in different motivational contexts (e.g., mental computation based on the structure of the monetary system used in everyday activities versus the written computation algorithms taught in schools). Eventually children will encounter tensions between their everyday experience and problems framed in mathematics lessons. Not all persons sharing a candy bar may insist upon receiving a full share; no person
can divide a candy bar equally, no matter how hard they try. Some water remains in jar 1 when we pour the contents into jar 2, and some water even evaporates. If one repeatedly takes half of an amount of liquid, one eventually arrives at the point where there is no liquid left to pour. Over time students learn to suppress realistic concerns in order to focus on mathematical relations. The socialization of their thought to conform to mathematical convention is reminiscent of Luria’s finding that formerly unschooled rural Asians exhibited syllogistic logic after several months of schooling (Luria, 1976).

Piagetian and sociocultural approaches to cognitive development provide crucial insights into the long-term development of children’s understanding of basic logical and mathematical principles. Far less is known about how their understanding is reorganized through contact with mathematical symbol systems and tools (e.g., the conventions of the decimal system notation, fractional notation, and transformations across conventional measuring units). Mathematics may even involve principles that have no direct counterpart in everyday contexts and therefore require creative and metaphorical applications of schemes. Developmental psychology tends to examine how children develop logical and mathematical understanding, while educators are left to deal with learning. However, if conventional symbolic representations indeed exert an influence over the direction and nature of reasoning, this distribution of labor may prove inadequate.

**Symbols, Conventions, and Mathematical Reasoning**

Vygotsky’s (1978) work has raised the intriguing prospect that representational tools, in mediating thought and communication, may actually transform cognition. One need not subscribe to the view that a representational tool immediately and directly influences cognitive processes. One could hold that tools channel and structure thought in ways that would not have otherwise occurred. Symbolic representations open up further avenues of thinking and evoke certain comparisons to things the learner already knows. The tools and representational systems used by the individual play a role in the structure and direction of mathematical thinking, allowing for different aspects of mathematical reasoning to come to the forefront. This is why schools have a legitimate interest in having students learn the “tools of the trade” of mathematics.

Although mathematicians (like students themselves) often create their own representations, and sometimes their own notations, very few prove themselves worthy of adoption by the mathematical community. As Cajori (1929/1993) notes, “many notations are invented, but few are chosen” (p. 337). He finds that no mathematician, with two possible exceptions, has ever introduced more than two notational conventions into the language of mathematics. Constructivist mathematics educators thus find themselves in a perplexing position: they want to encourage students to express their understandings through symbols meaningful to them. But they need to recognize that some representations offer more promise over the long run. A child’s partially iconic drawing of a fishbowl with 17 fish, 6 of which are crossed out, may meaningfully convey the story that Mary had 17 fish, 6 of which died. But this representation may be ill-suited for other contexts and the notation “17 − 6” or displacements drawn on a number line will prove more generally useful: what the latter representations lose in reference to the particular problem context may be offset by their ability to represent a large set of possible contexts, with or without fish (Carraher & Schliemann, 2002). The zone of proximal development is less about the assimilation of knowledge and symbolic representations where there were none before than the gradual adjustment, progressive schematizing, and replacement of representations so as to become more coherent and applicable to a wide variety of circumstances.

Children may develop certain notions of probability before they have received instruction in mathematics. However, learning how to multiply opens up possibilities for approaching probability in systematic ways and to compare the relative likelihood of various sequences of events. It is true that children will not comprehend probability unless they have already acquired basic concepts such as ratio and proportion that require a long time to develop. These prerequisites themselves will have already benefited from a wide range of experience and exposure to conventional representations in natural language, diagrams, tables, and written notation.

A high school student of today can solve algebra problems that a Greek mathematician from antiquity would have been hard pressed to represent. Ancient Greeks represented problems essentially through natural language and geometry; modern algebraic notation emerged only in the past 500 years (Harper, 1987). Even when we take on such “simple” concepts as addition and multiplication, we find that students of today make use of representational advances such as place value notation and column multiplication that were practically unavailable to students before 1500.

Psychologists may see a “developmental pattern” in the emergence of concepts such as multiplication, ratio,
and proportion—overlooking the fact that students in today’s schools are given explicit instruction about these topics from around 9 years of age. How are we to understand development when we leave the present historical moment? Are we to assume that European children in the middle ages who never learned to multiply, much less recognize the proportionality of equivalent ratios, did not fully develop? How do we handle the fact that Greek mathematicians of antiquity did not have a means to directly represent irrational numbers, yet a large portion of today’s high school students routinely operate on irrational numbers? Several years ago many Piagetian psychologists believed that proportion al thinking was intimately tied to a period of formal operations. Now that we find that many preadolescent children comprehend ratio and proportion, what are we to conclude? Are these children entering formal operations earlier? Or was this characteristic unduly associated with the period? Is any mathematical content tied to invariant periods of cognitive development? What if we discover that, given the proper circumstances, young children can learn to make mathematical generalizations and use algebraic notation with meaning at the age of 9 years? Should we conclude that our theories of cognitive development were off the mark? Or that the children were going through “accelerated development”? Should theories of psychological development define stages in terms of any mathematical content? If not, how can we distinguish stages of development? Or perhaps we need to abandon the goal of casting mathematical competence into the mold of development. Perhaps we should refer to the “evolution” of mathematical ideas to convey the idea that there is no single path of mathematical learning. These are not easy questions to answer.

When psychologists evaluate the “development” of children who have already entered school, they are not dealing directly with cognitive universals. Developmental psychology should not restrict itself to explaining learning in terms of universals but should identify issues, processes, and structures that place learning in a relatively long-term perspective. In the case of mathematical learning this can only be achieved if psychologists are willing to delve deeply into the intricate and subtle issues posed by the subject matter itself.

**BEYOND DEVELOPMENTAL PSYCHOLOGY**

Whenever one considers a particular mathematical topic, particular issues arise that cannot be foreseen by psychological theory. Division by zero becomes an issue in a Hindu–Arabic numeral system but not in the case of Roman numerals, for example. Several of the difficulties students encounter are associated with the paradoxes that the premise, “zero is a number,” brings to the fore—limits, infinitesimal quantities, and so on. In this regard, the history of mathematics may provide important insights into some of the issues students of today face.

Developmental psychology needs to address the specific issues involved in mathematical learning and evolution while considering the history of mathematics and the psychology of mathematics education. This relatively new field of study offers concepts such as additive and multiplicative structures that help us make connections across topics that would otherwise be difficult to make. It attempts to clarify how operations rely on generalized schemes that may be grounded in a variety of mundane situations. While bringing to the fore the role of quantities and quantitative relations in the evolution of mathematical ideas, it considers the tension between the logic of mathematics and the logic of everyday reasoning. It documents the evolution of students’ mathematical representations as they participate in out of school activities and in classroom instruction. Developmental psychologists have eagerly pointed out that what one learns depends on the learner’s level of development. They have been far less likely to note how development benefits from what has been learned and how cognitive functioning relies heavily on the tools one becomes acquainted with in schools.

In attempting to fully understand the development of mathematical reasoning we need analyses of how children learn as they participate in cultural practices, as they interact with teachers and peers in the classroom, as they become familiar with mathematical symbols and tools, and as they deal with mathematics across a variety of situations. The teaching and learning of mathematics as a discipline unfolds from children’s basic logical and mathematical understandings, leading to more general, complex, and explicit knowledge. To acknowledge this, however, is not enough. We need to analyze how children’s logical and mathematical understandings developed outside of schools can be further expanded as they participate in instructional activities. Ultimately we need to find “the most adequate methods for bridging the transition between (…) natural but nonreflective structures to conscious reflection upon such structures and to a theoretical formulation of them” (Piaget, 1970, p. 47).

In this article we first report on studies of mathematical understanding developed outside of school. We
will contrast everyday mathematics to school mathematics, analyze the strengths and limitations inherent to its contextualized nature, and consider its relevance for the development of mathematical understandings in schools. We then show examples from our third-grade classroom intervention studies on early algebra that illustrate how children’s mathematical understandings, while benefiting from everyday experiences, are extended as they have access to new experiences and new ways to represent quantities, events, and relationships.

EVERYDAY MATHEMATICS

Children and adults gain an important grounding in mathematical concepts through activities such as buying and selling, carpentry, weaving, lottery, agriculture, tailoring, and so on (see Nunes, Schliemann, & Carraher, 1993, and reviews by Carraher, 1991, and Schliemann, Carraher, & Ceci, 1997). People with restricted school experience can learn about arithmetical operations, the properties of the decimal system, proportionality, measurement, geometry, and probability.

In our earlier work (Carraher, Carraher, & Schliemann, 1982, 1985; Nunes, Schliemann, & Carraher, 1993) we interviewed young Brazilian street vendors as they worked selling goods and found that in 98% of the cases they gave correct answers to arithmetical problems involving prices of goods. When, a week later, in a school-like context, we gave them what we considered to be equivalent problems, the percentage of correct answers dropped to 74% in a verbal problem condition and to 37% in computation exercises that involved “pure numbers.” At work street sellers solved the problems using mental computation strategies that were not learned at school. In the school-like situation they attempted to use written school algorithms.

Motivation and social interaction might have accounted for the above differences in performance. To rule out these factors we conducted a study with 16 third-graders who, although not regularly working as street vendors, had experience dealing with money transactions (Carraher, Carraher, & Schliemann, 1987; Nunes, Schliemann, & Carraher, 1993). Each child was asked to solve 10 arithmetic problems embedded in the following conditions: (a) a simulated store condition where the child posed as a shopkeeper and the interviewer as a customer, (b) verbal problems, and (c) computation exercises. We presented the problems orally but the children had paper and pencil available in case they wanted to use them. The children’s performance was significantly lower in the computation exercises and, when they chose to solve the problems orally, they were significantly more likely to succeed than when they relied on written computation algorithms. The following example (Nunes, Schliemann, & Carraher, 1993, p. 46) illustrates the differences between school and nonschool strategies in handling the problem “200 – 35.”

![Image](image-url)

**FIG. 1.** A first attempt to compute 200 minus 35.

Ronaldo (R) begins by writing 200 and 35 (see Fig. 1) in accordance with the school algorithm. He writes 200 as the result, writing the digits from right to left.

R: Five to get to zero, nothing. Three to get to zero, nothing. Two, take away nothing two.

The interviewer (I) then asks: Is it right?

R: No. So you buy something from me and it costs thirty-five, you pay with a two hundred-cruzeiros note and I give it back to you?

I: Do it again, then.

Ronaldo writes 200 and 35 in column alignment once more and proceeds as follows, this time getting 235 as a result.

R: Five take away nothing, five. Three take away zero, three. Two, take away nothing, two. Wrong again.

I: Why is it wrong again?

R: Now you buy something and it costs thirty-five. You give me two hundred and I give you two hundred and thirty-five on top?

I: Do you know what the result is?

R: If it were to cost thirty, then I’d give you one hundred seventy.

I: But it is thirty-five. Are you giving me a discount?

R: One hundred sixty-five.
We might represent Ronaldo’s final answer as follows:

\[
\begin{align*}
35 &= 30 + 5 \\
200 - 30 &= 170 \\
170 - 5 &= 165.
\end{align*}
\]

Although the street vendors did not explicitly express the associative nature of addition they revealed their implicit use of the property through the transformations they made on the values given. The standard school algorithm for column subtraction invokes the same general property but decomposes the given values in a different manner.

The street sellers develop a basic understanding about the properties of our numerical system. Their failure in school arithmetic arises not through cognitive deficits, but rather from troubles in adopting written symbolic systems and procedures. Computation algorithms provide students with symbolic representations and procedures that are not always understood. Moreover, algorithms are frequently used without reference to physical quantities or to the situation being dealt with. In contrast, the mental computation strategies developed as tools to solve problems at work reveal understanding and constant attention to the meaning of the situation and the adequacy of solutions.

Our studies suggest that everyday mathematics can provide a meaningful basis for the development of more advanced mathematical activities in school and to the meaningful learning of conventional symbolic systems. But, as is shown next, everyday experiences may constrain and limit the knowledge children and adults will come to develop (Carraher & Schliemann, 2002; Schliemann & Carraher, 1992; Schliemann, Araújo, Cassundé, Macedo, & Nicéas, 1998; Schliemann, 1995).

**Generalization and Context Specificity**

Schliemann and Acioly (1989) examined the generality of everyday mathematics by asking Brazilian lottery bookies to use what they knew about permutations of numbers, an important memorized feature in their work, to deal with problems involving permutation of letters. To a mathematician the problems are isomorphic in the sense that one can directly match the structure of one version to that of the other. However, some of the bookies viewed the problems with letters as completely different from problems with numbers, as the following transcript (from Schliemann & Acioly, 1989, p. 206) shows:

Interviewer: I want you to find out in how many different ways you can arrange the letters in the word CASA (shows word written on paper) without leaving any letters out and without using any other letters.

Subject (who has just given the permutations for a set of numbers): This one is even harder (than with numbers) because I can’t read.

Interviewer: But you don’t have to read. I want you to tell me about how many different ways you can change the position of these letters.

Subject: I can’t do this.

Interviewer: What if you try to do it as in the Animal’s Game?

Subject: This is very hard because reading is more difficult than working with numbers. I know how to do a few calculations but I don’t know how to read.

Interviewer: What if you make believe that “C” is a number like “1,” the “A” a number like “2,” the “S” is number “3,” and this “A” is number “2.” Couldn’t you do it?

Subject: No, because one thing is different from the other.

When we examined how the bookies’ responses related to their school experience, we found that only those with less than 1 year of schooling responded incorrectly to the letter version of the problems. Even very short exposure to schooling can make a difference in people’s reasoning (see Luria, 1976; Scribner, 1977).

Our next step was to clarify whether procedures that were not solely based on memorization could be seen as applicable to other contexts. We did this by examining the generality of everyday price computation strategies in a study among fishermen in a community in northeastern Brazil (Schliemann & Nunes, 1990). Fishermen’s strategies to compute the price of many items based on unit price appear to go beyond use of a memorized procedure since they are able to invert the strategies in order to compute the price of one item given the price of more than one. We found that even those fishermen who had never been to school used the computation procedures to solve problems relating amounts of processed to unprocessed seafood, something they never had to do in their work.

In another study (Schliemann & Magalhães, 1990) we asked female cooks enrolled in an adult literacy class to solve missing value proportionality problems in three contexts presented to them in three different orders.
Two of the contexts (sales transactions and cooking recipes) were part of their everyday experience. The third was an unknown context of a mixture of pharmaceutical ingredients. Cooks who first solved price problems nearly always worked out precise answers to these problems. By contrast, the cooks who responded first in the context of pharmaceutical and recipe problems tended to give nonproportional, and hence incorrect, answers. In this case, about half of the solutions for recipes were estimates. For medicine problems, roughly one-half of the answers appeared to be guesses or the result of meaningless computation. Results for recipe problems in a second presentation, after solution of sale transaction problems, were clearly better (61% as opposed to 18% correct responses). The percentage of correct answers for medicine problems given after sale problems and before recipe problems, however, remained low (27%).

These results suggest that everyday situations can “prime” reasoning in novel contexts. The fisherman had experience with ratios between quantities of processed versus unprocessed seafood and the cooks had experience with quantities involved in recipes. Those experiences seem to allow them to recognize that problems involving such relations can be solved through the same computation procedures they use for prices. But when subjects had no prior experience with the context, as was the case of medicine formula in the cooks study, they did not assume that the amounts in the problem should involve the same relationships.

Problem solving is initially tied to the meanings and goals of particular situations. With increasing practice and experience, people begin to develop an understanding of proportional relations as a scheme they can make use of in other contexts. This transition fits Piaget and Garciaí’s (1991) view that logical and mathematical knowledge have foundations in a logic of meanings (Schliemann, 1998). The logical properties first appear in specific contexts and are linked to the properties of the objects and situations at hand. But with increasing activity and practice, general and systemic logical understanding may develop. Different cognitive and sociocultural factors, however, such as the value attributed to everyday practices, the conceptual understanding underlying everyday solution strategies, or how much is known about how variables in different contexts interrelate, are crucial components in this process.

**Everyday Proportional Reasoning and Mathematical Principles**

Street sellers’ mathematics is intimately tied to the meaning and goals of the situation at hand, with numbers being always used in connection to their physical referents. Street sellers typically start from the price of one item and perform successive additions until they reach the number of items to be sold (Carraher, Carraher, & Schliemann, 1985; Nunes, Schliemann, & Carraher, 1993; Schliemann & Carraher, 1992). Vergnaud (1983) describes this strategy as a “scalar approach”; it is sometimes referred to as “building up.” If we try to understand their procedure in terms of displacements in a function table, they work as if moving down the number column and the price column, summing money with money, items with items. In contrast, the functional approach focuses on the ratio between any two values in a row. This latter approach arose later historically and is more difficult for students to understand, but nonetheless has the advantage of being more closely tied than the scalar approach to functions and their algebraic description.

The following is an example of a coconut seller’s use of the scalar strategy to determine the price of 10 coconuts at 35 cruzeiros each: “Three are one hundred and five, with three more, two hundred and ten (pause). There are still four. It is (pause) three hundred and fifteen (pause), it seems it is three hundred and fifty” (Carraher, Carraher, & Schliemann, 1985).

The street sellers’ scalar approach involves a linking of a unique y value to each value of x and, as such, captures the essential idea of a function and reveals an implicit understanding of proportionality. It may therefore constitute a meaningful initial approach to solve multiplication and proportion problems. But this understanding may be limited to mathematical principles that are relevant to the specific goals of the situation while principles that are not relevant to these goals are never considered. The commutative property of multiplication as applied to repeated additions seems to be a case in point.

We asked Brazilian school children and street sellers who had received little or no instruction on multiplication to solve aloud pairs of verbal problems where they had to compute the price of a certain amount of chocolates based on unit prices (Schliemann, Araujo, Cassundé, Macedo, and Nicéas, 1998). The following is an example of the problems pairs we used:

**Type 1:** A boy wants to buy chocolates. Each chocolate costs 50 cruzeiros. He wants to buy 3 chocolates. How much money does he need?

**Type 2:** Another boy wants to buy a type of chocolate that costs 3 cruzeiros each. He wants to buy 50
chocolates. How much money does he need?

Participants first solved a problem where the larger number denoted the price of one item and the smaller one indicated the number of items to be bought. Immediately after they were given the corresponding problem where the smaller number denoted price and the larger one denoted number of items and were asked whether they knew its answer without doing any computation. If they used the former problem to answer the latter, we took this as an indication that they relied on the commutative property of multiplication. The group of school children who had received school instruction in multiplication (second- and third-graders) solved the first problems in each pair via multiplication and frequently relied on the commutative property to answer the second problems. In contrast, street sellers tended to use repeated additions throughout and rarely invoked the commutative property to answer the second problem. Instead, they successively added the number of cruzeiros, a cumbersome procedure leading to frequent errors if they had to add, for instance, 3 cruzeiros 50 times.

The above results suggest that, although people can learn meaningful mathematical ideas in mundane, nonacademic situations, they nonetheless need access to new symbolic systems and representations they are not likely to acquire out of school. In what follows we look at ways we have tried to build on children’s understanding while introducing more novel representations. The mathematical content concerns linear functions.

**LINEAR FUNCTIONS, TABLES, AND GRAPHS IN THE CLASSROOM**

Linear functions are often approached through equations such as “\( y = mx + b \),” where \( x \) and \( y \) are (independent and dependent) variables, \( m \) is a constant of proportionality, and \( b \) is the \( y \) intercept when the function is graphed as a straight line in a Cartesian space. Functions and rates can be represented in many additional ways such as tables, graphs, and fractions. Students begin understanding (linear) functions and (constant) rates long before they make any sense of an expression such as \( y = mx + b \). Educators effectively teach about functions and rates long before showing such expressions to students. For instance, a multiplication table might be thought of as an embodiment of the expression \( y = mx \), where \( x \) and \( y \) are integers along the margins and \( m \) corresponds to the number in the \( m \) times table.

In a pilot study with a third-grade classroom (Schliemann, Carraher, & Brizuela, 2000, 2001; Carraher, Schliemann, & Brizuela, 2000) we attempted to introduce linear functions. When we gave them an incomplete data table with number of items in one column and the corresponding prices in the other, we found that the students could correctly fill in the tables, but they did so in a columnwise fashion as if they were solving two unrelated problems. Their approach was generally consistent with scalar reasoning that flourishes out of school settings. But because we wanted them to eventually understand expressions such as \( y = 3x \), we needed to discourage students from using their “double sequence” approach to tables.

First we broke the order of items in the table so that the columns, when read downward, no longer expressed easily interpretable number sequences. This puzzled the students and most still tried to use the standard buildingup strategy. We then moved to a “Guess My Rule” game to eliminate altogether the possibility that students would approach the problems in a “downward” fashion. For each step in a game we presented an input value and asked students to predict an output value. This corresponded generally to the idea of filling out a table, row by row. Given the rowlike nature of the problem and the fact that we followed no apparent order when moving from one input to the next, there was no way for students to guess the output values by scanning the values in a downward fashion. This proved to be a useful way to encourage children to focus on the functional relationship. Eventually the children began to adopt mapping notation (e.g., \( n \rightarrow n + 3 \)) we introduced to summarize the rules. The arrow was read as “becomes.” With the mapping notation they were able to solve problems corresponding to linear functions (e.g., \( n \rightarrow 2n - 1 \)). Such notational conventions lend themselves not only to the problems at hand. We have found that 9-yearolds increasingly use similar notation to express relations among unknown values in other contexts (Carraher, Schliemann, & Brizuela, 2001).

The introduction of “\( n \)” to represent any value appeared to help children move from the computational aspects of the task to generalizations about how two sets of values were interrelated. However, on some occasions children were inclined to instantiate variables—to assign fixed values to what were meant to be variable quantities—without recognizing their general character.

The following interview with two of the children exemplifies the tension between instantiation versus generalization (Carraher, Brizuela, & Schliemann,
2000). The context was a height problem in which Martha was said to be 3 inches taller than Alan, but no information about Martha’s or about Alan’s height was provided. When the interviewer suggests calling Alan’s height \( x \), one of the children believes that it would be strange to do so:

David: . . . Do you think it’s strange (to call Alan’s height \( x \))?
Jennifer: Yes, ’cause it has to, it has to have a number. ’Cause . . . Everybody in the world has a height.

Jennifer, 9 years, believes that it would be inappropriate to use the letter \( x \), representing any height, to describe Alan, since Alan must have a particular height. The interviewer turns the discussion to another context to see if this will eliminate her concern:

David: OK, I’ll tell you what: I’ll take out, I’ll take out a nickel here, OK. And I’ll give that to you for now. I’ve got some money in here [in a wallet] can we call that \( x \)? (hmm.) Because, whatever it is, it’s that, it’s the amount of money that I have.
Jennifer: You can’t call it \( x \) because it has . . . if it has some money in there, you can’t just call it \( x \) because you have to count how many money [is] in there.
David: But what if you don’t know?
Jennifer: You open it and count it.

Jennifer insists that it would be improper to refer to the money in the wallet as \( x \), since it holds a particular amount of money. The remarkable thing here is that Jennifer has learned about the concept of mathematical variable according to which letters stand not for single unknown values but for a whole set of values (input and output sets, for instance). Her discomfort stems from the fact that the interviewee’s example does not conform to her expectation—encouraged by activities such as the “Guess My Rule” game—that letters be able to stand for multiple values.

In fact, it is somewhat curious that a variable stands for many values, yet we exemplify or instantiate it by using an example for which only one value could hold (at a time). Jennifer eventually reduces her conflict by treating the amount of money in the wallet as, hypothetically, able to take on more than one value: “The amount of money in there is . . . any money in there. And after . . . if you like add five, if it was like . . . imagine if it was fifty cents, add five more and it would be fifty-five cents.” Fifty cents is only one of many amounts that the wallet could have (in principle) held.

When the conventions regarding variables clash with Jennifer’s understanding of everyday situations (people have one height only; purses contain a particular amount of money), Jennifer actually recontextualizes the everyday situation to conform to the mathematical conventions. It is precisely this sort of example that compels us to conclude that mathematical conventions can exert an influence over reasoning.

Creating Contexts for the Graphical Representation of Functions

In an ongoing longitudinal study, we explored how 48 children in three third-grade classrooms deal with linear functions as they start being introduced to the conventions of graph representation.

Graphs constitute symbolic conventional systems for representing certain quantitative aspects of changes in quantities and events. The conventions adopted in a graph obey a coherent set of rules so that the spatial relationships in the graph must be consistent with the relationships between the quantities or events they supposedly describe. In the case of graphs of functions a single line can represent the infinite number of possible number pairs that satisfy a certain function. Function graphs also allow one to represent and to visually compare multiple functions. As such, the graph of a function captures, differently than a function table, the essence of a functional relationship. Piaget’s extensive work on children’s conception of space (Piaget & Inhelder, 1948/1956) and geometry (Piaget, Inhelder, & Szeminska, 1948/1960) shows that children as young as 9 or 10 years of age show an understanding of vertical and horizontal dimensions as a coordinate system. Thus we could assume that most of our third-graders would have some understanding about the coordination of vertical and horizontal lines in space. Our challenge was to create situations that would provide the ground for children to focus on functional relationships as they learned the conventions for graphing functions. As is shown, this involves constant attention to reconciling everyday experiences and mathematical relations.

We had been working with these children since they were in second grade as part of a longitudinal study aimed at exploring the algebraic character of arithmetic. The intervention consisted of eight 90-min weekly classes given during their second grade. During their first term in third grade, in eight weekly meetings, we explored additive functions (Carraher, Brizuela, & Earnest, 2001). In the second term of Grade 3 we focused on multiplicative functions and graphical rep-
resentation (Schliemann, Goodrow, & Lara-Roth, 2001). On the first day of multiplicative functions activities we presented the following statement to the children: “Karen has twice as many dollars as Franklin.” We would be treating this statement as a function that can be solved by many pairs of values. As such, we were departing from its normal everyday interpretation as a statement about the relation between two particular values. This shift in focus from relations between particular number to sets of numbers (or variables) is fundamental to the early algebra program we were exploring.

Children immediately started giving examples of how many dollars Karen and Franklin could have, consistent with the ratio of 2 to 1. The instructor listed the value pairs in a two-column table, suggesting new values for Franklin's column while the children computed the corresponding value for Karen. The children concluded that “twice as much” meant the same as “double.” When asked to complete the statement “Franklin has (blank) as many as Karen,” some children suggested that the statement should become “Franklin has twice as less as Karen” and the instructors then introduced the expression “half as many.”

Each child then received a handout with the statement “Karen has twice as many dollars as Franklin” with the instruction to “Show this in as many ways as you can.” Children worked in groups and the researchers joined the different groups discussing the work. The most common representation consisted in attributing a number value to Karen's amount of dollars, either by multiplying it by 2 or by adding it to itself. A few children, spontaneously or after prompt, made use of the algebraic representation for variables that had been introduced a few weeks before, representing Franklin's amount as \( N \) and Karen's as \( 2N \) or Karen's amount as \( N \) and Franklin's as \( \frac{1}{2}N \).

We then took the children to the gym and had them make two parallel number lines, with values labeled from zero to 12 spaced about 1½ feet apart on the floor of the gym. In a series of trials we asked one child to choose a value for Franklin in one line and then invited a second child to move in the other line to the number position that represented Karen's amount, always maintaining the relationship “twice as many.” The rest of the class sat in the bleachers watching and occasionally recommending where each child should go.

After a few trials, we rotated Karen's line at the origin by 90°, whereby it became a y axis, perpendicular to Franklin's line (the x axis). After a few trials with a pair of children moving along the line and discussions about how the number taken by a child was related to the number for the other child in terms of doubles and halves, we helped the children in the class “plot themselves,” one by one, at the intersections of invisible projection lines in the graphing space. For example, if Franklin's amount was $5.00, the child would plot herself at the intersection corresponding to (5, 10).

Some children were initially uncertain about where they should stand and needed help from the instructor or from other children. Others initially walked diagonally from the number on one line directly to the number on the other line. With prompting they then moved to the imagined intersection. The positions on the “graph” were named \((0,0), (1,2), (2,4), (3,6)\), and so on, and the child in a position received a piece of paper with his/her ordered pair written on it. Later, we gave all the children located on the “double line” a string to connect their points. We then proceeded in a similar fashion for the case of “three times as many.” The class ended with two plotted lines of children, the \textit{doubles} and the \textit{triples}.

The following week we introduced a gridlike diagram to depict the graph made in the gym. The children were quick to note that the implicit perspective was that of a person located high up above the gym floor, looking down. We displayed the statement “Karen has twice as many dollars as Franklin” and asked the children to draw a table of possible values of Karen's and Franklin's money and to find the places in the graph corresponding to each possibility. Throughout the discussion that followed the instructor and the children referred to the positions specific children took in the larger scale graph. We then worked with another statement: “Ann has three times as many dollars as Franklin.” We were surprised by how easily most children in the three classrooms could find the intersection points and could say what the ordered pair at each point represented. Drawing the function line, however, was still an issue that not all of them seemed to have grasped. Several children connected the points from diverse functions as they might in a connect-the-dots drawing.

In the following week we introduced a new context for Cartesian graphs. We asked the students to imagine the intersections in the graph space as places where a table and chairs would be placed in the gym. Each table would have a certain number of chairs where children could sit. On each table there would be a certain number of candy bars to be shared equally by the children sitting at the table. We began by asking the students to locate the points corresponding to a table with four chairs and four candy bars and then a table with six
chairs and six candy bars. The students could easily do so and, after some discussion, they agreed that if the candy bars were equally shared at each table, children at the “four for four” table each get as much candy as the children at the “six for six” table. Albert expressed this as “It wouldn't matter because if he [the child] went to [the table with six candy bars and] six people, he would, you would get one candy bar.” The instructor asked whether there would be a better table to sit at, where one would get more candy than in the first two. Jessie proposes that the table with five chairs and six candy bars would be better, and he locates this case at the appropriate intersection on the graph. Erika immediately proposes: “I'd rather go to the seven-to-one table” and correctly locates the coordinate (1, 7) corresponding to the table with one chair and seven candy bars. The instructor then asks the students to find the worst table: the table to send someone who misbehaved. Eric chooses the point corresponding to the table with seven chairs and only one candy bar. As children discussed different points in the graphing space, the instructor also showed and asked the children to represent the ordered pairs corresponding to the tables as fractions.

Throughout the discussion the children repeatedly drew upon their prior experience in the gym and their everyday experience with sharing candy bars and fairness to lend meaning to the points in the graph and to the written representation of ratios as fractions. As the class continued, Paul proposed that the candy bar on the table with seven chairs could be a Hershey candy bar that comes with squares, easy to break apart. He drew a candy bar with two lines by seven columns of squares, explaining that each person would get two of the small pieces he drew.

Everyday referents helped the children but also led to choices that were not consistent with the mathematical model under discussion. For instance, as the class compared the points representing tables on the graph grid, Paul considered that the four-to-four table was a better choice than the one-to-one table because “Someone may not want their candy bar.” Another child proposed that in the table with two chairs and four candy bars not everyone will get two candy bars because one person could get one and the other could get three candy bars. In these occasions, the instructor appealed to the idea of fairness in sharing the candies so that each child sitting at one table would have the same amount as the others. The children adopted this constraint in solving the problem in Fig. 2. With this problem we hoped to start helping them to look at the

FIG. 2. Finding and comparing ratios.

lines in the graphic space as representations of distinct functional relationships.

The children worked in groups while the instructor and other members of the research team circulated around the class, offering help when needed. After answering the questions, the children located the points corresponding to each table on a graph where the x axis denoted the number of chairs or people sitting at each table and the y axis referred to the number of candy bars on the tables. The children used interesting sharing strategies to distribute the candy bars, most of them concluding that those sitting at tables A and B would each get one-and-a-half bars and those at table C were better off since they would get two-and-a-half bars. Most of them also located the points corresponding to each table on the graph. Some children correctly plotted the lines corresponding to different ratios and explained why they did so. Jennifer (not the same girl referred to above) found the answers to the questions using the diagrams in Fig. 3.

FIG. 3. Jennifer's work to determine the best table.
Darrell: Why do you think they go in the same line?
Jennifer: Because they’re the same.
Darrell: So, can you show me where that line would be?
Jennifer: [Draws the line starting at the origin, moving through points A and B.]
Darrell: Can I ask you a question? How come you didn’t draw it like this—go up to A and then over to C, then over to D and then over to B?
Jennifer: Because they’re not the same.
Darrell: They’re not the same. Ah. So, which points will fall on this line?
Jennifer: The points that are the same.

The concept of equivalence may rest upon a logical structure but it goes through a socialization. There are many senses in which the points (6, 4) and (3, 2) are different. But Jennifer is learning that what counts as being the same (for the teacher who introduced the conventions) is whether the amount of candy per person is equal in each case. The straight line visually depicts those points for which the amounts per person are equal.

In this class children built upon their previous understandings of space and the specific experience with the large-scale graph in the gym. They also drew upon understandings about sharing fairly. Throughout this process the tension between everyday understandings and mathematics structures was constantly present, sometimes helping, sometimes hindering the analysis of pure mathematical relations. As the instructor explicitly acknowledged this tension the students were able to focus upon the mathematical relations, hopefully being introduced to some of the crucial issues involved in the interplay between mathematical models and everyday contexts.

**DISCUSSION**

Children build a foundation for logical and mathematical thinking from their actions and reflections. Logical and mathematical thinking further evolves as children engage in social interactions, games, commercial transactions, and discussions with others. As students they encounter conventional representations and reasoning practices that will affect the course and even the nature of their mathematical thought. A theoretical account of mathematical reasoning requires uniting the findings of developmental psychology, everyday mathematics, and mathematical learning in schools. It will also require a careful analysis of the structure and semiotics of mathematics itself.
Developmental psychology provides important contributions to the study of mathematical reasoning among children. Cognitive development theory roots knowledge in actions and schemes from infancy and early childhood—schemes that later prove fundamental even to advanced mathematical thinking. Studies of everyday mathematics draw attention to how a variety of commercial and measurement contexts play a role in the shaping of mathematical thought. Buying and selling, for example, provide motives and logic that help render computations about quantities meaningful. But this is not all there is to mathematical learning and reasoning. Schools introduce students to a wide variety of tools and representations they would not have invented on their own nor understood without dedicating themselves to the task of understanding them.

Insofar as tables of values entail functions, one can look to studies of children’s understanding of functions from developmental psychology and thereby relate the present task to issues such as dependency among variable actions, inverse actions and operations, and so forth. When, as in several examples we presented here, the social context concerns the buying and selling of items, we can relate the students’ approaches to the “building up” strategies of street vendors. We will not be surprised by the fact that, given the choice, children prefer to maintain separate operations on quantities of like nature—numbers of items on numbers of items, prices onto prices. We can also relate this to the historical fact that ratios of different quantities emerged only recently in Western mathematics. But schooling is not merely about watching how development runs its course. Schools have an agenda. The fact that students will eventually have to understand and use algebraic expressions such as “y = 3x + 6” has significance for how one deals with tables when children are 9 or 10 years of age. Children’s strategies are a nice start, but they approach functions in ways that obscure the relation to representations via an equation. (Think of the distance between an expression such as “for every 2 apples Mary has, John has 3, and the equation, y = \(\sqrt[3]{x}\).”)

To teach effectively, an educator needs to constantly evaluate the conflict or fit between what children bring to the learning situation and where learning is headed—in large part due to the organization of the curriculum.

The design of classroom activities requires (a) considering children’s previous understanding and intuitive ways of making sense and representing relationships between physical quantities and between mathematical objects; (b) providing opportunities for children to participate in novel activities that will allow them to explore and to represent mathematical relations they would otherwise not encounter in everyday environments; (c) exploring multiple, conventional, and non-conventional ways to represent mathematical relations; and (d) constantly exploring the matches and mismatches between rich contexts and the mathematical structures being dealt with.

Our study of the graphical representation of ratios (Schliemann, Goodrow, & Lara-Roth, 2001) shows that third-graders can deal with the representation of points in a graph and that they can start understanding how straight lines in a graph represent the same ratio. These ideas do not arise spontaneously but seem to require situations carefully structured to draw upon students’ former knowledge while introducing new mathematical representations. In our classroom studies we had to build these situations and engage children in discussions where different approaches are proposed and considered by the instructor and by the other children. In this sense, the discussion was much closer to an everyday problem-solving situation than to a traditional mathematics classroom focused on the transmission and application of rules. But, differently from what usually occurs outside of schools, here the children had access to the new representations we introduced.

We argued elsewhere (Brizuela, Schliemann, & Carrera, 2000) that young children’s notations constitute tools to further understanding and thinking processes. Here we saw how algebraic notation and graphical representation help children consider mathematical relationships that are otherwise unwieldy if not intractable.

We look forward to seeing theories of mathematics education that draw upon findings from developmental psychology and everyday mathematics. We also look forward to seeing the cognitive developmental theories benefit from careful analyses of curriculum issues and of mathematical learning in schools. If human development is not only an individual but also a cultural enterprise, we need theories that show how culture and thinking come together.

REFERENCES


Algebra in Elementary School

Analúcia Schliemann  
Tufts University

David Carraher  
TERC

Báárbara Brizuela  
Tufts University

Susanna Lara-Roth  
Tufts University

Darrell Earnest  
TERC

Anne Goodrow  
Rhode Island College

Irit Peled  
University of Haifa

Increasing numbers of mathematics educators, policy makers, and researchers believe that algebra should become part of the elementary education curriculum. Such endorsements require careful research. This paper presents the general results of a longitudinal classroom investigation of children's thinking and representations over two and a half years, as they participate in Early Algebra activities. Results show that 3rd and 4th grade students are capable of learning and understanding elementary algebraic ideas and representations as an integral part of the early mathematics curriculum.

BACKGROUND AND EARLY RESEARCH QUESTIONS

Early research about algebraic reasoning highlighted shortcomings such as students' (1) limited interpretations of the equals-sign (Booth, 1984, 1988; Kieran, 1981, 1985; Vergnaud, 1985); (2) misconceptions about the meaning of letters standing for variables (Kieran, 1985; Kuchemann, 1981; Vergnaud, 1985); (3) refusal to accept an expression such as “3a + 7” as an answer to a problem (Sfard & Linchevski, 1994); and (4) difficulty in solving equations with variables on both sides of the equals sign (Filloy & Rojano, 1989; Herscovics & Linchevski, 1994). Many researchers originally attributed such findings to developmental constraints and the inherent abstractness of algebra.

Over time, however, data from innovative classroom activities began to support a new view. Davis (1985, 1989) gave convincing examples of how algebra could be introduced in 5th grade mathematics classrooms. Successful work in the former Soviet Union (Davydov, 1991, Bodanskii, 1991), with even younger children, came to the attention of researchers. Mathematics educators began to find common ground between arithmetic and algebra (Bass, 1998; Carpenter & Franke, 2001; Carpenter & Levi, 2000; Carraher, Schliemann, & Brizuela, 2000, 2001, 2003; Davis, 1985, 1989; Kaput & Blanton, 2001; Schifter, 1999, Schoenfeld, 1995; Schwartz, 1995). Approaching the introduction of algebra in the early grades from various, occasionally overlapping, perspectives (generalizing arithmetic, moving from particular to generalized numbers, focusing on mathematical structures common to sets of algorithms, introducing variables and co-variation in word problems, focusing on the concept of function, to tie together isolated mathematics topics, etc.), they identified previously overlooked opportunities to explore the algebraic character of early mathematics. These recent studies suggest that shortcomings of instruction may have had a decisive role in the gloomy results from early studies of algebraic reasoning among adolescents (Booth, 1988; Schliemann & Carraher, 2002).

In this paper we describe the general results of a longitudinal study we developed in 2nd to 4th grade classrooms. We will argue that, given the proper conditions and activities, elementary school children can reason algebraically and meaningfully use the representational tools of algebra. We hope that our empirical research on Early Algebra will help make advances regarding issues that most researchers in mathematics education recognize as important, such as development versus learning, the role of contexts, and the role of representational systems.

OUR APPROACH

Our approach to the introduction of algebraic concepts and notations in elementary school was guided by the following ideas about learning:

(a) Cognitive deficits and cognitive difficulties with algebra may result from the limitations of the mathematics curriculum elementary school children have access to; (b) Mathematical understanding is an
individual construction that is transformed and expanded through social interaction, experience in multiple meaningful contexts, and access to mathematical symbolic systems and tools; and (c) Children need to be socialized into the symbolic systems but also need to make them their own. To this goal, students benefit from opportunities to begin with their own intuitive representations and gradually adopt conventional representations as tools for representing and for understanding mathematical relations;

Furthermore, it rests on the following ideas about mathematics:

A. Concerning arithmetic, algebra, and their interrelations

(a) Opportunities to explore the algebraic character of elementary mathematics are present throughout existing curricula, though rarely seized upon; (b) Algebra is both a notational system and a field of mathematics devoted to the study of mathematical structures; (c) Arithmetic is a part of algebra, namely, the part that deals with number systems, the number line, numerical functions, and so on; (d) Generalizing lies at the heart of algebraic reasoning; and (e) Arithmetical operations can be viewed as functions.

B. Concerning symbolic representation

(a) Mathematical concepts (algebra included) are closely identified with four key symbolic systems (natural language, number, geometry, and algebraic symbolic notation); each of these has important roles to play already in early mathematics education; (b) Each of these systems has its own expressive rules and internal logic; and (c) A central problem in mathematics consists in moving back and forth between diverse representations, often across these key symbolic systems;

Our approach focuses on algebra as a generalized arithmetic of numbers and quantities. This highlights the shift from thinking about relations among particular numbers and measures toward thinking about relations among sets of numbers and measures, from computing numerical answers to describing and representing relations among variables. This requires engaging students in specially designed activities, so that they can begin to note, articulate, and represent the general patterns they see among variables.

In our longitudinal study, we worked with 70 students in four classrooms (three mainstream and one bilingual education classroom), as they learned about algebraic relations and notation, from grade 2 to 4. Students were from a multiethnic community (75% Latino) in Greater Boston. From the beginning of their 2nd semester in 2nd grade to the end of their 4th grade, we implemented and analyzed weekly activities in their classrooms. Each semester, students participated in 6 to 8 activities, each activity lasting for about 90 minutes. The activities related to addition, subtraction, multiplication, division, fractions, ratio, proportion, and negative numbers. The project documented, in the classroom and in interviews, how the students worked with variables, functions, positive and negative numbers, algebraic notation, function tables, graphs, and equations.

In our classroom work we generally began not with a polished mathematical product, such as a number sentence or a graph, but rather with an open-ended problem or a situation such as “Maria has twice as much money as Fred.” After holding an initial discussion about the situation, we ask students to express their ideas in writing. We discuss their representations and introduce a conventional representation, such as two parallel number lines drawn on the floor (on which Maria and Fred’s amounts correspond to positions); the new convention is often foreshadowed in students’ own drawings. We may ask them to show how the representations (their own and the conventional one) must be updated to account for new information, such as amounts changing while some properties remain invariant (the relation “twice as much” continues to hold). In the specific case of a Cartesian coordinate graph and of the problem involving Fred and Maria, we would then rotate one of the number lines by 90 degrees and ask the students to plot themselves as points at the intersections of ordered pairs for Maria and Fred’s amounts. A “Human Graph” is thus built and becomes the object of discussions. We explore the relations between the mathematical representation and the problem-situation in terms of correspondences between the graph and the underlying situation. What do you notice about the way in which students/points are patterned? Why are they falling on a straight line? (When each point is expressed through coordinate notation) what do you notice about the relation between the two numbers? If I choose a position on Fred’s line/axis, can you predict where the Fred-Maria point will land? If Fred has a really large amount of money can you say anything about where the Fred-Maria point will be located? (See Schliemann & Carraker, 2002; Schliemann, Goodrow, & Lara-Roth, 2001a; and our website-earlyalgebra.terc.edu-for detailed information and partial results of our Early Algebra activities).
RESULTS

Partial results of our longitudinal study have been reported in detail at PME meetings and published elsewhere. Here is a general description of our classroom results:

- Young students (9-10 years of age) can learn to think of arithmetical operations as functions rather than merely as computations on particular numbers (Carraher, Schliemann, & Brizuela, 2003; Schliemann & Carraher, 2002; Schliemann, Carraher, & Brizuela, 2003). They can also work with mapping notation, such as $n \cdot 2n - 1$, and realize that the algebraic expression constitutes a rule according to which one set of input numbers maps onto another, output set (Carraher, Schliemann, & Brizuela, 2003).

- For young learners, the number line can be a meaningful tool for representing numbers and operations and to solve problems (Carraher, Brizuela, & Earnest, 2001; Carraher, Schliemann, & Brizuela, 2001; Peled & Carraher, 2004 in preparation).

- Even young students can easily learn to accept the idea of negative numbers. However, operations involving negative numbers pose special challenges when dealing with word problems, number lines, graphs, and other contexts (Peled & Carraher, 2004 in preparation).

- The idea of “difference” (corresponding initially to the expression, $|a-b|$, and later to $(a-b)$) is important for appreciating the algebraic character of additive structures; yet it takes on subtle differences in meaning across the contexts of number lines, measurement, subtraction, tables, graphs and vector diagrams (Carraher, Brizuela, & Earnest, 2001).

- Certain large-scale activities where children enact mathematical objects and relations, can play an important role, helping to introduce new algebraic concepts. Such activities provide meaning for children to interpret mathematical notation and solve algebraic problems (Schliemann & Carraher, 2002; Schliemann, Goodrow, & Lara-Roth, 2001a).

- Children often complete function tables by treating each column as a number sequence task to be solved in a downward fashion regardless of the values contained in the other column. This led us to seek and successfully implement alternative ways to pose problems so as to highlight the functional relations across columns (Schliemann, Goodrow, & Lara-Roth, 2001b).

- There is an inherent ambiguity in how letters represent quantities in algebraic expressions. Students must recognize that letters may refer to particular values or instances, but also to sets of possible values or variables. This shift in meaning, often in the same conversation, has generally not been addressed in curricula. We found that, given appropriate activities, 3rd graders can grasp the meaning of variables, as opposed to instantiated values (Carraher & Schliemann, 2002; Schliemann, Carraher, & Brizuela, 2002).

- Graphs of linear functions are within reach of 3rd grade students, contributing to their initial understandings of function and of multiplicative structure concepts (Schliemann & Carraher, 2002; Schliemann, Goodrow, & Lara-Roth, 2001a).

- After participating in our activities, 4th grade students were able to solve algebraic problems using multiple representation systems such as tables, graphs, and written equations with variables on both sides of the equality (Brizuela, 2002; Brizuela & Schliemann, 2003).

- The symbolic systems used in algebra are an inherent and important part of learning algebra; children need both access to these systems as well as opportunities to constantly represent algebraic concepts in multiple ways, both conventionally and idiosyncratically.

At the end of 4th grade, three to four weeks after our last class, the students were interviewed and asked to solve problems. A control group (CG) of 26 5th graders from the same school, who had been taught by the same school teachers, were also interviewed and compared to our experimental group (EG). Here are some preliminary results:

**Question 1:** Is $6 + 9 = 7 + 8$ True or False?

Here we explored students' understanding of the equivalence in an equation, treating both sides symmetrically, instead of holding an “input – output” conception and thinking that they should do an operation on the left side and get a result on the right.

We found that 85% of the 4th grade students (EG) responded correctly that the equation was true while only 65% of the fifth graders (CG) did so.

**Question 2:** Below [A drawing of two boxes and another box plus 9 candies was shown under the question.] there are boxes of candy [each containing an unspecified amount] and loose candies. Each box has the same number of candies. Which would
you rather have? Two boxes of candy? Or one box of candy and 9 loose candies? Why?

Here we explored whether the students could relate and operate on an unknown quantity. Could they generalize and integrate their part-whole schema with a comparison schema in a situation with two piles each composed of different parts and involving unknown amounts? Could they handle situations in which there was no “one answer”, but rather a set of solutions or a variable that depends on the changing value of an amount in the situation (the independent variable)?

We found that a larger proportion of children in the EG (44%) could handle situations with unknown quantities, answering that their choice would depend on the number of candies inside each box, while 31% of the children in the CG did so.

**Question 3a:** The children were asked to complete a function table representing the following problem: Mary has three times as much money as John. Column 1 was labeled ‘John’ and column 2 was labeled ‘Mary’. After completing the table, we continued: If we don’t know how much money John has, we can say that he has N dollars. If John has N dollars, what could you write to say how much money Mary would have?

How would the students fill up the function table? Would they continue focusing on isolated columns as was the case in 2nd grade? Or would they focus on the functional relationship between the two variables?

We found that 65% of the EG filled the table working with functional relations and 50% of the CG did so. To represent that Mary had three times as much money as John, 70% of the EG accepted to represent John’s amount of money as N and Mary’s amount as John’s amount times three. In the control group, only 29% of the children did so.

**Question 3b:** Which of the graphs [three linear function graphs were shown as possible answers] shows that Mary has three times as much as John? How do you know you chose the correct graph?

Would the children be able to identify a specific linear function relationship in a graph? And if so, how would they justify their choice? Would they focus on isolated points or would they identify the general properties of the function depicted in the graph?

Here, 78% of the EG chose the correct line while only 46% of the CG did so. Note that the CG, had also received instruction on drawing graphs by their regular teachers. Of the children choosing the correct line, 39% in the EG provided general justifications that took into account any possible pair of numbers (e.g., “Because when you times John’s money by 3 it tells Mary’s number of money” Or “Because if I would times 3 all the bottom numbers it would be on that line.”). In the CG 25% adopted this general approach.

**Question 4:** In the last part of the interview, children were asked to represent in writing and to solve the following problem: “Harold has some money. Sally has four times as much money as Harold. Harold earns $18.00 more dollars. Now he has the same amount as Sally. Can you figure out how much money Harold has altogether? What about Sally?” Each step in the problem was presented gradually.

In this problem, we wanted to see if children could accept to work with an unknown amount, how they would represent the unknown amount, and whether children would use equations and the syntax of algebra to find a solution to the problem.

Of the 63 EG children who were interviewed, 56% represented Harold’s initial amount as N, X, or H and 49% represented Sally’s amount as Nx4. For Harold’s amount after earning 18 more dollars, 35% of the children wrote N + 18. 17% of the children wrote the full equation N + 18 = N x 4 and 27% children correctly solved the problem. However, only 6% (four children) systematically used the algebra method to simplify the equation. Two children, when prompted, correctly explained the algebra method. Apparently, as the children worked in their written representations, they easily inferred that Harold’s starting amount was 6, without the need to use the algebra method. As Albert stated, “I thought about six because it just popped in my head.” In the CG, 23% of the children solved the problem but no one wrote an equation or found the solution through use of algebra method or notation.

**DISCUSSION**

During the last few years, we have made certain strides forward in expanding students’ mathematical reasoning and in helping them develop and use algebra notations and tools to solve problems. However, we did not explore the limits of children’s capabilities regarding algebra. As we focused on discrete quantities, linear functions, and graph spaces in Quadrant I, we may have underestimated children’s potential to learn algebra.

The issue of sustainability of learning is also still open. In our research we worked with the students in
their classrooms, but met with them for only six to eight times per school term. We believe, and this is what we want to test in our next study, that much more can be achieved if children participate in early algebra activities on a daily basis, as part of their regular curriculum.

REFERENCES


Kieren, C. (1985). Constructing meaning for equations and equation-solving. In A. Bell, B. Low, & J. Kilpatrick (Eds.), Theory, Research & Practice in Mathematical Education (pp. 243-248). University of Nottingham, UK: Shell Center for Mathematical Education.


Vergnaud, G. (1985). Understanding mathematics at the secondary-school level. In A. Bell, B. Low, & J. Kilpatrick (Eds.), *Theory, Research & Practice in Mathematical Education* (pp. 27-45). University of Nottingham, UK: Shell Center for Mathematical Education.
Ability Grouping in School Practice
Sharyn Gallagher
University of Massachusetts Lowell

ABSTRACT
This paper reviews the research on the practice of ability grouping in schools, with particular focus on teaching mathematics in 7th and 8th grades. Ability grouping can be practiced in several ways in classrooms and its effectiveness has been studied for close to 40 years. There tend to be two views of ability grouping: student achievement versus equity of education. Proponents of the practice point to the ability to focus on common student needs within a classroom and therefore, to challenge students at their ability level to achieve appropriate educational goals. Critics of ability grouping note that students may not have access to the same educational opportunities. Often these students are disproportionately from disadvantaged backgrounds. All students benefit from attempts to improve education; most research supports ability grouping as one method that can assist with improving student achievement.

INTRODUCTION
Ability grouping is the concept that students should be placed in classrooms with other students of like ability. Ability grouping practice had begun in schools in the late 1800s as a way to help focus instruction and to challenge students at an appropriate level and maximize their learning. Educational researchers have been studying the effectiveness of this practice since the 1960s (Westchester Institute for Human Services Research, 2002).

The practice of ability grouping was challenged 20 years ago by those who argued that it somehow violated the principle of equity in education. Studies such as that conducted by Oakes (1985) questioned why students placed in the top classes with the best teachers were overwhelmingly white. Lower ability level students appeared not to be getting access to a quality education. Critics called for an end to grouping practices so that all students could have equal access to educational resources.

I became interested in studying this topic due to my personal interaction with school, as a student, parent and educator. My own education in the public schools included ability grouping in mathematics and English language arts beginning in fourth grade. In junior and senior high school, science, foreign languages and social studies were also taught in ability groups.

When my older child reached middle school, ability grouping was not practiced except for 7th and 8th grade mathematics; mathematics curriculum varied depending on the level of the class (pre-Algebra, Algebra, etc.). Four years later when my younger son reached middle school, ability grouping in mathematics had been discontinued because all students were to study the same curriculum (i.e., all 8th graders would take Algebra). I was skeptical about how this could be done because some students were having trouble with third grade mathematics skills; how could these students learn a subject when there were other students (like my son) who were advanced in mathematics, without either end losing out? I initiated discussion with public school teachers and administrators from different districts.

Taking a course in Education Reform provided me with the opportunity to do a more detailed study of the issue. It also coincided with conversations that some parents and I began with our school system to make sure that all students were being appropriately challenged to work at their peak level. It has been most helpful to me to review the research to see the pros and cons to frame my position.

The following sections are included in this paper: an outline of the key issues that define this debate; a description of the research methodology employed in gathering data and information about the topic; a review of research; a discussion of the research findings, patterns and intersections; and my concluding remarks.

DEFINING THE KEY ISSUES
Equity for all students requires a full range of opportunities that can stimulate each person to fully tap his or her interests and capabilities. Equity for all requires challenge for all.
— Distributed to staff in an urban public school district, April 2004

Ability grouping is the grouping of students for the “purpose of providing curriculum aimed at a common instructional level” (Fiedler, Lange & Winebrenner, 2002). When grouping students according to their perceived learning capabilities, curriculum can be differentiated for each class so that the top students are pushed farther and faster than slower learners who may need
more time or practice to master concepts. Teachers can focus their instruction on the relatively homogeneous needs of students in their classes to help those students fulfill their learning potential.

There are several ways in which ability grouping occurs in a school, such as within-class grouping, between-class grouping and tracking (Westchester Institute for Human Services Research, 2002). Within-class grouping is the practice of dividing students of similar ability into small groups; these groups either work on a project together or work with the teacher while other groups do related work. This is a common practice used in reading in elementary schools. Between-class grouping (also known as homogeneous grouping) refers to the practice of assigning students into different classes based on their perceived learning abilities. Sometimes between-class grouping is done across grade levels; for example, any student in 7th or 8th grade that reads at a high level is placed together in an advanced reading class. Tracking is defined as a practice of grouping students together for a series of courses, which was the typical practice before the 1980s. A track refers to the level of coursework a student takes (honors, remedial, etc.) The “anti-tracking movement” refers to people working to eliminate any ability grouping in schools (Loveless, 1999). My use of the term ability grouping in this paper is meant to reflect the between-class grouping scheme.

Other terms that relate to this discussion include heterogeneous grouping and differentiated instruction. Heterogeneous grouping is the process of assigning students to classes comprised of all levels of learners. Sometimes other dimensions are sorted on as well, such as racial background or socio-economic status. Differentiated instruction uses a variety of techniques and assessment tools to provide students with different channels for acquiring content and building knowledge (Tomlinson, 1995); differentiated instruction recognizes that students learn in different ways and learning can be assessed more effectively by more means than just paper and pencil tests. Differentiated instruction is often promoted with heterogeneous grouping as a superior classroom model to ability grouping.

There are four common reasons cited to justify ability grouping (Oakes, 1985). First, students learn best when in groups with those like them academically. This prevents the fast learners from being held back by slower learners and enables slower learners’ deficiencies to be addressed more directly. Second, attitudes of slower learners are more positive since they are not performing in the presence of students who are faster. Third, placement processes which use a variety of criteria for sorting students into levels is fair and accurate. Fourth, it is easier to teach, manage and fulfill individual student needs that are fairly homogeneous.

There are four common reasons cited when criticizing ability grouping. (Westchester Institute for Human Services Research, 2002). First, students in higher-level groups tend to be white and from middle/high income families. Thus some people conclude that the practice must be racist or elitist. Second, curriculum in lower level courses is low quality; it is not as challenging or engaging as in higher levels preventing access to an equivalent education. Third, lower level classes tend to be taught by poorer quality teachers. Last, labeling children publicly by the kind of class in which they are placed hurts their self-esteem and becomes a self-fulfilling prophecy for future performance (p. 2).

Research outlined in this paper will present more detail behind the arguments for and against the concept of ability grouping.

**RESEARCH METHODOLOGY IN GATHERING INFORMATION**

This paper is predominantly a review of literature related to the topic of ability grouping. As such, I sought out relevant sources that contained an analysis of data on this topic.

I acquired two meta-analysis studies on this subject as part of the reading for a doctoral course in education here at the University of Massachusetts Lowell (UML) in Spring 2004. These articles supported ability grouping. This surprised me because I had been led to believe by some staff in public schools that current research favored heterogeneous classes. I had subsequent conversations with the professor for that course and another professor who specializes in mathematics education at UML. Their comments in support of this topic encouraged me to pursue it in more depth.

Some of my resources came from the press but the majority came from researching various electronic databases at UML. The subject of ability grouping has been studied for decades, sometimes focusing on grade levels and other times focusing on course subject. In order to narrow the scope to a more manageable size, I decided to pursue information pertaining to ability grouping in 7th and 8th grade and/or mathematics in the United States.

Two online educational databases available from UML Libraries, ProQuest and EBSCO Host, were queried for journal articles on “ability grouping”, turn-
ing up hundreds of matches. There were several names that appeared frequently either as author or as a citation in another's work and tend to be regarded as experts in this field: Tom Loveless, Jeannie Oakes, James Kulik and Robert Slavin. I also queried the UML Library database for books on this subject and found a few match-
es, although they were less useful than the journal articles I acquired.

No study of ability grouping would be complete without reading Jeannie Oakes's book *Keeping Track*, published in 1985 and available in the UML Library. Given the other studies that were being published around that time about the poor performance of U.S. schools, this book stirred up a debate that still swirls. This book describes the core elements that are used to criticize the practice of ability grouping even today. She has produced subsequent studies that she uses to buttress her arguments.

In addition, I looked for some information related to “differentiated instruction” in both the two online databases and the UML Library since that topic is often mentioned as the technique to employ in lieu of ability grouping. There were not many resources which studied the effectiveness of this technique; most of the articles that I found discussed how to differentiate instruction but did not give any data about the limits of this technique (as will be discussed later).

I interviewed the assistant superintendents of curriculum for two neighboring public school systems in northeastern Massachusetts, one urban and one suburban, about this issue. Both referred me to other resources that were somewhat helpful. Several informal conversations were held with school personnel in many school systems throughout Massachusetts (my fellow student peers) about their practices. Some of their comments are referenced throughout this paper.

**MY FINDINGS**

**OAKES CHALLENGES ABILITY GROUPING**

The current debate about ability grouping was ignited by Jeannie Oakes's book, *Keeping Track*, which was published in 1985. Oakes studied data collected from 13,719 students in 25 schools in grades 7-12 across the country in 1977; the schools chosen reflected the diversity in American schools. This study was one of several that were being conducted with the same data about the state of schools. All of the schools had some form of ability grouping but varied in the sorting of students into classes. Oakes focused on the educa-
tional outcomes for students, such as classroom content, teaching quality and expectations. She also focused on mathematics and English courses since these courses were taken by most students and the content of them was fairly consistent across schools. She raised concerns about several issues that she observed which seemed to relate to how students were grouped into homogeneous classes (she used the term tracked classes, as I will here to present her points).

Although she did not evaluate the various methods by which schools placed students into tracks, she did note many common outcomes. First, the proportion of students from different races and lower socio-economic statuses (SES) was much higher in lower ability groupings than the other groupings. She concluded that ability grouping was being used to discriminate against these students. Second, the curriculum and teaching techniques across the various tracks were not the same: high tracks tended to teach more high status concepts and principles and encourage critical thinking while low track classes tended to teach basic skills and develop work habits and job skills that those students would be most likely to need. As a consequence, students in lower ability classes would be unlikely to be able to move up to a higher grouping because they were not getting the same breadth of curriculum necessary to do so. This, then, could perpetuate their low SES status. Third, teaching quality and expectations varied. Typically, students in higher tracks were taught by the best teachers who inspired them to work hard and develop intellectual independence; students in lower tracks were taught by teachers with less experience who did not generally challenge them to grow intellectually and who encouraged behavioral compliance. Fourth, time spent in active learning varied, with lower tracks spending more time on administrative or behavioral issues than on content. Homework time also varied with the higher tracks receiving about 30% more homework than the lower tracks. Last, student attitudes were different. Higher ability students had higher aspirations for life after high school (attend college, commence career) and higher self-esteem; lower ability students had low aspirations (begin job) and lower self-esteem. She referenced some studies from the prior 50 years that showed only the top students benefited from ability grouping and that the average and slow learners suffered.

Oakes (1985) acknowledged that there are factors outside a school's control that affect a student's motivation to learn, such as personal issues or family attitude towards education. However, in a country that prides
itself as a meritocracy with equal opportunity for all to rise as far as possible in life, Oakes argued that our educational system was not supportive of that notion. She concluded that ability grouping discouraged equal opportunity in education and must be eliminated.

Oakes and Wells (1998) reviewed the successes and challenges at ten schools of various sizes and located in various states, which began steps towards detracking. All were racially mixed and varied from 500-3000 students. These schools began by eliminating their lower level classes and adopting a variety of other measures (such as providing “double dose” instruction for struggling students, special tutoring assistance and multicultural curriculums.) They did not detrack as completely as they had hoped due to stiff opposition from parents who challenged the impact to the high level learners.

**Loveless supports ability grouping**

Loveless (1999) investigated the tracking reform movement by surveying 373 middle schools in California in 1991 and 1994 and 134 middle schools in Massachusetts in 1995. He discovered that many schools were in the midst of grappling with how to implement recent state advisories that recommended (but did not mandate) that ability grouping be discontinued. He stated that the decision about ability grouping is more than a discussion about race and class, but included variables about how educational policy is set in a town, each school’s characteristics, political influences and the technical challenge of the reform. The key outcome that should be the deciding factor when any reform is implemented is whether the educational achievement of students is improved and his data showed that eliminating ability grouping did not improve achievement.

Loveless (1999) reviewed several important studies about ability grouping. The two most frequent outcomes that are debated concern student achievement, especially of top students, and racial equity. Positive outcomes for within-class ability grouping in elementary school were found by most studies. He cited one study by Kulik and Kulik that detected consistent gains in achievement for all high school students when curriculum was adjusted for their learning level.

Loveless (1999) noted that many of the other studies that looked at this topic were done before reforms were made, and that ability grouping today is much different than tracking was years ago. Grouping now tends to vary by subject and can change from year to year; previously students were in a single group for the entire day for all subjects. Previously students were assigned to levels based upon IQ tests but now performance on pre-requisite work and teacher recommendations are used in addition to standardized tests. Using data from large national databases, such as National Education Longitudinal Study (NELS), does not include information on how classes are grouped. Schools that had mixed-ability classes often ran them as trials with volunteer students and teachers, which would not reflect the same results of classes where students and teachers were assigned randomly. Thus, results from these studies may not be relevant in setting policy today.

In reviewing the work of Oakes (1985), Loveless (1999) noted the comprehensiveness of data collection that was done and that some of her findings, such as the poor curriculum for low level classes, had been substantiated by other researchers. However, there were other claims that did not appear to be valid. The assertion about racism was contradicted by charts showing data by race for National Assessment of Educational Progress (NAEP) reading scores, NAEP mathematics scores, SAT scores and high school dropout rates.

The outcome gaps between white students and other racial groups shrank considerably in the ten-to-fifteen year period before the book’s publication in 1985 (p. 23). The progress of these same students slowed markedly after 1985……Outcomes were more equitable in 1985 than they were before 1985, and they made little progress on the equity front after that, even as the antitracking movement gathered steam and schools across the country embraced heterogeneous grouping. (p. 26)

There were several other findings that Loveless (1999) described. Urban areas that tended to have a greater mix of races had detracked classes more than suburban areas dominated by one race. Suburban areas with more high-achieving schools tended to hesitate to change programs which may be cause for their success. Subject area often influenced the conversation about ability grouping, with mathematics being the subject most commonly tracked in grades 7-12.

Heterogeneous grouping can negatively impact remedial students, especially during times of budget pressures. Classes for lower-level learners tend to have a lower student-to-teacher ratio than classes for average or higher-level learners. Putting the lower-level learners into larger classes with mixed ability students gives them less attention. Most teachers interviewed felt like
they could not successfully meet everyone’s needs. “You cannot successfully teach three things at one time” (Loveless, 1999, p.72).

Loveless (1999) pointed out several issues that had not been answered throughout this debate and required additional study before a definitive statement about ability grouping could be made. Since this study was based on data collected before 1996, schools did not have enough experience with detracking to fairly evaluate its success, although there was much anecdotal evidence. The first question that is typically asked is what happens to the students at both ends of the learning spectrum? High achievers can become bored if the pace is slow and low achievers may languish as lessons speed ahead of them; for example, nonreaders will not be able to learn to read by hearing a fluent classmate read aloud. If class sizes are large, a teacher may not have enough time to focus on each child’s need and provide detailed feedback to help each child advance.

Another unanswered question related to student behavior. Historically, lower track classes have had more students with behavioral problems. Dispersing these students across heterogeneous groups may have helped diffuse these problems and provided them with better examples of appropriate behavior, but Loveless found no evidence that this systematically occurs.

The issue of the impact to teachers’ work was also an unanswered question. With heterogeneous classes, there could be fewer preparations needed, but learning new instructional methods to effectively respond to varied abilities in the classroom takes time. Maintaining quality of education during the transition can be difficult.

Loveless (2003) reviewed updated data and summarized the debate more succinctly. He cited metastudies conducted by Robert Slavin (a tracking critic) and James Kulik (an ability grouping defender). Both Slavin and Kulik agreed that within-class ability grouping enhances achievement for all students in elementary classrooms. Slavin found that ability grouping had no benefit in grades 7-12, however his data was from old studies of classrooms that are unlike today’s; he also omitted data from programs targeted specifically to gifted students which may have resulted in skewed results. Kulik found that providing top students with an advanced curriculum did affect their academic achievement. Both Slavin and Kulik agreed that tracking does not hinder the achievement of any group.

Loveless (2003) also reviewed national surveys that collected data over the past 20 years, High School and Beyond and the National Education Longitudinal Study (NELS). Three key findings emerged: High ability students learned more than low ability students, even when prior achievement and other variables were statistically controlled. Second, race had no bearing on track assignment; NELS data showed that the gap in achievement between African-American students and white students was greatest at 8th grade and remained unchanged. Since students had been in heterogeneous classes throughout most of their K-8 schooling, ability grouping could not be to blame. When prior achievement was taken into account, disparities vanished. Third, NELS data revealed risks in detracking.

Low-achieving students seem to learn more in heterogeneous math classes, while high and average achieving students suffer achievement losses – and their combined losses outweigh the low achievers’ gains. In terms of specific courses, eighth graders of all ability levels learn more when they take algebra in tracked classes rather than heterogeneously grouped classes. For survey courses in eighth grade math, heterogeneous classes are better for low achieving students than tracked classes. (p.12)

Loveless (2003) found little conclusive evidence that ability grouping harmed a student’s self-esteem. Being in a lower level course may have caused embarrassment to some students, but so did the public display of a lack of knowledge or understanding in heterogeneous classes.

As for the permanence in a low track course, Loveless (2003) did find movement from year-to-year of students at all levels. However, there were a number of students who remained in the low track. He conjectured that perhaps the personal qualities needed to strive to improve, such as achievement motivation, independence and drive, may be lacking in many of these students. He cited a study by Camarena and Gamoran which found that in Catholic schools, students in low tracks did make significant progress, due to a stronger curriculum, a school environment that supported achievement and, most especially, the effort of the student.

Loveless (2003) emphasized that no matter what the data says about ability grouping, it should not side-track society’s efforts to improve the quality of education for all students.
OTHER PERTINENT STUDIES

The Westchester Institute for Human Services Research (2002) succinctly summarized the evidence found in other studies. Their findings included the fact that high-level learners who had a curriculum tailored to their skill level had positive benefits and low-level learners neither benefited nor suffered from ability grouping; this would cause the gap between these two groups to grow larger. Gaps in instructional quality existed, with higher-level students getting more thought-provoking and coherent instruction throughout whereas low-level students received more rote and mundane instruction with much less integration (coherence) of concepts. Students from lower income levels and/or who are black and Hispanic tended to comprise a higher percentage of students in the lower groups compared to Asians and whites. It was mentioned that there were not enough examples of truly untracked schools to compare in research studies to support detracking.

Fiedler, Lange & Winebrenner (2002) reviewed research and identified six commonly-held misinterpretations which they rebutted. Throughout this article they cited the need to challenge high-level students to enable them to achieve their potential. First, tracked classes from pre-1990 did not necessarily relate to ability-grouped classes of today, so they urged caution when making conclusions from old data. Second, countering the argument that ability grouping was elitist and racist, the authors pointed out that schools lauded talented athletes and provided separate teams (varsity, junior varsity) to reflect ability differences, and some sports were dominated by certain races than others. To not recognize intellectual ability or to label doing so as elitist was unfair. Also, in heterogeneous classes, a strong student might develop arrogance because he or she was one of a few in the class that is bright; being in a homogeneous class was more humbling as the student was most likely not always the best. Third, as for the charge that ability grouping was discriminatory, using a variety of performance-based measures instead of one test justified the classification system. Fourth, some studies did not show much affect on high-level student learning when in separate classes, which these authors said may be due to the “ceiling effect” of testing methods; if there are not enough challenging questions to capture good data on high learners’ achievements then one cannot detect how far they actually progressed. Fifth, many academics and policy-makers suggested that cooperative learning techniques in heterogeneous classes may help, but if the gap in capabilities of the learners is too wide, then this technique will not succeed. Sixth, opponents claimed that classroom climate improved when children of mixed abilities were together, assuming that otherwise students with poor behavior were concentrated in low-level classes when ability grouped. However, Fielder et al. (2002) pointed out that this assumed that high-level learners would behave the same regardless of class grouping, and this is not always the case. They cited research which revealed that students emulated behavior of those most like them in ability, thus low-level students with poor behavior were not likely to follow the examples of well-behaved high-level learners.

Carbonaro (2005) looked at the subject of ability grouping in a different way. He examined the relationships of students’ effort and ability grouping on students’ achievement and concluded that students in high-level classes exerted more effort than did students in low-levels. It was effort that related to learning and achievement regardless of the track of class a student was in. Differences in effort that students exerted were a function of both prior effort and achievement and the quality of the experience within the class. He suggested that further study be done in this area because effort was not only influenced by the instruction of the teacher but also by peer pressure and school environment.

Rudin and Lane (1998) cited Killion and Hirsch who noted that middle school students tended to do less well on national exams than they did when they were in elementary school. Many programs had been tried to change this result, but no clear methods had emerged as being effective. Since ability grouping had been in use in many 7th and 8th grades to some degree for decades, its effectiveness had been called into question as well. Rudin and Lane (1998) acknowledged the typical pros and cons of ability grouping but also identified these factors as not adequately included in the dialog: teacher groups supported ability grouping; teachers believed that homogeneous classes were easier; and student peer group norms, values, beliefs and media were strong influences on student performance.

PATTERNS AND INTERSECTIONS OF THE RESEARCH

Nothing is so unequal as the equal treatment of unequal people.

Thomas Jefferson

The timing of the publication of Oakes’ book was ripe for attention. In 1983, A Nation at Risk was published by the National Commission on Excellence in
Education indicating that schools had not kept up with changes in society. America's future depended on how well it educated students for an interdependent economy. Policy-makers and reformers developed several changes to school systems in an attempt to deepen student learning and achievement. Practices for grouping students were challenged as discriminatory. Many states, including California and Massachusetts, issued policies discouraging tracking in the 1980s and 1990s despite the fact that there was not much conclusive research to substantiate the claims (Loveless, 1999). The No Child Left Behind Act has challenged all school systems to improve the outcomes of their efforts to educate our children.

The debate currently tends to focus on two key positions: Achievement (specifically ensuring that top students are not held back in learning) versus Equity (providing the same education to everyone regardless of ability, race or economic background). Haury and Milbourne (1999) noted that studies which focused on achievement yielded different results than those studies which examined equity in education.

**The Need for Ability Grouping**

There is much research in support of ability grouping. The Assistant Superintendent of Curriculum for the suburban public school system says that students learn at vastly different rates and “it does not work to mix them.” (personal communication, March 22, 2005). Slavin (1990) mentioned Vygotsky’s Zone of Proximal Development concept which asserts that children learn from each other only when they are operating within a range of each other's intellectual developmental level. Loveless (2003) cited Slavin and Kulik as agreeing that within-class ability grouping benefited all learners. Oakes (1985) cited Bloom’s research that showed that the length of time to learn decreased for students as they experienced success.

Advanced learners can become mentally lazy and less motivated to work hard if success comes without much effort; student engagement is best if they can answer approximately 75% of questions accurately (Tomlinson, 1995; Hunter, 2004). In a mixed-ability class, if the Proximal Zone is too wide, the top students will be under-challenged and the bottom students will be lost. Both of these groups will lose interest in learning, and their behavior may reflect it.

Many teachers support ability grouping. By taking the strong students out of a class to be together, the other learners left in the class will “spawn new stars,” as students become less intimidated by the ones who always seemed to know the answer (Wisconsin Education Association Council, 1999). Especially over the past several years, when many state and local budgets were squeezed by recession, class sizes have risen, putting more of a burden on teachers. Putting the low-level learners into larger classes with mixed ability students gives them less attention; this lack of attention could mean the difference in whether they catch on to the material or not. High-level learners may also lose the personal attention that could push them to a deeper level of understanding. Teachers can feel discouraged at their inability to reach all students effectively.

Loveless (1999) stated that subject area often influences the conversation about ability grouping. In a dependent curriculum sequence, some learning objects are pre-requisite to others (Hunter, 2004). An independent curriculum sequence does not require material to be taught in a specific order. In a subject like English, students can study the same genre of literature but read different books according to their reading level. In mathematics, however, many teachers feel that content is a hierarchical sequence of concepts; students cannot be successful in future courses if they do not acquire the prerequisite knowledge. Over 95% of teachers and administrators that I have informally surveyed (representing over 20 districts) agreed that mathematics should be taught in ability-grouped classes beginning around 7th grade.

**Racism and Class Discrimination**

Oakes (1985) outlined several negative outcomes from ability grouping. The core of her argument was that ability grouping was a way for racism and class discrimination to continue to benefit the white middle and upper classes. But Hanushek and Raymond (2004) pointed out that separating the effects of race on student achievement was difficult because other influences, such as family factors, were correlated with racial composition. Carbonaro (2005) cited the factors of race and SES as less of an influence than effort, regardless of class grouping. The actual trends in achievement of white, African-American and Hispanic students in the 1980s run counter to Oakes’s assertion (Loveless, 1999). Loveless also quoted a Public Agenda Foundation report which said, “opposition to heterogeneous grouping is as strong among African-American parents as among white parents, and support for it is generally weak” (p.81).

Many studies (Oakes, 1985; Haury & Milbourne, 1999; Rudin & Lane, 1998) seemed to count bodies and calculate percentages, e.g., there are 23% black stu-
dents in the school but there are only 10% black stu-
dents in the top track. Loveless (2003) took into
account the selection criteria for the tracks in reviewing
the NELS data and found that race had no bearing on
class placement. “In fact, African-American students
enjoy a 10% advantage over white students in being
assigned to the high track” (p. 12). He also noted that
the gap in achievement between whites and African-
Americans is greatest at 8th grade, which is after learn-
ing in many years of heterogeneously grouped classes.
Thus, ability grouping does not appear to be racist or
discriminatory.

In addition, Loveless (1999) found that urban areas
that have a greater mix of races had detracked classes
more than suburban areas dominated by one race. For
example, one urban city in Massachusetts has 43%
white students and is untracked at 7th and 8th grades; its
neighboring suburban district in Massachusetts with
91% white students is tracked in 7th and 8th grades for
English and mathematics. Urban areas also tended to
have more low achieving schools and were more likely
to attempt new programs in the hopes of improving
student performance. Suburban areas with more high
achieving schools tend to hesitate to change programs
which may be cause for their success. The Deputy
Superintendent of Curriculum for the urban school sys-
tem noted that mathematics scores on standardized
tests were low and stagnant. “We had to do something”
to help students to learn more effectively (personal
communication, February 1, 2005).

POOR EXPERIENCES OF LOW-TRACK STUDENTS

Oakes (1985) identified the problems of poor qual-
ity instruction, low status curriculum and low expecta-
tions that she attributed to ability grouping. Other stud-
ies (Loveless, 1999; Westchester Institute for Human
Services Research, 2002; Hauri & Milbourne, 1999)
affirmed the existence of these problems. Some public
schools did away with “consumer math” and other
courses that were not rigorous; they now hold constant
the course requirements across the course levels but
vary the pacing and provide extra support for slower
learners. By ensuring that all courses contain the same
content, students are able to move between course lev-
els if they meet the pre-requisites. Loveless (2003) dis-
covered that, in fact, students do move between tracks,
so more students must be exposed to similar content. In
2003, one urban high school decided to discontinue its
“business” level track; a high school teacher told me
that some of those students are rising to the challenge
that the courses are offering and the higher expecta-
tions; other students are struggling and need special
support throughout the course (personal communi-
cation, March 22, 2005).

To blame tracking for these problems with instruc-
tion, curriculum and expectations may be ignoring the
true cause(s). Loveless (1999) cited Slavin as saying that
untracking would not improve student performance
unless curriculum and instruction changed. Carbonaro
(2005) reinforced the view that providing a more stimu-
lulating curriculum would motivate more low-level stu-
dents to exert more effort. Loveless (1999) hypothe-
sized that if the problems had been described differen-
tly, we may have taken different steps. If the quality of
the experience in the low track had been defined as the
problem, special focus for improving that instruction or
rotating the best teachers to teach different levels would
help. If low standards and expectations were the prob-
lem, more rigorous standards could have been imple-
mented. A school committee-woman from the urban
school system says that the biggest complaint she hears
from parents is that class work is not rigorous enough,
and most of these parents have children who are high-
level learners (personal communication, February 17,
2005). Perhaps the depressed standardized test scores is
less about ability grouping and more about the content
and requirements for all learners.

DIFFERENTIATED INSTRUCTION.

Slavin (1990), Hunter (2004) and Tomlinson
(1995) promoted the use of differentiated instruction
with heterogeneous group learning as an alternative to
homogeneously-grouped classes. Students work in
teams to produce projects and help each other learn.
Teachers can have activities and assignments that chal-
gen each student at his/her own level and use multi-
ple approaches to teach a lesson.

This sounds like a good solution, having children
of all abilities working together, learning from each
other, and being challenged. However, there are several
unanswered questions about its effectiveness. How
many levels can be effectively taught within one class-
room—three grade levels of ability, six grade levels, or
does it not matter? Is there a maximum class size—does
the technique work equally well in classes of 20 or 30
students? Does course content affect its success—does
this work for mathematics but not science? In using a
variety of projects, do we lose the rigor typically
involved when frequently expressing thoughts in writ-
ing? It takes years of practice to do differentiated
instruction well and Wisconsin Education Association
Council (1999) suggested that ability grouping is
important during this transition time to ensure that high-level learners do not lose out.

**Equity and Budgets**

Oakes and Wells (1998) described several programs that ten schools working to detrack classes had put into place to support the lower level student. One school had a special calendar to schedule classes to benefit these students, another provided extra classes. There were homework centers, summer workshops and special tutoring. In Massachusetts, there are special support services available to students who fail the MCAS exam. In 1994, U.S. public schools spent $285 billion on K-12 education and less than 2% is targeted for gifted learners (Mosteller, Light & Sachs, 1996; Capello, 2004). Most federal assistance programs target the remedial segment.

Slavin (1995) and Oakes (1985) contested ability grouping because they believed that it was undemocratic to provide a different education to different students. Loveless (2003) points to polls indicating that the majority of teachers, parents and students preferred ability grouping and thus continuing this practice reflects democratic decision-making. Given the amount of money that is spent on programs to support slower learners, one might question the equity in spending so much money to support that one segment of learner, let alone the effectiveness of those programs. As governmental budgets strain, how can we best allocate our funds for every child’s success?

**Agreement**

There seems to be one conclusion on which all research agrees: more thorough studies need to be conducted in this area. Loveless (1999) acknowledged the data that Oakes (1985) used was thoughtfully collected and processed, however it was done 28 years ago. According to Capello (2004), Oakes said that Kulik’s work was not rigorous and Kulik said that Oakes’ work was more rhetoric than science. Schools have implemented many programs to mitigate some of the concerns that Oakes raised in 1985. Scholastic Aptitude Tests and IQ tests have become more sensitive to cultural bias and have attempted to minimize such bias. There are not enough good examples of schools which are untracked to use for such research (Loveless, 1999). However, with so many variables that might be subjectively measured (teaching quality, for example), it may be difficult to ever conclusively answer this question.

**Conclusion**

Schools create policies for collectivities, for all of the students, parents, faculty, and assorted parties who operate within the educational enterprise?…Parents’ interests, on the other hand, are anything but universal, focused instead on protecting the interests of specific children: their children.

—Loveless (1999) p.81

The concept of ability grouping is a polarizing discussion. There are very valid concerns expressed by its opponents about the quality of low-level education. However, most research indicates a high opportunity cost to the high-level students when not in leveled classes.

The rigor of education for the high-level ability learners declines in the heterogeneous grouping with differentiated instruction environment. Perhaps teachers need more time to become proficient at teaching successfully in such environments, however each child only has 180 days each year to master grade level material. Parents are concerned that high-level learners will be challenged less than they deserve, become less motivated about learning and begin having conduct issues because they are either unoccupied or bored.

Equity of education means that each child can get an education suited to his or her own needs. There are so many other variables, such as effort exerted and parental support that affect a student’s performance that no school can expect to have all students performing at the same level. Adults work in different jobs because they have different abilities; public schools should not be afraid to admit that differences do exist.

Schools should continue working to improve the state of education. Teachers can improve their teaching methods to provide more challenging work to students of every level. Course content at each level can be reviewed to ensure that students are learning meaningful material. Expectations about what students should accomplish should be raised. All students can benefit from such efforts to raise the quality of education. Ability grouping will help with its delivery.

**References**


Fiedler, E.D., Lange, R.E. and Winebrenner, S. (2002). In search of reality: Unraveling the myths about tracking, ability grouping and the gifted. [Electronic version]. Roeperv Review, 24(3).


Finding Hope Where We Need It: Leading from the Gifts of Resilient Teachers

Cynthia Jacobs
University of Massachusetts Lowell

ABSTRACT
In high poverty communities, teachers face dispiriting prospects for their students. Many fail to graduate, few pursue post-secondary education, and in some schools the majority of students are assessed as failures by increasingly weighty standardized achievement tests. Given the well-demonstrated effects of teachers’ expectations on student outcomes, it is troubling to consider the repercussions of working amidst such high levels of educational failure. This paper examines the literature on hopeful and resilient teachers and its implications for educational leadership. Social justice motivation, love for students, intellectual stimulation and meaningful contact with colleagues appear to be important shared characteristics of these teachers. Future research in this area could improve recruitment and retention of these teachers in communities where positive expectations for students are especially critical.

While a good deal of educational research and reform effort has focused on the problems of education in major urban areas, less attention has been paid to communities known as “third-tier cities,” declined industrial centers with high rates of poverty and unemployment and relatively small populations. There are 396 such cities across the United States (Dutch, 2001) and the Commonwealth of Massachusetts ranks third for the number within its borders (Committee on Industrial Theory and Assessment, 2004). Presently, in many of these communities, limited education and continued poverty are likely outcomes for the majority of students.

In these cities, teachers’ optimism would seem to be significantly challenged by the simple probability of students’ failure. This is problematic, especially given the need for an effective educational system in these communities, since we have long known that teachers’ hopes and expectations for students have a powerful effect on student outcomes (Rosenthal & Jacobsen, 1968; George & Aronson, 2003). Despite the probabilities, we know that some teachers in high poverty communities do remain hopeful (Nieto, 2003; Patterson, Collins, & Abbott, 2004). Taking as a given the importance of teachers’ optimism regarding student potential, what follows is an exploration of how these teachers construct their hopes for students. A better understanding of hopeful teachers may point a way for researchers and educational leaders to more effectively recruit, retain and support teachers who have positive views of their students’ futures.

A CHALLENGING CLIMATE FOR HOPE

According to Massachusetts Department of Education reports on 2004-2005 standardized testing, a third or more of all students failed the eighth grade math test in more than one quarter of Massachusetts districts. In the third-tier city of Brockton, 51% of students failed both math and science tests in the eighth grade; 52% of eighth graders in Fitchburg failed in math, as did 70% of eighth graders in Holyoke and 53% in New Bedford. By tenth grade, the situation has improved somewhat, but failure rates in four third-tier cities (Holyoke, Fall River, Springfield, and Lawrence) still range from 37 to 46% (Massachusetts Department of Education, 2005). This situation is not unique to Massachusetts (Gordon, Piana, & Keleher, 2000).

As we think about how teachers face these probabilities at a time when teacher, student, and school performance are increasingly judged by such assessments, one possibly telling set of findings concerns teachers’ sense of efficacy. Surprisingly, efficacy has not been consistently found to be linked to students’ test scores (Gresham, 2001). While the inconsistent findings may be due to problems with the construct of efficacy and its measurement (Henson, 2002), there is at least one other possible alternative explanation. It may be that, for many teachers, especially those in schools with high rates of failure, separating certain objective outcome expectations from personal job goals has a protective effect. If the officially sanctioned goals and activities lead most often to failure, one way to avoid a sense of one’s daily work as meaningless or absurd would be to adopt a different set of goals, strategies, or both. This possibility raises an interesting question for educational leadership. If teachers with more positive expectations for their students are indeed also more effective teachers, from what do they derive their motivation and hope, and can their approach be productively adopted by leaders and shared with other teachers?
WHAT DO WE KNOW ABOUT HOPEFUL TEACHERS?

A small number of recent studies have looked at teachers’ hope and resilience through qualitative and quantitative methodologies. Some of their findings converge in a set of key characteristics of hopeful teachers.

SOCIAL CHANGE MOTIVATION.

Teachers who remain committed to their students’ growth in high poverty schools appear to come to teaching with “social justice” as a key motivation (Nieto, 2003; Patterson et al., 2004). “I felt there is something wrong with a society that doesn’t make kids learn and then sends them to prison, and I couldn’t be an engineer anymore. I just had to try to do something. So, I made a really purposeful decision to be a teacher” (Patterson et al., 2004, Findings, Section 1, ¶3).

LOVE AND CARING

Nieto (2003) is rare among researchers to describe this so simply, but she found that the highly effective teachers she studied often used the word “love” to describe their depth of caring for their students. Noddings (1984) discusses something similar in her construction of “caring.” This does not “imply romantic love” (p. 471) but working “from a position of respect or regard for the projects of the other” (p. 472). Patterson et al. (2004) relay a teacher’s story that echoes the findings of Epstein (2001) on the positive feeling that results from greater depth and breadth of contact with students’ lives. In this story, a teacher struggles for several months to engage a fifth-grade student and ultimately finds some success by linking him to a community-based mentor with whom she, too, develops a relationship. In the meantime, the teacher has had to block an attempt by the principal to move the boy to another classroom. While many teachers might (understandably) welcome relief from a difficult student, hopeful teachers seem to view their compassion as central rather than peripheral to their relationships with students.

INTELLECTUAL STIMULATION

Firestone and Louis (1999) claim that schools too often foster anti-intellectual environments where teachers and mathematicians disagree about “what the subject is” (p. 312). Hopeful teachers, even when they find themselves in schools which do not offer many such opportunities, seem to seek out (and successfully find) intellectual stimulation through informal collaboration with colleagues and more formal professional development, including involvement in curriculum development, classroom-based research, attending conferences, and publishing articles (Nieto, 2003; Patterson et al., 2004).

MEANINGFUL CONNECTION TO COLLEAGUES

Patterson et al. (2004) also found that the teachers they studied were more likely to take on leadership and mentoring roles within their schools, often without being asked or appointed, and much of the intellectual stimulation described by Nieto (2003) involves contact with colleagues. In both cases, it appears that these activities are initiated by the teachers and their peers.

CONTACT WITH/UNDERSTANDING OF STUDENTS AND THEIR FAMILIES

In her work on parent involvement, Epstein (2001) describes a new degree of positive regard for students and their families that appears to result from (rather than be a prerequisite for) efforts to involve parents. George and Aronson (2003) also present evidence that when teachers engage with students on a “more personal basis” (p. 13) they are less affected by stereotypes of student populations and become more supportive and willing to invest attention and time in students. Although these researchers do not discuss hope specifically, the positive attitudes increased willingness to invest time and effort in students and families, and reduced (consistently pessimistic) stereotyping, all seem likely to be associated with more optimistic views of student potential.

Previous research has clearly demonstrated that a teacher’s positive outlook for students has a powerful effect, in and of itself, on student achievement. The research described above begins to tell us more about teachers who retain such an outlook even in discouraging conditions. Some of these teacher characteristics (e.g., an inclination to pursue professional development) seem likely to contribute on their own to achievement. Future research could explore the causal and other relationships among these factors to determine how hopeful teachers might be attracted to and best supported in the educational system. Current findings alone, however, may offer some guidance in working with these teachers. In the following section, the teacher characteristics described above are discussed in light of research findings regarding educational leadership.
CAN LEADERS FOSTER HOPE?

Sence of purpose

Just as teachers appear to be supported in their work by a commitment to social justice, Louis, Toole and Hargreaves (1999) suggest that school leaders, too, might draw strength and direction from a personal sense of mission. This may support the leader’s own resilience but Louis et al. discuss the importance for the organization as a whole as this personal sense of purpose provides a “compass” (p. 260) in leadership. While these authors do not advocate for a social justice mission per se, George and Aronson (2003) are explicit in calling for educators to “acknowledge the negative impact” of “educators’ low expectations, based on racism or stereotyping” (p. 13), to “celebrate diversity and affirm self-worth” and to “promote equal opportunities for all students” (p. 15).

A leader’s clarity of purpose and public attention to a sense of moral purpose might help to counteract the troubling phenomenon Estola (2003) observes, in which young teachers are ashamed of their hopefulness about the idea of creating some sort of change through their work. It would seem foolish to allow young teachers’ hopes to be silenced, but Estola’s findings are not entirely surprising in light of the school culture described by George and Aronson (2003) or by Epstein (2001) when there is a lack of concerted efforts to counteract stereotyping and low expectations. Nieto (2003) in fact found that the effective teachers she spoke with (many of them veterans) were quite clear that the “ability to shape the future” was something that kept them committed to teaching (p. 18). A leader who shares such a vision seems far more likely to be successful in recognizing and supporting the same among staff.

Community

Beck and Foster (1999) call for leaders to see the “well-being of persons and their communities” as “a central and public purpose” (p. 352) of all schools. They argue that the administrator’s traditional focus on “efficiency……impartiality, and the dominance of individualism” (p. 352) works counter to a community-like school, the kind of school that would seem to be recommended by and supportive of “caring” orientation (Noddings, 1984) of the successful teachers described above.

Epstein’s (2001) findings regarding “family-like schools,” which would also seem to support these teachers, are quite consistent in showing that it is teachers (not parents) who are the “gatekeepers” of parent involvement. When schools make effectual efforts to reach out to parents (even in highly stressed, low income communities), teachers have more positive feelings about parents, students feel a greater sense of congruence between home and school, and they achieve more. Epstein makes very clear however that these efforts require substantial time, attention and facilitative structure. The role of the school leader is thus critical in supporting teachers’ efforts to work with parents. How they provide that support (through what sort of reward and organizational structure) is not a simple question (Ogawa et al., 1999), but this is clearly an important goal.

Natural leadership

The hopeful and successful teachers described by Nieto (2003) and Patterson et al. (2004) very often find and create their own opportunities for professional development, leadership, and mentoring, and seek out intellectual stimulation. By contrast, Firestone and Louis (1999) and Ogawa et al. (1999) associate teachers’ conformity and comfort in traditional structures with a “culture of blame” in urban schools. Putnam and Feldstein (2003) describe many situations where natural leaders emerge and organizations become most successful when organizers or administrators simply step out of the way and allow these leaders to bring together and motivate others. It may be that school leaders can create the most supportive environment for hopeful teachers by allowing them to emerge and evolve.

We are left with something of a circular problem here. It appears that hopeful and resilient teachers, almost by definition, find ways to meet their own professional needs regardless of an inhospitable setting. If we are to ask, then, what kind of leadership might support them, one answer seems to be any kind — the key is to find those special teachers. There may however be some lessons to be drawn from studying their approach to the work of teaching. Some of these lessons may even provide a model for hopeful leaders. In communities where students and teachers see so much failure, low expectations threaten student achievement. Current findings suggest that in recruiting, training, supporting and studying hopeful teachers, we will begin by recognizing their commitment to social justice, their compassion for students and families, and their view of education as an intellectually stimulating field. Through future research on resilient teachers we might effectively adopt hope as an educational strategy.
References


Henson, R.K. (2002). From adolescent angst to adulthood: Substantive implications and measurement dilemmas in the development of teacher efficacy research. Educational Psychologist, 37, 137-150.


The Real Challenges Facing Urban Public Schools in the 21st Century: Increasing Violence and Decreasing Social Capital

Charles Caragianes
Lowell High School

ABSTRACT

The demographics of urban public schools are rapidly changing in the United States. Students of color currently constitute more than one-third of students in public schools in America and by the year 2035 will constitute more than half of total school enrollment nationwide. These students live in poverty at a disproportionate rate, and are disproportionately Limited English Proficient (LEP). To compound these challenges urban public school students are also witnessing ever-increasing rates of violence in their neighborhoods, while experiencing ever-decreasing opportunities to build their own social capital through internships, community programs, and extracurricular school based activities. Helping to reverse the trends of increasing urban violence and decreasing social capital, as experienced by students, are goals the public schools must take on if our children are to be successful in the future.

INTRODUCTION

Read or listen to virtually any major address on education delivered by state officials in Massachusetts and one theme is preeminent: educational standards must be raised in every major curricular area and student achievement in relation to those standards must be measured using the Massachusetts Comprehensive Assessment System or MCAS.

Of course standards should be high. Yes, measuring student achievement is important. But anyone who believes that MCAS scores are the number one issue that must be addressed by schools in Massachusetts is living in a world utterly detached from the reality, which students in urban districts in Massachusetts face every day. That reality is starkly summarized in the first two paragraphs of a recent front-page news story in the Boston Globe:

Nearly 90 percent of Boston public high school students questioned in 2004 said they had witnessed acts of violence, and nearly a third said they had a family member killed in a shooting, stabbing, or beating, according to a survey commissioned by the City of Boston.

Taken long before the recent increase in homicides in the city, the survey found that many students said they had access to weapons. Half the boys reported that getting a gun would be “very or fairly easy” and a quarter of the students reported having seen someone shot in the past year. (Estes, 2005, December 27, p. A1).

Superior MCAS scores will not make our children bulletproof. Furthermore, demographic patterns and factors related to urban violence indicate that things are only going to get worse in cities around the country, of which Boston is but one example, unless steps are taken to change the path we are currently on in the United States.

From a broad educational point of view, examining why public school students are experiencing quantitative and qualitative increases in violence is essential if school leaders are to make thoughtful decisions around curricular choices. From these informed curricular choices will come meaningful high standards, and from these meaningful high standards will come appropriate instruments of measurement including standardized tests.

DEMOGRAPHIC TRENDS IN PUBLIC EDUCATION

Quantitative information describing current and projected student populations is relatively easy to locate thanks to voluminous data collection done in the United States related to public school children. Currently students of color in the United States, that is to say students of black, Hispanic, Asian, and Native American background, make up more than one third of the school age children attending public school (Villegas & Lucas, 2002, p. 3). Trends indicate that by the year 2035 this percentage will rise to approximately one half of the public school population with Hispanics making up nearly 26% of the public school population, African Americans making up nearly 16% of the total, Asian Americans constituting nearly 8% of the total, and Native Americans making up about 1% of the total (Villegas & Lucas, 2002, p. 5). These groups of students are disproportionately poor with poverty rates
among students of color reaches approximately 40% as compared to 16% for white students (Villegas & Lucas, 2002, p. 10), and are disproportionately Limited English Proficient with nearly 3 million students identified as LEP, a more than twofold increase in a single decade from 1986 to 1995 (Villegas & Lucas, 2002, p. 7). Poverty correlates strongly with violence in society, and urban youth of color are far more likely to live in poverty than white or suburban youth (Taylor & Whitaker, 2003, pp. 188-189). If our schools ignore issues around English language acquisition and the trends of increasing poverty and the associated increases of violence then student academic and social failure, particularly for students of color, will only increase.

**VIOLENCE AND URBAN YOUTH**

From a qualitative point of view, increasing violence as experienced by urban youth is a bit more difficult to analyze. Thanks to recent work by people such as Geoffrey Canada in *Fist Stick Knife Gun: A Personal History of Violence in America* and Robert D. Putnam in *Bowling Alone: The Collapse and Revival of American Community* the qualitative experience of urban youth is becoming more generally accessible.

In *Fist Stick Knife Gun* Geoffrey Canada explores the ever-increasing intensity of violence experienced by urban youth of color. Canada points out that in many urban centers it is not just the number of violent incidents that have increased over time, but the ferocity and lethality of those incidents that has also increased over time. As he puts it in his preface, “Some may think violence is new, but it’s not. Violence has always been around, usually concentrated amongst the poor. The difference is that we never had so many guns in our inner cities. The nature of the violent act has changed from the fist, stick, and knife to the gun. But violence, I remember” (Canada, 1995, p. xi). Canada’s point, that the qualitative nature of violence in America has changed, is amply supported.

In 1983 the firearms industry was experiencing a slump in sales of handguns. To boost sales in demographic groups beyond white males, the disproportionately traditional purchasers of handguns, manufacturers consciously undertook a marketing campaign aimed at expanding sales to women and youth by using tactics that had proven successful in the alcohol and tobacco industries (Canada, 1995, p. 123). The result of this marketing campaign was a huge corporate success: sales of handguns jumped dramatically among the target groups. On the ground in New York City Geoffrey Canada witnessed the human cost of these successful corporate efforts.

As violence on the streets in New York increased Canada gathered a group of boys and asked them to tell him what, if anything, they knew about guns. The conversation was startling:

They knew. They knew more than I imagined. They knew the names—Tech 9, Uzi, Glock 17, and on and on. They knew where to get them, they knew what they sounded like, they knew how much ammunition each held. They discussed these guns with same intimate knowledge that the boys I grew up with discussed cars and car engines. They also bought gun magazines. They were fascinated by guns, and, in the same way we looked forward to the new-model cars each year, they looked forward to the new models of handguns, with their new gadgets and high-tech sophistication (Canada, 1995, p. 124).

By the mid 1980s handguns became a fact of life for urban youth across the United States. It is a fact of life that urban youth continue to deal with today. Geoffrey Canada frames this reality simply: “If there is a greater threat to the internal security of this country than the current violence, I don’t know what it is” (Canada, 1995, p. 125). Not surprisingly, the implications of urban violence on the education of American children are enormous.

**SOCIAL CAPITAL AND URBAN YOUTH**

In the United States individual families are primarily responsible for raising children. Schools, community groups, and individual volunteers are some of the assets used to augment family resources as society addresses the needs of youth. Traditionally, when it came to raising children the roles of all these stakeholders have been complementary and focused on what are really two broad goals: increasing the human capital and social capital of each child. Though these two goals are complimentary in nature, they are frequently viewed as wholly separate concepts that are best imparted to children through separate entities.

Schools, for example, are primarily viewed as builders of children’s human capital. Educational training, in the form of knowledge and skills, is designed to increase each student’s future marketability and economic success in society. How much each child has increased her or his human capital through education-
al training is really what MCAS testing is trying to measure.

Schools, particularly high schools, typically offer a wide range of extra curricular activities designed to increase student’s social capital, but these activities are not required for graduation, are the first programs to be cut back in lean economic times, and frequently involve those students who already have experienced a degree of social success and have at least some healthy social networks in place. When it comes to the role of schools in American culture the building of social capital is a secondary function that is not required.

Before proceeding further, it is worth reviewing what is meant by the term social capital. To this end the following description in Bowling Alone by Robert Putnam (2000) is useful:

In recent years social scientists have framed concerns about the changing character of American society in terms of the concept ‘social capital.’ By analogy with notions of physical capital and human capital—tools and training that enhance individual productivity—the core idea of social capital theory is that social networks have value. Just as a screwdriver (physical capital) or a college education (human capital) can increase productivity (both individual and collective), so too social contacts affect the productivity of individuals and groups. (pp. 18-19)

In light of this description, it is hard to overestimate the importance of social capital. Consider the implications of social capital on simply finding a job: “Many Americans—perhaps even most of us—get our jobs through personal connections. If we lack that social capital, economic sociologists have shown, our economic prospects are seriously reduced, even if we have lots of talent and training “ (Putnam, 2000, p. 289). Just as schools have been viewed as the primary tool for building human capital in youth in urban areas, a variety of community groups, religious organizations, social service agencies, and volunteer networks have been viewed as the tools for building social capital in youth in these same urban areas. Unfortunately, as Putnam and others have documented, this traditional division of roles is rapidly eroding.

Thomas H. Sander, executive director of the Sauaro, Civic Engagement in America Project at Harvard University’s Kennedy School of Government, considers the implications of eroding social capital in urban centers on youth, and the entire community. “We seem to be waking up to the material class gaps that have grown for almost 40 years, since 1967. But attention to this real and important economic class gap could blind us to an equally troubling, less visible gap between the classes—a social capital gap” (Sander, 2005, November 14, p. A15).

Sander drives home the point of a real and growing social capital gap using a compelling variety of arguments with broad implications for urban youth. Sander notes that the poor in the United States, those with household incomes under $20,000, were half as likely to have a friend who owned a business or who was a community leader as those wealthy Americans who have household incomes over $100,000. Additionally, the poor belonged to half as many nonchurch groups (Sander, 2005, November 14, p. A15). Another fact Sander points out is that overall volunteerism among youth in the United States is well up since 1995; however, students whose mother had graduated from college seek out volunteer opportunities at a rate 50% higher than those students whose mother had dropped out of high school (p. A15). These trends are also strongly present in church attendance, political activism, and future intent to vote (p. A15). Sander (2005) even touches on what these social realities mean for urban education: “Moreover, we ought to ensure that in our rush to teach the 3 Rs in inner city schools we don’t forget to teach the 2 Cs (connections and community). Youth, especially poor youth, ought to learn about social capital and understand the social cost they’ll pay for not building these ties” (p. A15).

The reality Sander is illustrating is certainly present in the urban high school where I work. Every day I see how the lack of social capital presents itself in basic social skills such as speech patterns, in after-school activities and participation, and in a view of education itself.

Speech patterns may seem like a small matter to some, but this basic social skill has huge implications for poor and disadvantaged youth. Many of the students I see daily that are struggling in school with issues of attendance and grades simply mix a variety of mild to major profanity into their speech patterns. This is not done maliciously. Along with profanity a healthy dose of street slang is present in these students’ speech pattern including the now ubiquitous “nigga” that is actually used as a term meaning friend. On the streets, hanging out with friends and even in their homes such speech is an acceptable means of expression. I would also point out that such students are really pretty good
kids as a group. They are caring, thoughtful young people who are simply unaware of the social norms that are about to impact them massively. As these students compete for positive teacher attention, after-school jobs, and community internships their basic speech pattern is actually a huge disadvantage that is seldom adequately addressed or explained to them. Such students lose out on opportunities and no one has ever bothered to explain why they have. It is tough to play the game of social competition when no one has ever explained the rules, or helped with practice and training.

Disadvantaged students who are struggling in school also almost never report that they are involved in any extracurricular activities. This includes community-based activities or the activities sponsored by the school. Occasionally some of these students have duties at home such as babysitting, but these duties do not serve to extend their social network. An extended network of contacts and friends helps the teens land after-school job, helps with schoolwork, with entertainment, and with opportunities involving personal interests. Involvement in extracurricular activities increases community attachment, keeps kids out of trouble, and puts kids in contact with adult mentors. All of these advantages are lost to these students.

It is easy to see how disadvantaged students can begin to believe that the educational and social system is simply rigged against them. Sander (2005) is quite right to point out that school leaders need to address the growing gap in social capital between affluent students and disadvantaged students as a solution to this perception.

CONCLUSIONS AND RECOMMENDATIONS

If public education in urban centers is to remain relevant and effective, demographic trends in student populations require close and thoughtful examination. The increasing violence being experienced by youth, and the decreasing opportunities for students to build social capital within the community must also be acknowledged and addressed by school leaders and teachers alike. Indeed, failure to account for these documented social changes by communities and their leaders would have grave consequences for the future. Current decisions related to broad educational policy, the nature of school organization, the creation of adequate student support services, and curricular choices that connect to students’ lives will determine the future success, or failure, of our schools.

So what can be done?

Some issues may well prove to be beyond the realm of schools as institutions and must be addressed by society at the broadest levels. Though they certainly affect youth, issues such as gun accessibility, standards for housing, and the distribution of jobs and wealth in America are just some of the matters for society as a whole to debate and consider. The role of schools in such matters is to do everything possible to train students to be functional members of society capable of fully engaging in civic affairs and debate. In many other areas, however, schools as institutions do indeed have an important direct role to fill in students’ lives.

At the school level a restructuring with a focus on support services will be required. This could be termed a whole child approach where educational issues are no longer separated from other key factors affecting the child. Many behaviors that are currently viewed as disciplinary issues alone are, in reality, student responses to lack of academic success, social stressors, physical stressors, or psychological stressors. Take hunger, for example. Most people understand that if a student is hungry that student will have difficulty learning. That is one of the reasons why free and reduced lunch and breakfast programs exist in schools. This seemingly simple example and solution has broad implications for more general school policy. Perhaps it is time to also consider the impact of substandard housing on learning, of health issues on learning, and of culturally based learning styles on learning to name but a very few items. Schools do not have, and will not have, the resources to tackle all these issues. Schools do have the
resources, and ought to use those resources, to connect children and their families to local, state, and federal agencies that can help address all of these issues.

At the classroom level, where one third, or more, of students may be dealing with issues of poverty, English language acquisition, limited social success and limited social capital, and simple physical safety, teachers must come to terms with the simple fact that their roles in the classrooms of the 21\textsuperscript{st} century have changed in many ways. To foster student engagement teachers would have to insure that curricular choices actually connect to students’ lives and are seen by the students as having utility and worth. And, by the way, this need not come at the expenses of standards. A student can be trained to recognize simile, metaphor, and allusion from 50 Cent’s latest rap, and then analyze the content of that rap and its impact on society in a well-constructed five-paragraph essay. Such an assignment would satisfy several strands of the \textit{Massachusetts Curriculum Frameworks in English and Language Arts}.

Further, the ideas that a teacher is a role model and a resource for students have never had more relevance. Teachers may well be among few adults that certain students see who point the way to future success in American society. For these students teacher’s dress, demeanor, speech patterns, interaction with colleagues, and professionalism are of enormous importance as models for success. Additionally, teachers in the 21\textsuperscript{st} century must, at a minimum, be prepared to refer students to appropriate support services for a myriad of issues. To name but a few items, student success is linked to stable housing, physical safety, mental health, and physical health. Teachers increasingly are the adults capable of referring students to those that can help with these issues.

These recommendations merely scratch the surface of what might be done to address the educational needs of our children as the 21\textsuperscript{st} century unfolds. The trends are clear, the need is great, and the clock is ticking. It is time to get to work.

\section*{References}


Educational Resources

Handholds as Assessment Tools in the High School Science Classroom

Andrew Nikonchuk, Patrick Kaplo, Michael Wall, and Michelle Scribner-MacLean

INTRODUCTION

Science educators are often among the first to employ emerging technologies in the classroom and laboratory. For the technologically savvy science teacher, the handheld computer is a terrific tool. A handheld computer is a portable electronic device which serves to help organize (via calendars, contact lists, to do lists) and integrate electronic data (documents, spreadsheets, media, e-mail, companion software) into the mobile lifestyle of busy professionals and many students.

Handheld devices have long had the potential for applications in the classroom, but recent advances and affordability in wireless technologies have enhanced their applicability in schools and created opportunities for educators to improve upon process and management efficiencies. These tools have become more than just a convenient, expensive, electronic date book. Current models have a variety of features and programs, expanded memory, and extended battery life, making them useful tools for all educators to collect many types of assessment data.

MANAGING ATTENDANCE AND GRADING DATA

Using the handheld in the classroom can improve the efficiency of checking the completion of homework, which is time-consuming when using clipboard or paper grade book. Typically a, science teachers routinely spend valuable class and prep time transferring this data a second time into electronic grade books (like Jackson GradeQuick™). The handheld device can eliminate one of these steps by allowing the teacher to enter the data only once.

Many grade book software packages come bundled with the handheld component or can be purchased for a nominal additional fee. This establishes a nearly seamless transition between handheld interface and the familiar desktop companion, virtually eliminating software “ramp-up” time. When synched with the desktop PC, the homework record will be up-to-date without any additional steps required by the teacher.

The use of handhelds for electronic grading is a great tool for communicating up-to-date information about a students’ progress. During parent conferences electronic grade book reports on the handheld allow a teacher to sort assessment data to focus on specific areas needing improvement in an instant. For students, handheld grade book reports can quickly communicate paperless and truly confidential grades without including every student grade, class average, or rank.

Because handhelds enable grading information to be available and automatically calculated as soon as new data is input, long hours spent calculating student and class averages is eliminated. This is extremely useful and beneficial during highly stressful times at the end of marking terms and semesters. The teacher is more organized and reduces the amount of paperwork by utilizing some of the basic functions of the handheld computer.

HANDHELDs IN THE LAB

Many handheld devices have built-in digital cameras which can be invaluable for assessing lab work. After taking pictures of lab setups, photos can be posted online for students to integrate into their lab reports. This gives the students a visual reminder of what they did in lab and the ability to comment specifically on setup issues using evidence from the pictures.

The camera can also be used for a post-lab assessment. While projecting the pictures of the setup of a laboratory experiment using a liquid crystal display
(LCD) projector, the teacher can ask students questions about elements of an effective setup versus one that could be improved. By analyzing their own experimental setups immediately, the students gain valuable skills in lab analysis that might contribute to their performance in the future. The handheld allows nearly instant scrutiny as the pictures can be transferred wirelessly via Bluetooth technology. This analysis could be powerful because the lab work is still fresh in the students’ minds.

Handhelds are also effectively used for data collection during laboratory exercises. Grading scales and rubrics for lab activities are written into the desktop computer (using programs such as Word and Excel) and synchronized onto the handheld computer for use during lab. As students are working on a particular part of the laboratory exercise the teacher records the progress of student work onto the handheld computer. As students work on a particular part of the laboratory exercise the teacher records the progress of student work onto the handheld computer. These data can be input in the form of pictures of laboratory setup and progression, a narrative in a word processing document, or entries into a rubric set up on a spreadsheet. The screenshot shows a rubric for group work that also has space for individualized notes. The teacher then carries the handheld computer while circulating among students, and enters data without the cumbersome paperwork. By inputting data as students work, immediate assessment is performed and available for the student and teacher. Grades on laboratory tasks are calculated instantly and can be synchronized to the desktop computer to be printed out a paper copy if so desired. No paperwork is necessary. By inputting data as students work, immediate assessment is performed and available for the student and teacher. Grades on laboratory tasks are calculated instantly and can be synchronized to the desktop computer to be printed out a paper copy if so desired.

MANAGING COOPERATIVE LEARNING

Increasingly many science teachers want to incorporate cooperative learning in their classrooms, but struggle with ways to accurately assess learning associated with this teaching approach. No matter how carefully rubrics are constructed, teachers find that they must continually reviewed and modified, and notes must be taken while students worked in their teams. It is quite likely that during the process one might be missing critical information for feedback that would help students improve their performance. Using handheld technology can offer a solution to managing cooperative learning.

By setting up a spreadsheet that holds copies of a rubric for group work, teachers can quickly and efficiently take notes and evaluate student work. The spreadsheet book holds individual pages for each group, linked to a master class roster. Each group page has the individual rubric, with spaces for notes. While it is also can be done on the paper, the advantage of the handheld is that total scores are automatically tallied and transferred to the master roster. When the handheld is synched back to the computer, the spreadsheet is updated on the hard drive, and the teacher then has a convenient record of notes and the students’ grades that can be accessed and modified from the teacher’s desktop computer. This takes a minimum of setup and can greatly improve a teacher’s ability to accurately assess student group work.

Figure 1 shows a biology teacher’s sample rubric for a cooperative group activity involving jigsaw method for the different types of genetic technology. Once the scores are entered in the individual categories for each home team, they are automatically totaled and sent to a different sheet, which is a summary of the students and their scores. The instructor can click on each individual descriptor for a full explanation of the point values, and he or she can also take notes on each individual group, which will be saved and transferred to the desktop upon synching.

Handhelds are also could be used for evaluating student presentations in a similar manner. Taking and recording notes about presentations can be time-consuming and the turn-around time for students to receive feedback can be quite long when there are many students in class. Using rubrics synched into the handheld from the desktop computer, the teacher can assess
and evaluate student work immediately and have instant feedback for the student. During a presentation the teacher records student work on the electronic rubric and can later synchronize the students’ work to a desktop computer to be printed out. Familiarizing oneself with the Graffiti programs installed in handheld computers also allows the teacher to write in other comments to give the student valuable feedback. With a little practice the teacher can easily master this handwriting program.

DATA SYNCHRONIZATION

Teachers can sync handhelds to desktop computers by using a dock, but many teachers have found that setting up a local Bluetooth™ network has been quick, easy, affordable, and effective solution for minimizing data synchronization operations. Essentially replacing a wired data transmission connection (like a USB or Firewire cable), Bluetooth™ allows the teacher to connect the handheld to the desktop computer from anywhere in the classroom. Since many devices are sold with integrated Bluetooth™ capabilities, one needs only to enable the classroom desktop PC with a Bluetooth™ antenna (many USB varieties sell for under $20) to provide the connection with a handheld.

For example, after taking attendance, checking homework, documenting learning with pictures or video, or any other data collection, a teacher can simply tap a single button to begin and then slip the device into a pocket and begin the lesson while data is transmitted to a desktop computer for future use.

CONCLUSION

Science teachers use a variety of teaching approaches that could bring management headaches. Trying to collect and give feedback in a lab environment adds to the challenge. Handhelds could support science classroom and laboratory activities while also allowing teachers to provide student with feedback in a timely manner. They can also greatly reduce the turn around time of graded work and can eliminate some of the paper work that can overburden teachers. They are excellent tools to help teachers spend less time managing grades and more time to interact with students and facilitate their learning.

Which handheld would be best for you……

Handheld devices are widely available at just about every discount electronics retailer and range in cost from about $99 to nearly $600. When evaluating a new technology, it’s tempting to fall for the bells and whistles, but there are many affordable handheld options available for educators. As with most electronic devices these days, the consumer will pay more for sharper, larger, and more colorful displays, faster processing power, and more memory. Most mid-level handheld devices come equipped with integrated Bluetooth™ antennas which allow the user to securely synchronize with a Bluetooth™ enabled network or Desktop PC without connecting any cables, as well as run scaled-down Internet browsers via a connection portal. The range of devices on the market essentially boils down to the end-user’s preference in operating systems.

Pocket PCs run scaled-down versions of the familiar MS Office suite of products, (although Palm devices can easily run these files when using their “Documents to Go” software), synch beautifully with desktop versions of Outlook to manage calendars and email, and use the Microsoft Activesync software to synchronize the desktop PC with the handheld device.

A Palm Zire 72 ($199) which is also able to sync with Outlook calendar and contact lists, but also works with handheld companion software for Jackson’s Gradequick™ program, allowing the using to run familiar gradebook functions like adding a homework/test grade while walking around the room checking student work (instantly synching with the desktop PC file) or checking attendance (perhaps remotely during a firedrill).
2007 Annual Colloquium on Research in Mathematics and Science Education

Call for Papers

Educators, researchers and graduate students are invited to submit papers that will be presented at the Eleventh Annual Colloquium on Research in Mathematics and Science Education and published in the Colloquium Journal, vol. XII. The papers must discuss issues and trends in Mathematics and Science Education.

WHEN SUBMITTING A PAPER, PLEASE USE THE FOLLOWING GUIDELINES.

1. Submit an electronic version of the paper and one hard copy, an abstract, approximately 150 words, and a biographical sketch, about 30 words. All pictures and diagrams must be submitted in a separate document.

2. Use double spacing with one-inch margins.

3. For references, diagrams, etc. follow the style described in the Publication Manual of the American Psychological Association (APA), Fifth Edition.

4. Paper length must not exceed 30 pages, including pictures, tables, figures, and list of references.

5. Paper must be received by November 15, 2006.

6. Authors will be notified about the status of their paper by January 15, 2006.

7. A Colloquium will be scheduled for April 2006.

SUBMIT PAPERS AND CORRESPONDENCE TO:

Dr. Regina M. Panasuk
Professor of Mathematics Education
The Graduate School of Education
University of Massachusetts Lowell
61 Wilder Street, O’Leary 5th Floor
Lowell, MA 01854

Phone: (978) 934-4616
Fax: (978) 934-3005
Regina_Panasuk@uml.edu