NCTM'S VISION OF MATHEMATICS ASSESSMENT IN THE SECONDARY SCHOOL: ISSUES AND CHALLENGES

JOANNE J. SPARKES

NCTM's Vision of Mathematics Assessment in the Secondary School: Issues and Challenges

Paper One: Recent Reform Efforts in Mathematics Education: Implications for Student Assessment

Paper Two: Student Assessment "Instruments:" Aligning their Uses with Instruction

Paper Three: Challenges Facing Assessment Reform Implementation: Where Do We Go From Here?

by

Joanne J. Sparkes, B.A., B.Ed.

A Paper Folio submitted to the School of Graduate Studies
in partial fulfillment of the requirements for the degree of
Master of Education

Faculty of Education
Memorial University of Newfoundland
St. John's, Newfoundland

September 1999

Acknowledgements

This paper folio was written with the guidance and support of many people. First, I wish to thank Dr. John Grant McLoughlin, my university supervisor, for his insight into mathematics education, his advice and editorial assistance in this paper folio, and most importantly, his uncanny ability to provide direction while permitting me to pursue my own interests.

I would like to express my most sincere gratitude to my family for supporting my efforts as I did my Master of Education and especially during the writing of this paper folio. Most particularly, I would like to thank Mom and Dad for their tremendous support and assistance. As my paper folio neared completion during the summer months, Mom spent many hours with Andrew, "Grandma's little boy," providing me the opportunity to do my final writing and revisions for this paper folio. I thank Dad who, over the years, as a parent and as my senior high school English teacher, aided in the growth of my writing style and instilled in me a desire to write. Mom and Dad, I love you dearly and I thank you from the bottom of my heart.

I thank my sisters, Jennifer, Sandra, and Susan, for helping to take care of Andrew during the final stages of the paper folio. I thank my brother, Douglas, for being part of some of the great times I had this summer – at times I was so engrossed in the final stages of this paper folio that I desperately needed someone to spend a few hours laughing with (Doug, I'm still curious about the compass and the flashlight!). I thank my husband, Joel, who has always provided me with love and encouragement; I acknowledge his unfailing confidence in my ability.

Above all, I thank the Creator of this world for providing the precious gift of human life – for without such a gift none of this would have been possible. I am especially thankful that my life has been blessed with magnificent people who care.

Folio Abstract

Most places one treads within the mathematics education arena there is either direct or indirect reference to two National Council of Teachers of Mathematics (NCTM) documents: *Curriculum and Evaluation Standards for School Mathematics* and *Assessment Standards for School Mathematics*. These documents place strong emphasis on mathematics as communication, reasoning, problem solving, and making connections as well as the idea that students learn best in active student-centered classrooms as opposed to more traditional passive settings. Consequently, NCTM advocates a call for change in many components of traditional mathematics teaching, including the manner in which teachers instruct and assess students.

Folio Paper One summarizes the major recent reform efforts in mathematics education as advocated by NCTM. Sources of current theory, research, and practice are cited that adhere to the philosophical underpinnings of NCTM regarding curriculum reform. The paper examines the evolution of learning theory research as it pertains to mathematics reform efforts and, more specifically, mathematics assessment reform efforts. The paper evolves into an examination of assessment reform including NCTM's Assessment Standards and the proposed shifts in assessment practices. The varied purposes of assessment are also addressed.

Folio Paper Two describes the necessity, stemming from a constructivist framework of learning, to change both the manner in which teachers elicit evidence of students' mathematical thinking and the way they use that evidence to monitor students' progress and guide instructional decision making. Emphasis is placed on the idea that expanding the purposes of assessment beyond accountability and assigning grades

becomes an asset to all those involved in the assessment process. Various forms of alternate assessment are described and supported with examples of current research and practice. The assessment "instruments" described include: journal writing, open-ended problems, interviews, formal and informal observations, portfolios, self-assessment, and teacher-made and other tests. The paper concludes by focusing on some of the advantages of multiple forms of assessment.

Folio Paper Three discusses many of the challenges facing teachers in the area of mathematics assessment: (1) the challenge of teachers removing themselves from some of the comforts they have in their traditional practices; (2) the challenge of teachers becoming comfortable with designing alternate assessment "instruments" and recording and reporting information obtained from their use; (3) the challenge of teachers juggling demands placed on their time; (4) the challenge of teachers meeting external expectations while simultaneously remaining accountable for their actions; (5) the challenge that teachers, like students, are active constructors of their practice and, hence, it will be difficult for them to implement the assessment ideas that NCTM advocates if their vision of mathematics education is distinctly different from that of NCTM; and (6) the challenge of building and sustaining a constructivist classroom environment necessary to support alternate assessment initiatives. All of these challenges are addressed within the context of current theory, research, and practice. Finally, the paper provides a potential developmental agenda for teachers in their efforts at overcoming such challenges.

Paper One

Recent Reform Efforts in Mathematics Education: Implications for Student Assessment

Table of Contents

Recent Reform Efforts in Mathematics Education: Implications for Student Assessment

Introduction

Most places one treads within the mathematics education arena there is either direct or indirect reference to two National Council of Teachers of Mathematics (NCTM) documents: *Curriculum and Evaluation Standards for School Mathematics* and *Assessment Standards for School Mathematics*. These documents place strong emphasis on mathematics as communication, reasoning, problem solving, and making connections as well as the idea that students learn best in active student-centered classrooms as opposed to more traditional passive settings. Consequently, NCTM advocates a call for change in many components of traditional mathematics teaching, including the manner in which teachers instruct and assess students.

Since it is impossible to discuss reform efforts in student assessment without considering the broader framework, this paper first summarizes the major recent reform efforts in mathematics education as advocated by NCTM. NCTM's societal and student goals for mathematics education are specifically stated followed by the idea that mathematics education is a non-hierarchical system in which the various components (curriculum, instruction, assessment, ...) are mutually dependent on each other and that there is a vision that penetrates throughout the system. Additionally, other sources of current theory, research, and practice are cited that adhere to the philosophical underpinnings of NCTM regarding curriculum reform.

The paper then turns its focus to the evolution of learning theory research as it pertains to mathematics and, more specifically, mathematics assessment. Though NCTM publications do not allude to specific learning theories, they clearly indicate that learning mathematics involves doing mathematics and inherent within this idea is a constructivist framework of learning. Since student learning and student assessment are not separate entities, this paper discusses mathematics assessment in light of constructivism.

The generic review of mathematics educational reform and the discussion on constructivist learning theory "set the stage" for what NCTM is advocating in the student assessment arena. This paper next evolves into an examination of assessment reform efforts including the proposed major shifts in assessment practices and NCTM's Assessment Standards. Finally, the paper examines the varied purposes of assessment as proposed by NCTM.

Mathematics Reform: The Broader Framework

Recent reform efforts in secondary school mathematics education have been quite substantial. NCTM has been at the forefront in developing and advocating ideas for reforming mathematics education. One of the primary issues they have addressed concerns revision of the goals of mathematics education. In its document, *Curriculum and Evaluation Standards for School Mathematics*, NCTM (1989) lists four societal goals and five student goals pertaining to mathematics education. The societal goals include the promotion of: (1) Mathematically literate workers; (2) Lifelong learning; (3) Opportunity for all; and (4) An informed electorate (pp. 3-4). The student goals reflect the importance of mathematical literacy, namely: (1) Learning to value mathematics; (2) Becoming confident in one's ability to do mathematics; (3) Becoming a mathematical problem solver; (4) Learning to communicate mathematically; and (5) Learning to reason mathematically (p. 5).

The Mathematical Sciences Education Board (MSEB) backs the need for changes in the manner in which mathematics is taught. MSEB (1990) has advocated restructuring the entire mathematics curriculum in terms of the following changes in the context of mathematics education: (1) Changes in the need for mathematics; (2) Changes in mathematics and how it is used; (3) Changes in the role of technology; (4) Changes in society; (5) Changes in understanding of how students learn; and (6) Changes in international competitiveness (p. 45).

Undoubtedly, reform is evolutionary. As society changes, our vision of education must change. NCTM (1989) states: "All industrialized countries have experienced a shift from an industrial to an information society, a shift that has transformed both the aspects of mathematics that need to be transmitted to students and the concepts and procedures they must master if they are to be self-fulfilled, productive citizens in the next century" (p. 3). Brosnan & Hartog (1993) state: "It is acknowledged that the typical mathematics curriculum of a generation ago emphasized teaching facts, standard procedures, and skills to groups of passive recipients. In the last decade, a more integrated, child-centered curriculum presented to more active, participating students has emerged in response to deteriorating public confidence in the quality of ... education" (p. 1).

Mathematics curricula are undergoing significant changes. It must be realized, however, NCTM perceives that mathematics education is a non-hierarchical system in which the various components (curriculum, instruction, assessment, ...) are mutually dependent on each other and that there is a vision that penetrates throughout the system (Figure 1). It should be noted that the elements in Figure 1 do not comprise an exhaustive chain. Therefore, visions and curricula, designed on the finest principles with the very best intentions, will affect little change in classroom practice if other aspects of the system remain unchanged.

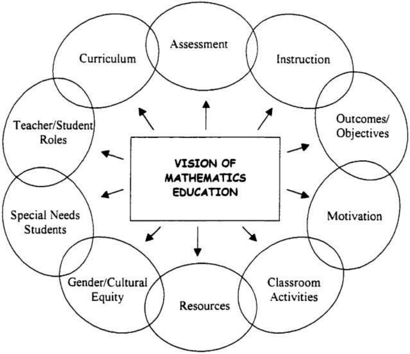

Figure 1: Mathematics Education: A Non-Hierarchical System

Learning Theory and Mathematics

NCTM, in its *Curriculum and Evaluation Standards for School Mathematics*, states: "What a student learns depends to a great degree on how he or she has learned it" (1989, p. 5). The National Research Council (NRC), in its report *Everybody Counts*, points out that "students learn mathematics well only when they construct their own mathematical understanding" (1989, p. 58). NCTM (1989) emphasizes that "knowing mathematics is doing mathematics" (p. 7). The Atlantic Provinces Educational Foundation (APEF) in its *Foundation for the Atlantic Canada Mathematics Curriculum*, indicates that "students learn best in an environment which supports exploration, investigation, critical and creative thinking, risk taking, reflection and other higher order thinking skills" (1995, p. 27).

Though there are many learning theories that address the issue of how students learn, the three primary learning theories are behavioral, cognitive, and constructivist. Though not specifically stated, NCTM, NRC, and APEF advocate a constructivist theory of learning. Since curriculum and assessment go "hand in hand," this has direct implications on how we assess our students.

Piaget's constructivist theory of learning centers around the idea that cognitive development involves a set of structures constructed by continuous interaction between a learner and the external world. Piaget (1973) states: "I will above all stress the spontaneous aspect of development … what the child learns by himself, what none can teach him and he must discover alone; and it is essential that this development which takes time … it is precisely this spontaneous development which forms the obvious and necessary condition for the school development" (pp. 2-4). Piaget (1970) believes that learners are active agents who continuously explore and rediscover their environments and construct new knowledge; the fundamental processes operating in the construction of knowledge are assimilation (integrating new knowledge into existing cognitive structures) and accommodation (the adjustment of cognitive structures to the specific features of the environment).

Papert (1993) constructs his model of the learner by using Piagetian cognitive theory and artificial intelligence theories as well as research on social facets involved in doing mathematics. Papert emphasizes that Piaget's theoretical investigations have focused upon the mind's internal events, but that his own perspective, although based on Piaget's, is more "interventionist:" "My goals are education, not just understanding. So, in my own thinking I have placed greater emphasis on two dimensions implicit but not elaborated in Piaget's own work: an interest in intellectual structures that could develop as opposed to those that actually at present do develop in the child, and the design of learning environments that are resonant with them" (Papert, 1993, p. 161).

Vygotsky also believed that human mental abilities are developed through the individual's interaction with the world. However, he emphasizes the role of social and cultural factors, particularly language, in learning and development. Vygotsky's principle of zone of proximal development -- that the tasks that children can complete independently indicate only the level of development children have already attained, they do not reflect children's potential for learning -- emphasizes that, for effective development and learning, joint sociolingual intellectual action should occur (Harel, 1991, p. 28).

Even though behavioral learning theory has presided in education for many years, the philosophical basis of the current thinking of experience-centered learning by the previously mentioned theorists is actually rooted in Dewey's work. Dewey's insistence on the requirement that education be built from and serve the needs of individuals as opposed to external, traditional academic sources, is indeed a thread that runs through current educational thought. So too, we see the constructivist "philosophy" when we think back to Virgil acting as a guide and teacher for Danté. Virgil's greatness rested in his understanding that his student must have certain experiences before discussion would be of true value. Constructivist theory emphasizes that learning is an experience, not necessarily a product of an experience -- how we come to know is seen in our interactions with the environment, not as a product of those interactions.

Though no learning theories prescribe specific teaching or assessment techniques, it becomes clear that there is a critical need that learning and assessment are active, experience-based, meaningful processes. NRC (1993) states: "Important mathematics is not limited to specific facts and skills students can be trained to remember but rather involves the intellectual structures and processes students develop as they engage in activities they have endowed with meaning" (p. 70).

Romberg & Carpenter (1986) and Romberg (1993) respectively state the following:

> Current research indicates that acquired knowledge is not simply a collection of concepts and procedural skills filed in long-term memory. Rather the knowledge is structured by individuals in meaningful ways, which grow and change over time (p. 851).

> The assessment challenge we face is to give up old assessment methods to determine what students know, which are based on behavioral theories of learning and develop authentic assessment

> procedures that reflect current epistemological beliefs both about what it means to know mathematics and how students come to know (p. 109).

Assessment and Reform Efforts

It becomes obvious that traditional ideas and forms of assessment will not suffice to reach all of the societal and educational goals embraced by NCTM's vision of secondary school mathematics. Additionally, if classroom activities are to reflect a constructivist view of learning as a process of coming to know rather than as the remembering or recall of facts and procedures, then it will no longer be satisfactory for teachers to solely follow the regime of teach and then "assess."

NCTM's advocacy of mathematical power for all students calls for, among other things, assessing a student's disposition toward mathematics, ability to reason and analyze, ability to communicate mathematically, and problem-solving skills. NRC (1993) states: "Assessment that is out of synchronization with curriculum and instruction gives the wrong signals to all those concerned with education" (p. 21). Additionally, NRC (1993) states: "Mathematics assessment must change in ways that will both support and be consistent with other changes under way in mathematics education. ... If current assessment practices prevail, reform in school mathematics is not likely to succeed" (pp. 30-31).

NCTM advocates that assessment be a continuous and dynamic process in which multiple assessment "instruments" are used. Exclusive use of traditional paper-and-pencil tests often limit opportunities to learn and thus, narrow or dilute curriculum and instruction. NCTM believes that in order to achieve excellence in secondary school mathematics education, teachers must broaden their forms of assessment "instruments" as well as come to grips with the timing, rigor, usability, and multiple purposes of assessment. Assessment "instruments," including journal writing, open-ended problems, interviews, formal and informal observations, portfolios, self-assessment, and teacher-made and other tests have to be used in the classroom. If teachers use a broad range of strategies in an appropriate balance, students will have multiple opportunities to demonstrate their knowledge, skills, and attitudes.

Figure 2 summarizes the major shifts that, as advocated by NCTM, we should be moving toward and away from with regard to assessment practices.

TOWARD	AWAY FROM
• Assessing students' full mathematical power	• Assessing only students' knowledge of specific facts and isolated skills
• Comparing students' performance with established criteria	• Comparing students' performance with that of other students
• Giving support to teachers and credence to their informed judgment	• Designing "teacher-proof" assessment systems
• Making the assessment process public, participatory, and dynamic	• Making the assessment process secret, exclusive, and fixed
• Giving students multiple opportunities to demonstrate their full mathematical power	• Restricting students to a single way of demonstrating their mathematical knowledge
• Developing a shared vision of what to assess and how to do it	• Developing assessment by oneself
• Using assessment results to ensure that all students have the opportunity to achieve their potential	• Using assessment to filter and select students out of the opportunities to learn mathematics
• Aligning assessment with curriculum and instruction	• Treating assessment as independent of curriculum or instruction

• Basing inferences on multiple sources of evidence • Viewing students as active participants in the assessment process • Regarding assessment as continual and recursive • Holding all concerned with mathematical learning accountable for assessment results	• Basing inferences on restricted or single sources of evidence • Viewing students as the objects of assessment • Regarding assessment as sporadic and conclusive • Holding only a few accountable for assessment results

Figure 2: Major Shifts in Assessment Practices
(Source: NCTM, 1995, p. 83)

Evolving from NCTM's *Curriculum and Evaluation Standards for School Mathematics*, which call for more attention to classroom problem solving and higher-order thinking in a constructivist learning environment, came NCTM's document *Assessment Standards for School Mathematics*. The vision of the *Assessment Standards for School Mathematics* (1995) corresponds with that of the *Curriculum and Evaluation Standards for School Mathematics* and presents six standards for assessment. These six standards, which are essentially criteria that aim to ensure that assessments foster the goals of excellent mathematics education, include: Mathematics Standard, Learning Standard, Equity Standard, Openness Standard, Inferences Standard, and Coherence Standard (NCTM, 1995).

The Mathematics Standard states: "Assessment should reflect the mathematics that all students need to know and be able to do" (NCTM, 1995, p. 11). NRC (1993) indicates that assessment has to do much more than test discrete procedural skills and that rather than forcing mathematics to fit assessment, "assessment must be tailored to the mathematics that is important to learn" (pp. 5-6). This Standard emphasizes the nature of mathematics as communication, reasoning, problem solving, and making connections.

The Learning Standard states: "Assessment should enhance mathematics learning" (NCTM, 1995, p. 13). This Standard addresses the need for assessment to support and enhance learning, necessitating the alignment of curriculum, instruction, and assessment practices. Too often teachers follow the pattern of stopping instruction and then assessing students. NCTM advocates that assessment should contribute directly to student learning and, hence, the need exists for assessment and instruction to occur simultaneously.

The Equity Standard states: "Assessment should promote equity" (NCTM, 1995, p. 15). Since individual students have different abilities and experiences, assessment should allow for multiple approaches. NRC (1993) states: "The challenge posed by the equity principle is to devise tasks with sufficient flexibility to give students a sense of accomplishment, to challenge the upper reaches of every student's mathematical understanding, and to provide a window on each student's mathematical thinking" (p. 8).

The Openness Standard states: "Assessment should be an open process" (NCTM, 1995, p. 17). Before students are assessed, they should be informed about what they need to know, how they will be expected to demonstrate that knowledge, and the consequences of assessment. NCTM (1995) states: "Everyone is best served by an assessment process that is public, participatory, and dynamic" (p. 18).

The Inferences Standard states: "Assessment should promote valid inferences about mathematics learning" (NCTM, 1995, p. 19). A student's cognitive processes cannot be observed directly and, hence, the need exists for inferences based on the student's performance. After a teacher has gathered evidence, he/she must use his/her informed judgement to interpret and use the evidence to make inferences about what knowledge the student has demonstrated. Such inferences must, clearly, be based on multiple forms of assessment data. NCTM (1989) states: "An exclusive reliance on a single type of assessment can frustrate students, diminish their self-confidence, and make them feel anxious about, or antagonistic toward, mathematics" (p. 202).

The Coherence Standard states: "Assessment should be a coherent process" (NCTM, 1995, p. 21). Coherence in assessment involves three aspects: (1) The assessment process forms a coherent whole, the phases fit together; (2) The assessment matches the purposes for which it is being done; and (3) The assessment is aligned with the curriculum and with instruction (NCTM, 1995, p. 21). If there is harmony within assessment, then the totality of student assessments will provide a comprehensive picture of the knowledge, skills, and understandings of students.

Purposes of Assessment

As previously stated, assessment should provide the opportunity to gain useful insight into students' understanding and knowledge of mathematics, rather than just identifying their ability to use specific skills and apply routine procedures. The purposes of student assessment that NCTM advocates include: to monitor students' progress, to make instructional decisions, and to evaluate students' achievement. NCTM's overall aim is for students to increase their mathematical power. NCTM (1991) defines mathematical power:

> Mathematical power includes the ability to explore, conjecture, and reason logically; to solve nonroutine problems; to communicate about and through mathematics; and to connect ideas within mathematics and between mathematics and other intellectual activity. Mathematical power also involves the development of personal self-confidence and a disposition to seek, evaluate, and use quantitative and spatial information in solving problems and in making decisions. Students' flexibility, perseverance, interest, curiosity, and inventiveness also affect the realization of mathematical power (p. 1).

Using assessment "instruments" to monitor a student's progress is not a new concept for many teachers. However, NCTM (1995) indicates that the following shifts with regard to assessment are mandatory if students are to increase their mathematical power:

- A shift toward judging the progress of each student's attainment of mathematical power, and away from assessing students' knowledge of specific facts and isolated skills.
- A shift toward communicating with students about their performance in a continuous, comprehensive manner, and away from simply indicating whether or not answers are correct.
- A shift toward using multiple and complex assessment tools (such as performance tasks, portfolios, writing assignments, oral demonstrations, and portfolios), and away from sole reliance on answers to brief questions on quizzes and chapter tests.
- A shift toward students learning to assess their own progress, and away from teachers and external agencies as the sole judges of progress (p. 29).

Informing and improving instruction is a crucial component of assessment as well. Assessment can inform teaching by providing feedback that may be used to modify instruction in an effort to better facilitate learning. Teachers should ask themselves: "How can I use evidence about my students' progress to make instructional decisions?" Essentially, this purpose of assessment links with the Learning Standard. NCTM (1991) states: "Assessment of students and analysis of instruction are fundamentally interconnected" (p. 63). As Lambdin & Forseth (1996) point out, "Good teaching is seamless – assessment and instruction are often one and the same" (p. 294). If used appropriately, assessment can promote learning, build confidence, and develop a student's understanding of himself or herself.

NCTM advocates that, though assessment for the exclusive purpose of evaluation must be downplayed, using assessment for the purpose of evaluating a student's achievement is nonetheless important. Evaluation is defined as "the process of determining the worth of, or assigning a value to, something on the basis of careful examination and judgment" (NCTM, 1995, p. 88).

Kulm (1994) identifies five primary purposes of assessment in the classroom that are similar to those advocated by NCTM: (1) Improvement of instruction and learning; (2) Evaluation of student achievement and progress; (3) Feedback for the students, providing information to aid them in seeing inappropriate strategies, thinking, or habits; (4) Communication of standards and expectations; and (5) Improvement of attitudes toward mathematics (p. 4).

Clearly, sole use of traditional paper and pencil tests will be inadequate in addressing these multiple purposes of assessment. Reform efforts focus on creating mathematical classroom environments in which student understanding and student meaning flourish; hence, the need exists for alternative forms of assessment. Alternate forms of assessment will send very different messages to students about what is important in mathematics learning; such assessment "instruments" will foster the development of mathematically literate students, the primary vision of NCTM.

Undoubtedly, there will be a shift in emphasis from producing correct answers to the expectation that students must think and communicate.

Conclusion

NCTM is advocating changes in mathematics curriculum, instruction, and assessment. These changes must work together. Changes in what we teach and how we teach must be accompanied by changes in assessment. NCTM clearly indicates that students should be actively doing mathematics by using mathematical ideas and concepts to work on problems, tasks, and investigations. Curricula should emphasize understanding concepts and good mathematical thinking versus the memorization of facts, procedures, and formulas that are only dimly understood. The enactment of behaviorist teaching and assessment is becoming passé; constructivist practice, necessitating change in classroom activities to give students more control over their mathematics education, must surface.

> Effective teachers are those who can stimulate students to learn mathematics. Educational research offers compelling evidence that students learn mathematics well only when they construct their own mathematical understanding. To understand what they learn, they must enact for themselves verbs that permeate the mathematics curriculum: "examine," "represent," "transform," "solve," "apply," "prove," "communicate." This happens most readily when students work in groups, engage in discussion, make presentations, and in other ways take charge of their own learning (NRC, 1989, pp. 58-59).

Clearly, learning mathematics is a cumulative process that occurs as experiences contribute to understanding. Mathematics involves more than just finding the correct answer to a specific problem. The strategies and procedures used to approach mathematical tasks as well as the communicative skills employed in conveying understanding are all important. Therefore, the assessment of a student's mathematical knowledge must include his/her ability to solve problems, to use the language of mathematics, to reason and analyze, to communicate mathematically, and to make connections among mathematical phenomena. Assessment must be made in a context that is significant and similar to the learning environment. "When the focus and form of assessment are different from that of instruction, assessment subverts students' learning by sending them conflicting messages about what mathematics is valued" (NCTM, 1995, p. 13).

Assessment should also examine the extent to which students have integrated and made sense of mathematical concepts and procedures and whether they can apply concepts and procedures to situations that require creative and critical thinking. Assessment "instruments" must fit the curriculum being taught, requiring students to use the kinds of thinking and concepts that they have been developing. Journal writing, open-ended problems, interviews, formal and informal observations, portfolios, self-assessment, and teacher-made and other tests will be required as the reform efforts of NCTM come into "full force."

Multiple assessment "instruments" will assist in achieving the varied purposes of assessment as advocated by NCTM. As students are given opportunities to explain and justify their thinking and to discuss their observations, teachers will have opportunities to monitor a student's progress, make instructional decisions, and to evaluate a student's achievement. Student assessment must provide feedback to both teachers and students that assists them in making good decisions and that aids them in the next steps of their teaching and/or learning.

The vessel of mathematics assessment reform focuses on systemic change: a mutual dependence on all major components within mathematics education (curriculum, instruction, motivation, ...). NCTM has launched the vessel and it is up to mathematics teachers to keep it afloat. Undoubtedly, there will be times when the seas are rough; however, it is then that mathematics teachers have to put extra effort into steering their course. It must be realized that there is no final destination to the voyage; it is the journey of providing students with ample opportunities to learn more meaningful mathematics that is of interest.

References

Atlantic Provinces Educational Foundation. (1995). Foundation for the Atlantic Canada mathematics curriculum. Halifax, Nova Scotia: Atlantic Provinces Educational Foundation.

Brosman, P. & Hartog, M. (1993). Approaching standards for mathematics assessment (Report No. EDO-SE-93-10). Washington, D.C.: Office of Educational Research and Improvement. (Eric Document Reproduction Service No. 359 069).

Harel, I. (1991). Children designers: Interdisciplinary constructions for learning and knowing mathematics in a computer-rich school. Norwood, New Jersey: Ablex Publishing Corporation.

Kulm, G. (1994). Mathematics assessment. San Francisco, California: Jossey-Bass.

Lambdin, D. & Forseth, C. (1996). Seamless assessment/instruction = good teaching. Teaching Children Mathematics, 2, 294-298.

Mathematical Sciences Education Board. (1990). Reshaping school mathematics: A philosophy and framework of curriculum. Washington, DC: National Academy Press.

National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1991). Professional standards for teaching mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1995). Assessment standards for school mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (1989). Everybody Counts: A report to the nation on the future of mathematics education. Washington, DC: National Academy Press.

National Research Council. (1993). Measuring what counts: A conceptual guide for mathematics assessment. Washington, DC: National Academy Press.

Papert, S. (1993). Mindstorms: Children, computers, and powerful ideas. New York, NY: Basic Books.

Piaget, J. (1970). Science of education and the psychology of the child. New York, NY: Orion Press.

Piaget, J. (1973). The child and reality: Problems of genetic psychology. New York, NY: Grossman.

Romberg, T. (1993). How one comes to know: Models and theories of the learning of mathematics. In Mogens Niss (Ed.), Investigations and assessment in mathematics education: An ICMI study (p. 109). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Romberg, T. & Carpenter, T. (1986). Research on teaching and learning mathematics: Two disciplines of scientific inquiry. In Merlin Wittrock (Ed.) Handbook on research on teaching (3rd ed., p. 851). New York, NY: Macmillian.

Paper Two

Student Assessment "Instruments:" Aligning their Uses with Instruction

Table of Contents

Student Assessment "Instruments:" Aligning their Uses with Instruction

Introduction

Recent cognitive research has invited considerable change in our understanding of what learning is and how it happens. It is evidenced that learners actively construct personal meaning from information and experiences by linking new information with their pre-existing knowledge and understanding. Resulting from this is a call for change in instructional practices and, hence, assessment practices within areas such as secondary school mathematics, the focus of this paper.

NCTM's documents *Curriculum and Evaluation Standards for School Mathematics* and *Assessment Standards for School Mathematics* support recent cognitive research. NCTM indicates the necessity, stemming from a constructivist framework of learning, to change both the manner in which teachers elicit evidence of students' mathematical thinking and the way they use that evidence to monitor student's progress and guide instructional decision making.

This paper first "sets the stage" for the necessity of changing assessment practices by comparing traditional passive mathematics instruction with the more active student-centered format of instruction that NCTM advocates. The paper then proceeds to examine mathematics assessment and the effect of assuming a constructivist approach to learning.

After individually examining mathematics instruction and assessment, it is reemphasized in the next section of this paper that the two issues cannot, realistically, be compartmentalized. NCTM's Standards documents indicate the importance of using assessment to guide instruction and to improve teaching, expanding the purpose of assessment beyond accountability and assigning grades. This paper discusses the idea that assessment's real power, its ability to shape and direct classroom instruction, is frequently untapped and that using assessment to inform instruction is one of the most powerful tools that a teacher has to improve their teaching and student learning.

The focal point of the paper becomes the direction in which teachers should turn with regard to incorporating assessment within instruction. Adhering to NCTM's philosophical underpinnings, various forms of alternate assessment are described and supported with examples of current research and practice. The assessment "instruments" described include: journal writing, open-ended problems, interviews, formal and informal observations, portfolios, self-assessment, and teacher-made and other tests. Such "instruments" allow teachers to assess students' mathematical content knowledge, mathematical processes, and mathematical disposition.

The paper next evolves into an examination of the advantages of multiple forms of assessment. Essentially, at this juncture, the paper comes "full circle" as emphasis is placed on the primary advantage of assessment – that of student growth and learning, the ultimate aim of simultaneous instruction and assessment. Finally, there is an exploration of the idea that, despite popular perception, alternative assessment is not a new commodity.

Mathematics Instruction

Conventional secondary school mathematics instruction in Newfoundland, for the most part, has not been in line with NCTM's advocacy of mathematics as communication, reasoning, problem solving, and making connections. Textbooks and/or worksheets have generally been used to provide students with exercises (typically questions that each have a single correct answer) designed to be solved in passive environments. The answers to these exercises have generally been obtained by using a procedure that the teacher has taught very recently. I believe it would be fair to say that the hallmarks of conventional mathematics instruction have been passiveness, memorization, and replication.

What should be the hallmarks of mathematics instruction? One of the primary ideas that NCTM advocates is that mathematics classrooms should be discourse communities and the teachers therein should be facilitators of mathematical discourse. In the *Professional Standards for Teaching Mathematics* (NCTM, 1991), many aspects of the teacher's role during instruction are identified:

> Posing questions and tasks that elicit, engage, and challenge each student's thinking; listening carefully to each student's ideas; asking students to clarify and justify their ideas orally and in writing; deciding what to pursue in-depth from among the ideas that students bring up during a discussion; deciding when and how to attach mathematical notation and language to student's ideas; deciding when to provide information, when to clarify an issue, when to model, when to lead, and when to let a student struggle with difficulty; and monitoring a student's participation in discussions and deciding when and how to encourage each student to participate (p. 128).

Undoubtedly, effective mathematics instruction must involve students being active participants in the learning process. One of the key components of learning is that students reconstruct mathematical ideas. NRC (1989) makes a point that is consistent with this constructivist view of learning and that supports NCTM's idea of the teacher's role during instruction:

> Students construct meaning as they learn mathematics. They use what they are taught to modify their prior beliefs and behavior, not simply to record and store what they are told. It is students' acts of construction and invention that build their mathematical power and enable them to solve problems they have never seen before (p. 59).

Mathematics Assessment

NCTM (1995) defines assessment as "the process of gathering evidence about a student's knowledge of, ability to use, and disposition toward mathematics and of making inferences from that evidence for a variety of purposes" (p. 87). I would argue that, currently, much of the assessment that occurs in secondary school mathematics classrooms revolves primarily (and, in some cases, perhaps solely) around written tests, quizzes, and assignments for the sole purpose of evaluation (as defined by NCTM, see Paper One, p. 13-1).

Three issues come to the forefront: (1) Many teachers and students are "caught up" in the idea of marks – it must be realized that evaluation is only one use of assessment information; (2) Teachers' assessment of students must involve more than written instruments; and (3) Assessment often influences what teachers teach and, consequently, what students learn. Crooks (1988) elaborates on the third issue:

> Classroom evaluation [assessment in terms of NCTM's definition]... guides [student] judgement of what is important to learn, affects their motivation and self-perception of competence, structures their approaches to and timing of personal study,

> consolidates learning, and affects the development of enduring learning strategies and skills. It appears to be one of the most potent forces influencing education (p. 467).

It stands to reason that justice is not being served if teachers limit their assessment instruments to traditional paper-and-pencil tests, quizzes, and assignments. Hence, a need exists for what NCTM refers to as alternate or authentic assessment "instruments." Stenmark (1991) indicates:

> Authentic assessment tasks highlight the usefulness of mathematical thinking and bridge the gap between school and real mathematics. They involve finding patterns, checking generalizations, making models, arguing, simplifying, and extending -- processes that resemble the activities of mathematicians or the application of mathematics to everyday life. When we see students planning, modeling, and using mathematics to carry out investigations, we can make valid judgments about their achievement (p. 3).

It is imperative that we have the broadest and richest information about our students. Rather than merely producing a few numbers or grades, assessments should yield profiles, descriptive information, interests, attitudes, and other information that can provide a clear picture of abilities and aptitudes. A teacher's goal, nonetheless, is not to elicit multiple forms of assessment as a goal in and of itself; the primary purpose of multiple forms of assessment is the value they provide for the improvement of teaching and learning.

Kulm (1994) identifies three basic criteria for assessment items: (1) The item should give all students the chance to demonstrate some knowledge, skill, and understanding; (2) The item should be rich enough to challenge students to reason and think, to go beyond what they expect they can do and perhaps more than the teacher expects; and (3) The item should allow the application of a wide range of solution approaches and strategies (p. 38).

Aligning Instruction and Assessment

NCTM advocates that instruction and assessment have to occur simultaneously in order to help students develop their powers of communication, reasoning, problem solving, and making connections which they believe are at the heart of a student's mathematical learning. Webb and Briars (1990) agree: "Assessment must be an interaction between teacher and students, with the teacher continually seeking to understand what a student can do and how a student is able to do it and then using this information to guide instruction" (p. 108).

NCTM (1995) emphasizes that there should not be artificial barriers between teaching, learning, and assessment; blurring the boundary between instruction and assessment is consistent with the Learning Standard (p. 46). Assessment must be seen as an opportunity for learning as opposed to an interruption to it. Assessment and instruction are far too often regarded as separate entities -- a teacher teaches certain concepts, students do practice problems, a test is given, and the cycle continues until all units in a course are "covered." Instruction does not solely drive assessment and assessment does not solely drive instruction. Just as flowers provide bees with nectar and bees provide a mechanism for the exchange of genetic material among flowers, so too, assessment and instruction are mutually dependent on one another. NCTM (1991) reemphasizes this idea:

> Assessment of students and analysis of instruction are fundamentally interconnected. Mathematics teachers should monitor students' learning on an ongoing basis in order to assess and adjust their teaching. Observing and listening to students during class can help teachers, on the spot, tailor their questions or tasks to provoke and extend students' thinking and understanding. Teachers must also use information about what students are understanding to

> revise and adapt their short- and long- range plans: for the tasks they select and for the approaches they choose to orchestrate the classroom discourse. Similarly, students' understandings and dispositions should guide teachers in shaping and reshaping the learning environment of the classroom (p. 63).

Peterson (1988) indicates that if assessment is to be aligned with good instruction, instruction should reflect the following three characteristics: (1) The teacher provides learning activities and an environment in which there is emphasis on meaning and understanding; (2) There is a classroom atmosphere that encourages student autonomy, persistence, and independent thinking; and (3) There is direct teaching of specific problem-solving and reasoning strategies (p. 126).

Undoubtedly, assessment should be a continuous and dynamic process. NCTM (1995) states, "When the focus and form of assessment are different from that of instruction, assessment subverts students' learning by sending conflicting messages about what mathematics is valued" (p. 45). NRC (1993) further emphasizes this idea when they state, "Even when certain tasks are used as part of a formal, external assessment, there should be some kind of instructional follow-up. As a routine part of classroom discourse, interesting problems should be revisited, extended, and generalized, whatever their original sources" (p. 11).

Assessment "Instruments"

Typically, as previously stated, paper-and-pencil tests have been used extensively (and sometimes exclusively) by most teachers. Aside from the idea that such tests oftentimes reinforce the misconception that mathematics is a set of isolated skills that can be easily decomposed and taught, a concern with excessive usage of paper-and-pencil tests is that they do not take into account individual differences in how students display their mathematical knowledge. Kulm (1994) comments:

> For some students, the anxiety of taking a formal test can limit their performance. Others are more reflective and need extended time to think through problems. Others do their best mathematical thinking through hands-on performance or work on projects and activities. For still others, an opportunity to write or to explain concepts orally can open the way to better performance (p. 49).

Another central concern with excessive usage of paper-and-pencil assessment is that information obtained from the assessment is not sufficiently helpful to improve instruction and learning. Many teachers would be wealthy if they had a quarter for every time a student asked questions like: Is this going to be on the test? Is that what you're looking for for the answer to that question? Day after day many students make these queries. Marolda & Davidson (1994) state that for many students "the issue in mathematics is not the learning of mathematical topics and procedures but rather the ability to produce solutions" (p. 97). Berenson & Carter (1995) comment:

> Teachers are left with a sense of unease about students' understanding of the relationship between learning and grading. ... Learning is equated with producing an exact copy of what is in the teacher's mind. Students who feel this way may fail to understand why they should learn. They may become dependent imitators rather than creative innovators. Furthermore, they may never experience the joy of independent learning nor reach the goal of becoming life-long learners (p. 182).

Undoubtedly, the attitudes that many students have about learning can partially be attributed to the manner in which teachers assess. How, then, should teachers assess and what should these assessments entail?

NRC (1993) indicates, "Assessment programs must inform teachers and students about what the students have learned, how they learn, and how they think about mathematics" (p. 82). A variety of assessment "instruments" should be selected or devised to gather information related to how well students are achieving curriculum learning outcomes; a good mixture should provide an opportunity for students to focus on the primary goals of learning in an effort to achieve excellence in education.

Some of the assessment "instruments" that NCTM advocates for use in mathematics classrooms include: journal writing, open-ended problems, interviews, formal and informal observations, portfolios, self-assessment, and teacher-made and other tests. An elaboration of each of these "instruments" is provided below. The assessment "instruments" used at any given time will depend on several factors such as the type of learning outcomes (knowledge, understanding, skill, attitude, value, process, ...), the specific "topic" being taught, the instructional strategies used, the student's level of development, and the specific purpose of the assessment.

Journal Writing

Gopen & Smith (1989) indicate that writing, encompassing thought processes, is a foreign concept to most students in mathematics classes. They state:

> "Thought" (they believe) is the sort of thing encountered more often in classes devoted to the subject – philosophy, history, ... Math is in another category altogether. While it is clear to them that you have to "think" hard to solve the problems, you do not necessarily have to have "thoughts." You have to think in order to *do* things. ... You "think" first; then you do the math problem. You "think" first; then you "reduce your thought" to writing. In order for students to benefit more fully ..., they must come to understand that they are engaging in a process of thought, in a new mode of thought. Requiring them to *write* about what they are doing will in turn force

> them to *think*, to conceptualize what they are doing. At the same time, we need to demonstrate to them the inextricable intertwining of thought and writing – of thought and expression of thought. (pp. 211-212).

Nonetheless, despite the foreignness of journal writing in mathematics classes, such writing is beneficial to both students and teachers. Kulm (1994) states:

> Journals can be used to gather information concerning noncognitive aspects, such as the students' interests, their persistence, and changes in their attitudes toward mathematics; students answer reflective questions like "What do you like best about _____ ?" "How have you thought about the problem?" "What did you discover?" Through journal writing, students are given a private place to address concerns they would not otherwise express or reveal to the teacher (p. 48).

Answering questions such as those raised by Kulm will enable teachers to get to know their students more fully. Raymond (1994) indicates that journals can challenge students to reflect on both cognitive and metacognitive aspects of how they think about mathematical tasks (possibly resulting in solidifying understanding) as well as provide a medium through which teachers are able to assess their students' mathematical comprehension (p. 16). The reflection that students engage in as they write in journals provides teachers with "insights into students' thinking, mathematical language, misconceptions, and disposition toward mathematics" (Shulman, 1996, p. 66).

Mayer & Hillman (1996) state:

> The information I receive from my students' writing is irreplaceable. From reading my students' writing, I am able to structure my lessons to highlight their strengths and strengthen their weaknesses in mathematical knowledge and understanding. Through my comments about their writing, my students know that I value their thoughts, comments, and concerns. I cannot imagine a more effective way to assess what my students know and are able to do mathematically (p. 432).

Berenson & Carter (1995) give some helpful hints for teachers as they begin to have students participate in journal writing (p. 183). These hints include: (1) Begin writing with "feeling" questions in student journals. These are perceived as less threatening since there are no right and wrong answers. (2) Encourage students to write more words by discussing with the class your expectations or showing other students' writing as models. (3) Respond to students in writing. For journals, it is not necessary to respond to all entries. Collect 5 –10 journals a day for review, or ask students to select what entry they are particularly interested in having read. (4) Set a timer or have a specific time period set aside each day or week where students know they will be expected to write about mathematics.

Rose (1989) offers a variety of benefits to student journal writing:

- When students are stuck on a problem and write out their thought processes, they see their errors and often solve the problem.
- Journal writing slows the thinking process, which gives students a chance to arrive at their own solutions as well as to understand their thought processes.
- Teachers benefit as they receive feedback on lessons and become aware of when students are reached by certain activities.
- Students make notes, not take notes, and produce interpretive comments and personal reminders.
- As the teacher writes back to the students, students realize the teacher hears and cares.
- Students gain the opportunity to formulate, organize, internalize, and evaluate concepts; answer self-generated questions; and generate a record of their thinking (pp. 26-27).

Open-Ended Problems

Stenmark (1989) defines an open-ended problem as one in which the student is given a situation and is asked to communicate a response, usually in writing. Open-ended problems, which permit creative and divergent reasoning and problem solving, require a student to construct their own answers and thus are more in line with the constructivist view of learning. Such problems oftentimes allow for more than one solution or response to be given and more than one skill to be used. Additionally, students with various backgrounds can respond in unique ways. "Open-ended questions often provide opportunities for students to make decisions; articulate their conceptual knowledge; collect, analyze, and represent data; and communicate their findings to an intended audience" (Shulman, 1996, p. 64). Additionally, as NCTM (1995) indicates, open-ended problems allow students to "select from a variety of mathematical representations [pictures, graphs, tables, charts, diagrams, models, symbols, formulas] to demonstrate their understanding. Such a multiplicity of representations can ... provide broader access, allow for greater diversity in solution strategies, and support more complete demonstrations of students' understanding than many traditional forms of assessment" (p. 58).

The Massachusetts Department of Education (1989) adheres to the underlying philosophy of NCTM:

> An answer alone is but a weak indicator of understanding. In contrast, when we ask students to explain or to justify their responses, we can evaluate not only the procedures which they used, but the premises upon which those procedures were based. ... When students are asked to puzzle and explain, to apply their knowledge in an unfamiliar context, they must construct meaning for themselves by relating what they know to the problem at hand. In other words, they must act like mathematicians. This kind of activity encourages them in the belief that mathematics is primarily a reasonable enterprise, founded in the relationships apparent in everyday life and accessible to all students (p. 41).

Such a philosophical position requires a reconsideration of the models we use for assessment. One such model is to use rubrics as shown in Figure 1. This figure illustrates an example of how feedback from open-ended problems can be given to students through an analytic scoring scale.

Analytic Scoring Scale	
Understanding the Problem	0: Complete misunderstanding of the problem 1: Part of the problem misunderstood or misinterpreted 2: Complete understanding of the problem
Planning a Solution	0: No attempt, or totally inappropriate plan 1: Partially correct plan based on part of the problem being interpreted correctly 2: Plan could have led to a correct solution if implemented properly
Getting an Answer	0: No answer, or wrong answer based on an inappropriate plan 1: Copying error; computational error; partial answer for a problem with multiple answers 2: Correct answer and correct label for the answer

Figure 1: Feedback Scale for Open-ended Problem
(Source: Charles, R., Lester, F., & O'Daffer, P , 1987, p. 30)

Open-ended problems may also include student investigations. NCTM (1995) states, "To demonstrate real growth in mathematical power, students need to demonstrate their ability to do major pieces of work that are more elaborate and time-consuming than just short exercises, sets of word problems, and chapter tests" (p. 36). Student investigations meet this criterion. Grant McLoughlin (1999) indicates that investigations are "intended to represent an open-ended problem solving activity. Beginning with a mathematical statement, a set of numbers, or a topic, students explore by conjecturing, posing problems, and pursuing directions that are neither unique nor prescribed. The essence is to move the experience of students toward those of mathematicians themselves" (p. 8). Personal experience with such an investigation, during a mathematics education graduate course with Grant McLoughlin, highlighted that students can develop thinking and reasoning skills through such experiences.

Interviews

Lankford (1992) reports that many experts have observed that the extensive use of single correct answer paper-and-pencil tests in mathematics has led to the neglect of the idea of listening to students as a vital aspect of instruction and assessment. NCTM (1995) states, "One of the most powerful sources of evidence about students' learning comes from listening to students explain their thinking" (p. 32). Students "learn language through verbal communication; it is important, therefore, to provide opportunities for them to 'talk mathematics'" (NCTM, 1989, p. 26).

Interviewing students permits a teacher to gain insight into a student's thinking, understandings, learning styles, attitudes, and beliefs about mathematics.

> Advantages of using interviews include the opportunity to delve deeply into students' thinking and reasoning, to better determine their level of understanding, to diagnose misconceptions and missing connections, and to assess their verbal ability to communicate mathematical knowledge. An additional benefit of using interviews occurs as students provide detailed information about what they are thinking and doing - they realize that this knowledge is valued (Huinker, 1993, p. 80).

Interviews may be conducted with individuals or small groups. Teachers can set up a specific time, calling a student or students aside as the remainder of the class is engaged in other activities. So too, interviews can be informal, asking a student or group of students specific questions as they work. During an interview, whether formal (a teacher following a standard protocol) or informal, teachers should use questions that probe students' thinking. These questions could include, but certainly shouldn't be limited to: What do you mean when you say that? How could you answer the question without setting up a quadratic equation? Why did you do this problem the way you did? Questions such as these require students to explain their conceptual understandings of mathematics (Shulman, 1996, p. 64).

In addition to knowing the types of questions to ask students during an interview, teachers should be cognizant of other more general information. Berenson & Carter (1995) provide some useful hints for teachers as they interview their students:

- Put students at ease. Conduct the interview as if it were a conversation. Explain to the students why you are interviewing them.

- Use neutral reinforcement terms such as "I hear what you're saying." Stay away from leading responses such as "Good, that's right!" Remember to keep nonverbal cues as neutral as possible. Nod, maintain good eye contact, and restate what it is that you think you have heard.

- Try not to lead the students or turn the interview into an instructional session, unless you want the interview to serve as remedial instruction.

- Plan a few basic questions that will allow you to gain understanding of students' ideas. Use probes to draw out students' ideas (e.g., "Can you tell me more about that?", "Can you explain your thinking?", or "Where did your idea about this come from?").

- If possible, record the session so that you are not distracted from responding to and listening to student ideas (p. 185).

Formal and Informal Observations

Teachers can use the information they obtain from observing students (both formally and informally) in the classroom to judge students' progress as well as the success of their instructional approaches. Observing students should be a natural part of teaching; the intent is not to observe every student every day. However, "insights gained during these times can be quickly lost in the hurly-burly of the classroom if some form of documentation does not occur during the course of instruction" (Clarke, 1994, p. 542). Sometimes checklists, similar to the one in Figure 2, can be used to expedite the process. Additionally, brief notes next to a student's name can be very insightful to a teacher at a later point in time. Clarke (1994) states, "As classrooms become more student-centered and less teacher-centered, teachers will have more freedom to observe" (p. 543).

Clarke (1994) indicates that a teacher should look for three primary things when observing students: mathematical content, mathematical processes (including problem solving, communication, reasoning, and connections), and mathematical disposition.

Problem-Solving Observation Rating Scale
Student: ______________ **Date:** ______________

	Frequently	Sometimes	Never
1. Selects appropriate solution strategies	____	____	____
2. Accurately implements solution strategies	____	____	____
3. Tries a different solution strategy when stuck	____	____	____
4. Approaches problems in a systematic manner (clarifies the question, identifies needed data, plans, solves, and checks)	____	____	____
5. Shows a willingness to try problems	____	____	____
6. Demonstrates self-confidence	____	____	____
7. Perseveres in problem-solving attempts	____	____	____

Figure 2: Observational Checklist
(Source: Charles et al., 1987, p. 18)

Portfolios

Portfolios are an effective tool for collecting a variety of student work, including the products from other assessment "instruments." Paulson, Paulson, & Meyer (1991) define portfolios as "purposeful collections of student work that exhibits [sic] the student's efforts, progress, and achievements in one or more areas" (p. 60). The wide array of student work provides different kinds of indicators of what students know and can do, as well as how they think. As an overall picture of learning, portfolios document conceptual understanding, problem solving, reasoning, and communication abilities. Additionally, one of the richest aspects of a portfolio is that it gives an overview of a student's progress over an extended period of time.

Stenmark (1991) indicates that portfolios provide evidence of knowledge and understandings far beyond facts and recall of procedures. Additionally, portfolios provide a permanent record of a student's progress, they give a clear and overall picture of a student's ability, they allow for different styles of learning, and they provide opportunities for improving the self image and confidence of all students by engaging students in assessing and selecting their own work. Coates (1995) suggests that portfolios have the potential to reveal a lot about their creators; they can be a "window into the students' heads" (p. 2). As with most forms of alternate assessment, portfolios enable teachers to construct their own knowledge of students, how students learn, and how students evaluate their own learning.

A portfolio collection should include "student participation in selecting contents, the criteria for selection, the criteria for judging merit, and evidence of student self-reflection" (Paulson, Paulson, & Meyer, 1991, p. 60); thus, portfolios oftentimes help students see their strengths and weaknesses so that they are more able to link successes and failures to performance. NCTM (1995) indicates that "the process by which students select what they consider to be their best work is an important means by which they learn to reflect on their own work" (p. 36). Students generally place their best work in a portfolio, thereby enabling them to see their growth and improvement over time so that, hopefully, they develop pride in their accomplishments. Portfolios also help encourage responsibility for learning and may facilitate goal setting.

Lesh, Lamon, Behr, & Lester (1992) offer a cautionary note:

> One of the common criticisms of portfolio-based assessment projects has been that they often produce more information than decision-makers are able to use, with the result that the rich information available is ignored or reduced to simplistic generalizations that have the same negative characteristics as single-number test scores (p. 413).

Kenney, Schloemer, & Cain (1996) suggest that one means to use the rich information contained in portfolios is during parent teacher interviews. They indicate that portfolios are an excellent means to show parents exactly how their child is doing; the portfolio "contains evidence that facilitates communication between teachers and parents or guardians about students' progress that is probably not readily available from report card grades or other forms of summative reporting and that may not deal exclusively to mathematics" (p. 193).

Self-Assessment

Kenney & Silver (1993) define self-assessment as "the process of actively monitoring one's own progress in learning and understanding and of examining one's own mathematical knowledge, processes, and attitudes" (p. 229). Lesh, Lamon, Behr, & Lester (1992) indicate that, in as many ways as possible, it is important that teachers reflect responsibility back onto students for documenting their own achievements, and for analyzing, summarizing, and evaluating the quality of their own work (p. 413). NCTM (1995) states:

> Students learn to share responsibility for the assessment process as they come to understand and make judgements about the quality of their own work. The shift in teaching toward helping students increase their capacity for analysis and their ability to formulate problems and communicate correct mathematical work is supported when students become adept at judging the quality of their own work and that of others (p. 39).

Indeed, self-assessment permits students to reflect on their learning experiences, thus becoming more aware and observant of their own learning. Raymond (1994) emphasizes that reflection forces students to solidify their understanding (p. 16). When students are actively involved in the assessment process, they can be empowered by not seeing the teacher as the giver and judge of all knowledge as is currently the case in many classrooms.

Although assessment "instruments" such as journal writing, interviews, and portfolios incorporate elements of self-assessment, more specific activities can be designed which focus on students critiquing themselves or work that they have done. According to Schoenfeld (1983), when students are asked to analyze their problem-solving processes, there is a measurable effect on performance (p. 21).

Schoenfeld (1985) indicates that students often need initiation to use self-monitoring and self-evaluative strategies. Therefore, it is crucial, at least initially, for teachers to provide experiences through which students can develop their own capability for self-assessment. Teachers, for instance, can provide instruments that focus students' attention on their own mental processing. NCTM (1995) provides a table that would give students guidance in the assessment of their own work. This table (Figure 3) guides students' self-assessment by having them rate themselves on a continuum in each of four categories (Understanding the Task, How you Solved the Problem, Why – Decisions Along the Way, So What – Outcomes of Activities).

Student Self-Assessment			
Understanding the Task			
I didn't understand enough to get started or even make progress.	I understood enough to solve part of the problem or get part of a solution.	I understood the problem.	I identified special factors that influenced the way I approached the problem.
How you Solved the Problem			
My approach didn't work.	My approach would only let me solve part of the problem.	My approach would work for the problem.	My approach was efficient or sophisticated.
Why – Decisions Along the Way			
I had no reasons for the decisions I made.	I knew I was reasoning but it's hard to see from my work.	Although I didn't clearly explain the reasons for my decisions, my work suggests reasoning was used.	I clearly exhibited reasons for the decisions I made along the way.
So What – Outcomes of Activities			
I solved the problem and then stopped.	I solved the problem and then made comments about something I observed in my solution.	I solved the problem and connected my solution to other math that I knew or I described a use for what I learned in the "real world."	After I solved the problem, I made a general rule about the solution or I extended the solution to a more complicated situation.

Figure 3: Student Self-Assessment
(Source: NCTM, 1995, p. 43)

Kenney & Silver (1993) provide an eloquent summary of student self-assessment:

> One goal of a mathematics program ... is for students to gain mathematical power. One important attribute of mathematically powerful learners is their ability to know how much they know, to judge the quality of this knowledge, and to know what they need to do in order to learn more. These characteristics are also at the heart of student self-assessment. For students, self-assessment encourages them to assume an active role in the development of mathematical power. For teachers, student self-assessment activities can provide a lens through which the development of students' mathematical power can be viewed (p. 236).

Teacher-Made and Other Tests

An analysis of current assessment practices in many Newfoundland schools, I am convinced, would yield that teacher-made and other tests are frequently used. Therefore, for the purpose of this paper, I provide less elaboration on this form of assessment.

For the most part, teacher-made and other tests entail written forms of assessment similar to our current unit tests, midterms, and finals. However, new types of paper-and-pencil tests can be devised so that their substance and format can capture important evidence about what and how students are thinking. There is nothing wrong with teachers placing open-ended problems on tests. For instance, teachers may provide students with a graph and ask them to describe a situation that the graph could possibly represent. It is essential that teachers forego the "one correct answer" mentality for all items on their paper-and-pencil tests.

Nonetheless, it is important to realize that traditional testing is not "out the door!" Paper-and-pencil testing (as most teachers know it) may indeed be the best way to assess in certain instances such as that of factual recall. And, of course, a good traditional test is obviously preferable to a poorly constructed or trivial alternate assessment.

Notwithstanding, as NRC (1989) indicates, "we must ensure that tests measure what is of value, not just what is easy to test. If we want students to investigate, explore, and discover, assessment must not measure just mimicry mathematics" (p. 70).

Advantages of Multiple Forms of Assessment

Berenson & Carter (1995) state that most forms of alternate assessment share common characteristics:

> Students receive high marks for higher order thinking, problem solving, and creativity in alternative assessments. Multiple answers, strategies, and invented processes are valued, recognized, and rewarded by the teacher. Students discover that the new rules of grading alternative assessments reward their unique contributions rather than their short-term memories. These changes in assessment practices can, in many cases, lead to students taking pride in and responsibility for their learning (p. 182).

Arising from these many assessment "instruments" are several key issues. First, an overall assessment mix is richer and far more informative for students, teachers, parents, and other interested parties. Second, alternative assessments should not be viewed as "add-ons." Third, when assessing, teachers should step back and ask themselves if what they are assessing is worth assessing and, if so, what "instrument" is best for measuring the progress of that particular learning outcome. Certainly, sole or extensive use of traditional paper-and-pencil tests will be challenged within the NCTM reform efforts currently underway; traditional paper-and-pencil tests often limit opportunities to learn and thus, narrow or dilute curriculum and instruction.

Undoubtedly, there are many potential advantages of multiple forms of assessment being used in synchronization with instruction. Obviously, if teachers use a broad range of strategies in an appropriate balance, students will have multiple opportunities to demonstrate their knowledge, skills, and attitudes. However, the advantages go far beyond this. I believe Berenson and Carter (1995), as previously quoted, allude to the key advantage – that students will become creative innovators versus dependent imitators. Stenmark (1991) elaborates on this concept as evidenced by what she regards as the advantages of alternative assessment. These advantages, categorized for students and teachers, are given in Figure 4.

Students	Teachers
• Think more deeply about problems • Feel free to do their best thinking because their ideas are valued • Ask deeper and more frequent questions of themselves, their classmates, and their teachers • Improve their listening skills and gain an appreciation for the role of listening in cooperative work • Feel responsibility for their thoughts and ownership of their methods • Observe that there are many right ways to solve a problem • Experience the value of verbalization as a means of clarifying one's thinking • Form new insights into mathematical concepts • Learn ways to identify the places where they need help • Increase their self confidence and self-esteem as a result of genuine interest shown by a teacher or classmate • Feel more tolerance and respect for other people's ideas • Focus their energy on exploring and communicating ideas about mathematical relationships rather than on finding answers	• Gain access to student thinking • Enhance their ability to use nonthreatening questions that elicit explanations and reveal misconceptions • Strengthen their listening skills • Show respect for their students by being nonjudgmental • Use interview results as a source of questions to pose on written assignments for the whole class • Encourage respect for diversity by modeling appreciation of varied approaches • Pose questions that encourage students to construct their own understanding • Feel reinforcement for letting go of "teaching as telling"

• Develop strategies for conducting self-interviews while solving problems in other settings • Find satisfaction and confidence in their ability to solve problems • Look less to the teacher for clues about the correctness of their methods and focus less on imitating the "right" way	

Figure 4: Advantages of Assessment Alternatives
(Source: Stenmark, 1991, p. 4)

Additionally, two other advantages to multiple forms of assessment that are not specifically stated above include: (1) Teachers will not limit their assessment to summative means for the sole purpose of evaluation; and (2) Students may change their emphasis from grades to learning.

Longevity of Assessment Concepts

An investigation into the "newness" of the idea of using multiple forms of assessment reveals that NCTM has not developed a brainchild. For example, though NCTM's Standards documents surfaced in the late 1980's and continue to meet with revision to the present day, prior to this time many authors alluded to the importance of going beyond paper-and-pencil tests that primarily assess knowledge-oriented concepts. For instance, Bentley & Malvern (1983) state:

> By far the greatest part of pupil assessment in schools is of the continuous kind, aimed at providing the teacher with information about the progress, strengths and weaknesses of individual children and, through them, of the class as a whole. This is mainly done by observing children as they go about their day to day class work and by correcting and discussing their work with them (p. 35).

Additionally, an examination of the ideas of prominent 1940's math educators reveals that the concept of alternate assessment is definitely not new. Hartung & Fawcett (1946) state, "In preparing test items, try to modify the conventional forms of presenting exercise material so that rote learning is less likely to provide successful responses and that more thorough understanding of principles is rewarded" (p. 163). Brownell (1946) states, "Other evidences of learning are best assessed in other ways [non-traditional paper-and-pencil tests], for example, by examining pupil's work products, by questioning pupils in the classroom and in conferences, and by observing their behavior … . Such opportunities to evaluate learning are too important to be neglected" (p. 1).

Conclusion

Just as taking one's temperature will not lead to better health, more and varied assessments will not necessarily lead to better quality in school mathematics. If one's temperature is higher than "normal," the necessary steps, combined with periodic reassessment, are generally taken to aid in lowering the temperature. So too, if assessment reveals a particular student weakness, this weakness should be addressed via further simultaneous instruction and assessment.

Undoubtedly, it's the quality and not quantity of assessments that counts. Good alternate assessments give teachers a better idea of how their students think and understand; they permit students to take more responsibility for their learning. If assessment "instruments" are aligned with instruction, they will involve students as they are learning, thus inviting students to reflect on their progress. Herman, Aschbacher, &

Winters (1992) state, "Meaningful learning is reflective, constructive, and self-regulating" (p. 3). Additionally, assessments, like instruction, should occur on a continual basis and be dynamic.

The alternative assessment "instruments" discussed in this paper can be used by teachers as catalysts for change. However, they are merely "instruments." A musical band can have ample instruments but unless these instruments are played in an appropriate balance, the resulting melody will not be "sweet" to the ear. Likewise, there are ample assessment "instruments" at a mathematics teacher's disposal; however, effectively integrating them into instruction is crucial. It must be realized that just as there is no formula for the creation of a new musical piece, so too there is no formula for aligning assessment "instruments" with instruction; it is the teacher's role to make the "melody" as sweet as possible.

References

Bentley, C. & Malvern, D. (1983). Guides to assessment in education: Mathematics. London: Macmillan.

Berenson, S. & Carter, G. (1995). Changing assessment practices in science and mathematics. School Science and Mathematics, 95 (4), 182-186.

Brownell, W. (1946). Introduction: Purpose and scope of the yearbook. In Nelson B. Henry (Ed.), The measurement of understanding: Forty-fifth yearbook of the National Society for the study of education (pp.1-21). Chicago: University of Chicago Press.

Charles, R., Lester, F., & O'Daffer, P. (1987). How to evaluate progress in problem solving. Reston, VA: National Council of Teachers of Mathematics.

Clarke, D. (1994). Valuing what we see. Mathematics Teacher, 87 (7), 542-545.

Coates, D. (1995). Alternative assessments to reflect a changing mathematics curriculum. Internet site: http://www.frontiernet.net/~dcoates/altass.htm.

Crooks, T. (1988). The impact of classroom evaluation practices on students. Review of Educational Research, 85 (4), 467.

Ediger, M. (1998). Appraising pupil progress in mathematics. (Eric Document Reproduction Service No. 424 290).

Gardner, H. (1993). Multiple intelligences: Theory into practice. New York: Basic Books.

Gopen, G. & Smith, D. (1989). What's an assignment like you doing in a course like this? Writing to learn mathematics. In P. Connolly & T. Vilardi (Eds.), Writing to learn mathematics and science (pp. 209-228). New York: Teachers College Press.

Grant McLoughlin, J. (1999). Mathematics assessment and "doing mathematics:" Narrowing the gap. Unpublished document. Prepared for submission to Prospero.

Hartung, M. & Fawcett, H. (1946). The measurement of understanding in secondary-school mathematics. In N. Henry (Ed.), The measurement of understanding: Forty-fifth yearbook of the National Society for the Study of Education (pp. 156-174). Chicago: University of Chicago Press.

Herman, J., Aschbacher, P., & Winters, L. (1992). A practical guide to alternate assessment. Alexandria, Virginia: Association for Supervision and Curriculum Development.

Huinker, D. (1993). Interviews: A window to students' conceptual knowledge of the operations. In N.L. Webb (Ed.), Assessment in the mathematics classroom: 1993 yearbook of the National Council of Teachers of Mathematics (pp. 80-86). Reston, VA: National Council of Teachers of Mathematics.

Kenney, P., Schloemer, C., & Cain, R. (1996). Communicating about alternative assessment beyond the mathematics classroom. In P. Elliott & M. Kenney (Eds.), Communication in mathematics, K-12 and beyond: 1996 yearbook of the National Council of Teachers of Mathematics (pp. 187-196). Reston, VA: National Council of Teachers of Mathematics.

Kenney, P. & Silver, E. (1993). Student self-assessment in mathematics. In N.L. Webb & A.F. Coxford (Eds.), Assessment in the mathematics classroom: 1993 yearbook of the National Council of Teachers of Mathematics (pp. 229-238). Reston, VA: National Council of Teachers of Mathematics.

Kulm, G. (1994). Mathematics assessment. San Francisco, California: Jossey-Bass.

Lankford, F. (1992). What can a teacher learn about a pupil's thinking through oral interviews? Arithmetic Teacher, 40 (2), 106-111.

Lesh, R., Lamon, S., Behr, M. & Lester, F. (1992). Future directions for mathematics assessment. In R. Lesh & S. Lamon (Eds.), Assessment of authentic performance in school mathematics (pp. 379-425). Washington, DC: American Association for the Advancement of Science.

Marolda, M. & Davidson, P. (1994). Assessing mathematical abilities and learning approaches. In C.A. Thornton & N.S. Bley (Eds.), Windows of opportunity: Mathematics for students with special needs. Reston, VA: National Council of Teachers of Mathematics.

Massachusetts Department of Education. (1989). On their own time: Student response to open-ended tests in mathematics. Quincy, Massachusetts: Massachusetts Department of Education.

Mayer, J. & Hillman, S. (1996). Assessing students' thinking through writing. Mathematics Teacher, 89 (5), 1996.

National Council of Teachers of Mathematics. (1991). Professional standards for teaching mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1995). Assessment standards for school mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (1989). Everybody counts: A report to the nation on the future of mathematics education. Washington, DC: National Academy Press.

National Research Council. (1993). Measuring up: Prototypes for mathematics assessment. Washington, DC: National Academy Press.

Paulson, F., Paulson, P., & Meyer, C. (1991, February). What makes a portfolio a portfolio? Educational Leadership, 60-63.

Peterson, P. (1988). Teaching for higher-order thinking. In T.J. Cooney & D. Jones (Eds.), Effective mathematics teaching. Reston, VA: National Council of Teachers of Mathematics.

Raymond, A. (1994). Assessment in mathematics education: What are some of the alternatives in alternative assessment? Contemporary Education, 66 (1), 13-17.

Rose, B. (1989). Writing and mathematics: Theory and practice. In P. Connolly & T. Vilardi (Eds.), Writing to learn mathematics and science (pp. 15-30). New York: Teachers College Press.

Schoenfeld, A. (1983). Beyond the purely cognitive: Belief systems, social cognitions, and metacognitions as driving forces in intellectual performance. Cognitive Science, 7, 329-363.

Schoenfeld, A. (1985). Metacognitive and epistemological issues in mathematical understanding. In E. Silver (Ed.), Teaching and learning mathematical problem solving: Multiple research perspectives (pp. 361-379). Hillsdale, NJ: Lawrence Erlbaum Associates.

Shulman, L. (1996). New assessment practices in mathematics. Journal of Education 178 (1), 61-71.

Stenmark, J. (1989). Assessment alternatives in mathematics. Berkeley: University of California.

Stenmark, J. (Ed.). (1991). Mathematics assessment: Myths, models, good questions, and practical suggestions. Reston, VA: National Council of Teachers of Mathematics.

Webb, N. & Briars, D. (1990). Assessment in mathematics classrooms, K-8. In T. Cooney (Ed.), Teaching and learning mathematics in the 1990s: 1990 yearbook of the National Council of Teachers of Mathematics (pp. 108-117). Reston, VA: National Council of Teachers of Mathematics.

Paper Three

Challenges Facing Assessment Reform Implementation: Where Do We Go From Here?

Table of Contents

Challenges Facing Assessment Reform Implementation: Where Do We Go From Here?

Introduction

Today, in the area of mathematics assessment, teachers face many challenges and hurdles, perhaps primarily, though not solely, attributable to a changing information-based society that places different demands on individuals. NCTM (1989) notes that "All industrialized countries have experienced a shift from an industrial to an information society, a shift that has transformed both the aspects of mathematics that need to be transmitted to students and the concepts and procedures they must master if they are to be self-fulfilled, productive citizens in the next century" (p. 3). Undoubtedly, there is a demand to graduate students who can demonstrate mathematical literacy, an ability to reason, communicate, and tackle non-routine problems. Developing from this is the need to go beyond paper-and-pencil testing as teachers assess students.

NCTM's philosophy that curriculum, instruction, and assessment are interdependent has major implications for this paper. It is impossible to address the challenges of implementing the assessment reform ideas of NCTM in isolation from the broader challenges of implementing mathematics reform ideas. Therefore, although the primary focus of this paper is on assessment reform implementation, the paper examines the viability and challenges associated with some of the broader goals at several junctures. I argue that the challenges of assessment reform become much easier to confront after a teacher recognizes and tackles the broader challenges of mathematics reform.

An examination of how a teacher's vision of mathematics education impacts their instruction and, consequently, their assessment of students "sets the stage" for this paper. It is openly stated that perhaps the primary challenge of assessment reform implementation is the necessity on the part of many individual teachers to align their vision of mathematics education with that of NCTM. It is pointed out that NCTM's assessment ideas are not conducive to "chalk and talk" classrooms and, hence, a modification of classroom environment (in which students are active participants) is mandatory en route to confronting further challenges of assessment reform implementation.

The paper then proceeds to focus attention on six additional challenges pertaining to assessment reform implementation. These challenges relate to the teacher's role in reform: (1) comfort in traditional practice, (2) design, orchestration, and report difficulty, (3) the issue of time, (4) meeting external expectations, (5) teachers as constructivists, and (6) building a constructivist classroom environment. Each of these challenges is addressed within the context of current theory, research, and practice.

Next, the paper explores some starting points for teachers as they begin or continue their efforts at overcoming some of these challenges. There is elaboration on providing teachers with education, resources, and support as they endeavor to implement NCTM's assessment reform ideas. The discussion emphasizes the potential benefits of collaboration among teachers. Finally, it is pointed out that individual teacher initiatives are critical to successful reform implementation.

The Impact of One's Vision of Mathematics Education on Assessment

Every teacher's vision of the purpose of mathematics education is somewhat different and I believe it would be fair to say that a teacher's vision (encompassing their educational philosophy) drives his/her instruction, his/her classroom activities, his/her approach to outcomes/objectives, and, of particular interest for the purpose of this paper, his/her student assessment practices. I present the following analogy. Consider a painter who is brought out into the country and asked to paint the beautiful scenery that lies before him. I would argue that it is impossible for that painter to stand outside his painting. That painter's thoughts will be inherent within the way he/she paints the landscape, just as a teacher's thoughts are inherent within the way he/she assesses his/her students.

Because I so strongly believe that a teacher's vision directly factors into the assessment of his/her students, I believe it is important at this point for me to present NCTM's vision of mathematics education, the vision on which I base the remainder of this paper. My personal vision is relatively consistent with NCTM's vision that mathematics education involves the development of mathematical power in all students.

> Mathematical power includes the ability to explore, conjecture, and reason logically; to solve nonroutine problems; to communicate about and through mathematics; and to connect ideas within mathematics and between mathematics and other intellectual activity. Mathematical power also involves the development of personal self-confidence and a disposition to seek, evaluate, and use quantitative and spatial information in solving problems and in making decisions (NCTM, 1991, p. 1).

This vision coincides with that of the APEF mathematics curriculum, which should be of particular interest to mathematics teachers in this province as the province embarks upon secondary mathematics curriculum implementation in September 1999. The Atlantic Canada mathematics curriculum is shaped by a vision which "fosters the development of mathematically literate students who can extend and apply their learning and who are effective participants in an increasingly technological society" (APEF, 1995, p. v).

The visions of many teachers are seemingly different from those of NCTM and APEF; these teachers believe that the purpose of mathematics education is to foster skill development in classrooms where students are passive recipients of teacher-dictated knowledge -- they are not concerned about mathematics as communication, problem solving, and reasoning. Such teachers, if they are unwilling to modify their vision, will face an abundance of challenges in their attempts at assessment reform implementation. I argue, therefore, that, first and foremost, perhaps the primary challenge of assessment reform implementation is the necessity on the part of many individual teachers to modify their vision of mathematics education. As previously stated, a teacher's vision has a profound influence on their instruction and, consequently, the manner in which they assess their students. Teachers who view mathematics as a "set of skills" that somehow have to be transmitted to students will find that, within their classrooms, many of the assessment reform ideas that NCTM advocates will be hard to orchestrate. As NCTM (1989) points out, "mathematics is not simply memorizing rules and procedures but that mathematics makes sense, is logical, and is enjoyable" (p. 29).

Consequently, though many teachers may find it extremely difficult to refocus education in the direction of the NCTM Standards, such refocusing, I would argue, is mandatory. Otherwise, it is almost certain that comments like "That's not going to work, it's too idealistic" and "I'll never have enough time to do all of that" will continue to be prevalent. On the other hand, a willingness by teachers to modify their philosophy, is likely to result in an overall understanding of the motive for constructivist teaching which, by its very nature, will lend itself to a merger between instruction and assessment and the realization on the part of teachers that alternate forms of assessment are complementary and necessary. Romberg (1993) indicates:

> The assessment challenge we face is to give up old assessment methods to determine what students know, which are based on behavioral theories of learning and develop authentic assessment procedures that reflect current epistemological beliefs both about what it means to know mathematics and how students come to know (p. 109).

Nonetheless, for a teacher to change or modify their assessment methods is not an easy process. In fact, difficulty is inherent in any change (regardless of its nature) as evidenced throughout this paper. Modifying one's philosophy of mathematics education is especially difficult -- a teacher's philosophy evolves throughout their teaching career. A teacher's will to change is a beginning; however, effort and time are needed to modify one's belief system.

Further Challenges to Assessment Reform

This paper proceeds to examine six additional challenges to assessment reform implementation: (1) the challenge of teachers removing themselves from some of the comforts they have in their traditional practices; (2) the challenge of teachers becoming comfortable with designing alternate assessment "instruments" and recording and reporting information obtained from their use; (3) the challenge of teachers juggling demands placed on their time; (4) the challenge of teachers meeting external expectations while simultaneously remaining accountable for their actions; (5) the challenge that teachers, like students, are active constructors of their practice and, hence, it will be difficult for them to implement the assessment ideas that NCTM advocates if their vision of mathematics education is distinctly different than that of NCTM; and (6) the challenge of building and sustaining a constructivist classroom environment necessary to support alternate assessment initiatives. All of these challenges are addressed within the context of current theory, research, and practice.

Comfort in Traditional Practice

No one enters any environment completely oblivious to previous happenings. The mathematics classroom is no exception. Both teachers and students bring to the classroom their beliefs about and dispositions toward the discipline of mathematics (Nespor, 1987). Many teachers and students, therefore, have a tendency to resist changes, especially those that do not conform to their beliefs. Lambdin (1993) addresses this issue:

> The most formidable impediment to innovative assessment techniques may be tradition. Educational assessment procedures that have been in place for decades are difficult to change. Tests and letter grades are well established as methods for evaluating and reporting students' achievements in mathematics ... . Even if teachers are convinced of the benefits of using more innovative methods to evaluate their students, they are unlikely to succeed unless their supervisors, students, parents – and even their fellow teachers – understand and support their break with tradition (pp. 12-13).

"We've been doing it this way for years – why change now? We've graduated students that have been successful – what's the big fuss about? They're telling us what to do and they're not in the classroom all day long -- what makes them think that this is going to work?" Comments such as these often permeate staff room discussions.

Traditional practice offers a sense of accomplishment for many teachers. Such practice primarily entails students and teachers moving through mathematical material in an orderly manner. Teachers explain, demonstrate, and monitor student practice. Students listen, observe, and then practice skills and procedures that can be applied to specific kinds of problems (Smith, 1996). Many teachers are "stuck in a rut" and resist "letting go of" what is currently, in their opinion, working well and does not require change. In addition, Ball (1992) states:

> Practitioners may need, in many contexts, to develop increased conviction and assertiveness in order to claim their right to do things differently. The uncertainty of practice itself, combined with teachers' sense that they do not have authority and power to work for change, means that they may have difficulty working experimentally and responsibly to develop their practice. They may also not know how to take a more experimental approach to their work, for the pressure to appear competent, smooth, and sure of one's methods and results predominates (p. 17).

It will be a great challenge for many teachers to move away from the mentality that learning mathematics is just applying a procedure and toward the mentality that students have to sometimes struggle as they are actively involved in mathematical learning processes. Teachers should realize that, in life, when confronted with a problem, very infrequently can they ask themselves, "What procedure do I apply here?" Likewise, teachers should realize that truly educating students entails more then asking them to apply a set procedure to several similar routine exercises.

Nonetheless, a lot of teachers believe the student-centered classrooms that NCTM advocates are disorderly and unfocused. It will be radically different for them to ask students to explain, describe, and show. However, teachers have to listen to or read about students' thinking and line of reasoning in order to understand if students understand – a fundamental component of teaching. Movement away from "recipe" teaching, a challenge in and of itself, is a prerequisite en route to minimizing further challenges of assessment reform implementation.

Many teachers will be challenged to overcome their uncomfortable feelings of observing students as they learn. Such teachers oftentimes feel they are not doing what they were hired to do and feel the need to put additional structure on activities. So too, many teachers feel as though students will not learn if they take a guide on the side approach to classroom activities. Oftentimes, when one is uncertain about something it is more difficult to carry it out in as successful a manner than if one was certain – potentially leading to the point where the challenge of overcoming being uncomfortable and uncertain leads to the challenge of getting back on "track." If a teacher is uncertain in their practice, students very quickly sense that uncertainty which can lead to disastrous situations including discipline problems.

This issue is further compounded by the fact that as teachers choose to move toward a new pedagogy, students' resistance to change confronts them. Most students, like teachers, are deeply rooted in tradition. When students reach the secondary school level, many of them will find it difficult to change what they have been used to doing and a modification to the manner in which they have been taught and assessed could become a stumbling block.

In September 1996, the start of my fourth year of teaching, I began to implement some of the Standards' assessment ideas. Initially when I assessed students as they worked on problems in groups, comments like "Miss, this is foolish ... just show us how to do it!" permeated. Undoubtedly, it was, at times, very challenging for me to stick with what I was doing. In fact, it wasn't until November of that year that I had students comfortable with a classroom climate that reflected the reform efforts.

Additionally, in some cases, student mathematical anxiety complicates the challenge of instructional, and consequently, assessment reform. Norwood (1994) states, "Students with high mathematics anxiety ... are more comfortable with a highly structured, algorithmic course than with a less structured, conceptual course in developmental arithmetic" (p. 248). Movement toward a student-centered classroom will make many of these students uncomfortable and may, in fact, increase their mathematical anxiety. Therefore, anxious students will be inclined to resist change – presenting a great challenge, at least in the interim, for teachers.

Design, Orchestration, and Report Difficulty

The challenge of designing alternate assessment "instruments" is greater than the "challenge" of designing traditional paper-and-pencil tests. For instance, many teachers will experience difficulty in finding and creating good problems and situations for promoting mathematical communication, reasoning, and problem solving. This challenge is heightened for some teachers as they orchestrate the implementation of these assessments in their classrooms. Many alternate assessment "instruments" provide a teacher with the challenge of learning the subtle skill of observing students and developing insight into their thinking. This challenge must be overcome in order for teachers to be able to orchestrate classroom discussions and group work in ways that are productive mathematically.

Increased subjectivity with many alternate assessments makes recording and reporting student progress another challenge. Frustration may surface for some teachers as they attempt to record and report student information obtained through journals, observations, and interviews. Oftentimes fully understanding a student's written mathematical explanation or what a student is trying to articulate is difficult. Ball (1997) indicates that "knowledge of students is as essential a resource for effective teaching as is knowledge of mathematics itself" (p. 732).

Ball (1997) suggests three challenges in trying to figure out what students know: (1) Interpreting what students mean involves considerable skill at listening, watching, and studying written work; (2) Figuring out what students know involves generosity – giving them the benefit of the doubt – and skepticism – not assuming too much about what they mean; and (3) Students' understandings are sensitive to context – to the particular task they are given, to the adult who is asking them questions, and to the other students around them (pp. 735-736).

The Issue of Time

Central to implementing assessment reform is time. In a mathematics education graduate course that I took recently, the question arose: "How can a teacher find the time and the means to deal with so much individual assessment and respond with actions appropriate to each individual? Is this really possible?" (Brown, 1999). This question is common among secondary school mathematics educators as they try to shift their assessment practices toward using multiple assessment instruments in an active student-centered classroom. Many teachers wonder that with so little time to do what they have to do now, how are they possibly going to incorporate all of the different assessment strategies that the NCTM Standards advocate.

I believe the "answer" (and I use that term loosely) to this question goes back to a teacher's vision of mathematics. If a teacher's vision of mathematics education is consistent with the NCTM Standards, a teacher should have ample time for assessment. It must be realized, once again, that assessment is not done after instruction – the two occur simultaneously. Additionally, alternative assessments are not just "add-ons;" they should replace some of the written assessments (units tests, quizzes, assignments) that many teachers are currently so accustomed to using. Essentially, the premise that teachers should follow is that it is not the quantity of time they have that is important, it is the quality of its use.

It becomes a matter, therefore, of what a teacher values and how they "teach." As Ball (1988) points out, many teachers are "teaching" too much. In many mathematics classrooms there should be more student participation and, if this were the case, yes, teachers could assess many individuals using alternate forms of assessment, in every single class. However, using a lecture method for teaching (sage on the stage mentality) means that a classroom's structure is not as conducive to varied forms of assessment.

Nonetheless, in other ways time can be a challenge to assessment reform implementation. It would be practically impossible for a teacher to enter the classroom one day and implement the majority of NCTM's ideas – that concept is absurd. Teachers have to be given time to gradually phase in NCTM's ideas. Spillane, Thompson, Lubienski, & Reimann (1995) offer some of the many challenges with regard to time.

- Time to learn the knowledge required to enact these reforms;
- Time for local reformers to understand the reform ideas and figure out what they might mean for their existing practice;
- Time for local reformers to create opportunities for administrators and teachers to learn about the ideas;
- Time for teachers to grapple with the reform ideas and come to understand how they might reshape their existing practice around these ideas; and
- Time for educators to reflect on their attempts at carrying out these reforms (p. 59).

Lappan (1997) agrees that "teachers, and those who support teachers, need time -- time to learn, time to figure out what reform might mean for their school, time for reformers to build support among administrators and the community, and time to reflect on their attempts to carry out reforms" (p. 208).

Additionally, time can be a factor in making, using, and interpreting items for scoring open response items or performance tasks. Likewise, timetable structures may pose a challenge in that many Newfoundland secondary school classrooms operate on a 50-60 minute period basis and fitting many assessment initiatives into this condensed period of time is difficult; many new ideas resulting from alternative assessment are often not conducive to a scheduled agenda. "Classes of students actively discovering concepts while using technology and experimentation ... are better suited for longer time periods than more traditional lecture-format classes" (Dickey, 1997, p.9).

Meeting External Expectations

What we assess tells teachers, students, parents, and others concerned about mathematics education what we value. Dickey (1997) states, "We are at a time when our curriculum and instruction speak in the language of inquiry, constructivism, and active learning while many of our assessment methods listen only to the rapid recall of isolated facts" (p. 7). Why? I believe this can be at least partially attributed to teachers trying to meet the external expectations placed on them from varying sources.

Mathematics teachers in Newfoundland face a dilemma when they attempt to use assessment "instruments" that reflect the NCTM Standards' vision and, at the same time, they try to prepare many students for post-secondary studies. Mathematics assessments at many post-secondary institutes are primarily in the form of paper-and-pencil tests that emphasize procedural, knowledge-based outcomes with little attention given to applications and problem solving.

Additionally, in a world in which standardized testing is widely practiced, it is difficult for alternate forms of assessment to compete. Standardized tests have a profound influence on what is valued in the classroom; teachers often feel obligated to teach and assess in accordance to the many societal influences which, as is the case with a Standardized Achievement Test or a Mathematics Skills Inventory, are primarily structured around the "one correct answer" mentality.

Joyner & Bright (1998) state:

> It seems counterproductive to the overall emphasis on greater student achievement to put in place external assessments that are so "high stakes" that they encourage people (e.g., teachers, administrators) to focus only on multiple-choice assessments as the primary assessment tool while at the same time trying to align mathematics instruction with current reforms. It may be that teachers and administrators are unintentionally allowing external assessment to drive instruction in the "wrong" direction, in the sense that teachers work too hard to make their classroom assessment "match" the form and focus of those external assessments. It seems plausible that if students are learning mathematics deeply, then scores on external assessments will reflect that knowledge (p. 60).

Another challenge is placed on teachers as they endeavor to meet the expectations placed on them by school board officials. For instance, the evaluation scheme for secondary school mathematics in the Avalon East School Board, within which I teach, has the following percentage breakdown: Unit Tests (25%), Mid-term Examination (20%), Alternate Assessments (15%), and Final Examination (40%). In my opinion, this scheme poses substantial problems for teachers implementing NCTM's assessment reform ideas in that it doesn't fit within the framework of NCTM's assessment reform – too much emphasis is placed on paper-and-pencil tests. Many of these tests fail to assess students' achievements in problem solving, communicating mathematical ideas, connecting mathematics to reality, and reasoning mathematically. Therefore, if teachers enact a "constructivist" classroom, yet the school board dictates that only 15% of a student's grade will be based on alternative assessments, then teachers may feel "caught" between the school board and NCTM's reform ideas. However, in an effort to partially alleviate this "tension," the nature of questions on traditional tests could be revised to support the reform.

Parents, too, place some demands on teachers which, at times, can be quite challenging to contend with. For many parents, it will be difficult to convince them of the value of many of the alternate assessment "instruments." For the most part, the parents of current students were solely evaluated by paper-and-pencil tests. It will be a challenge to help parents understand that mathematics is about thinking and reasoning -- a very basic skill-- and not about practicing for a test.

One thing that may smoothen the transition for parents is to have them participate in what many of them would call the "new math" concepts and ideas. One manner in which this can be done is through Problem of the Week contests. I do this at the school in which I teach and I have had many parents comment to me about how their child enjoys doing the problems and how, in fact, they enjoy them as well. Oftentimes I offer open-ended problems for their consideration. I select problems that are engaging enough to get the entire family involved and thinking mathematically about them. Certainly, it is critical that we keep parents "on side." Parents are one of the key players in the school system as they are often called upon for ideas and to support the school in its various events.

Undoubtedly, it becomes very challenging for teachers to meet the expectations that various parties place on them while, simultaneously, being accountable for their actions. Ball (1992) states:

> As demands for accountability grow, teachers' latitude to experiment, to try new things, may be hampered. It seems paradoxical: In some sense, teachers are being urged to make their work yet more uncertain, even as they are simultaneously being asked to produce, more reliably, a set of ambitious outcomes. We want students to reason, to solve complicated problems, to perform intellectually challenging work. And, at the same time, we are creating tests to assess and monitor teachers' attainment of such ambitious goals. And, in general, societal support for such goals is ambivalent: the public wants students to be able to reason but also expects "math" in school to include all the things they remember from their own schooling. Tradition pulls conservatively on the reform agenda, leaving teachers uncertain about the space they have to make the changes articulated in the Standards (p. 15).

Further "expectation" challenges to assessment reform implementation arise as students move from the intermediate mathematics curriculum to the senior high mathematics curriculum. The Newfoundland intermediate curriculum is not currently changing to reflect NCTM's ideas and hence, students' prior experiences in the mathematics classroom will be an issue. Additionally, challenges arise within secondary schools that have more than one mathematics teacher. Because teachers are assessing individual students' understanding, classroom assessment, by its very nature, can be quite variable across classrooms. This, potentially, may create some tension among teachers within a given school in the sense that they may feel compelled to use another teacher's assessment methodologies.

Teachers as Constructivists

Knapp & Peterson (1991) state, "Most previous reform attempts in mathematics education are now judged to have failed primarily because researchers and curriculum developers failed to take into account the existing knowledge, beliefs, values, and purposes of teachers ... and of the cultures and contexts in which teachers work" (p. 2). McDiarmid, Ball, & Anderson (1989) indicate that "Recent research highlights the critical influence of teachers' subject matter understanding on their pedagogical orientations and decisions. ... Teachers' capacity to pose questions, select tasks, evaluate their pupils' understanding, and make curricular choices all depend on how they themselves understand the subject matter" (pp. 13-14). These authors allude to the idea that, in an effort to overcome many of the challenges of assessment reform implementation, it must be realized that teachers themselves need ample opportunities to construct new understandings of mathematics teaching. This should be one of the hallmarks as teachers are educated to implement NCTM's assessment reform ideas.

Teachers, like students, are active constructors of their practice. Lappan (1997) points out that in the same way that NCTM argues for a constructivist environment in which students explore and discover, "one has to consider that teachers do not learn pedagogical reasoning by being told about such reasoning. The environments that professionals build to educate and support teachers must help teachers construct their own professional knowledge" (p. 217). Therefore, just as NCTM calls for "classrooms as mathematical communities," Acquarelli & Mumme (1996) believe that teachers need to belong to learning communities that place inquiry at their center and that focus on building capacity for further learning (p. 481).

Cohen & Ball (1990) indicate that a paradox is created in that teachers are themselves products and producers of the traditional assessment that the reformers seek to change. Teachers' understandings, attitudes, images, and assumptions have been shaped in traditional mathematics classrooms with traditional forms of assessment. Thus, on the one hand, teachers, though potentially guided by educational support services, have to construct their own realities, and, on the other hand, have to intertwine these realities within NCTM's framework – quite a challenge if NCTM's framework is strikingly different from theirs!

Building a Constructivist Classroom Environment

Teachers also face the challenge of building and sustaining a constructivist environment in their classrooms. One of my best pieces of professional advice I was given in an undergraduate mathematics education course at Memorial University of Newfoundland by Dr. Lionel Pereira-Mendoza: "Don't teach too much!" At the time, truthfully, I didn't understand where he was coming from; I wondered how my students were going to learn if I didn't teach them. Upon completion of the course I still could not envision an active student-centered classroom in which students were learning with very few teacher explanations and being assessed without paper-and-pencil tests. In fact, such a concept of learning and assessment was inconceivable to me until I began my Masters degree when, once again, many of NCTM's ideas resurfaced. At that time, I began to "see the light." Indeed, at first it was a challenge for me to present a problem to my students and then "back off" and assess them as they worked on the problem. At that time, I felt as though my challenge was compounded with relatively large classes of students with dynamically opposed abilities and a set of curriculum objectives that I had to get "covered." However, very quickly, as I acted as a guide on the side and allowed my students to do a lot of work themselves, I found they were learning much more and I was able to assess them more frequently. It wasn't long before my apprehensions dissipated. Burrill (1997) offers advice with which I agree:

> We must step aside, which is sometimes very hard to do, while students are thinking and experimenting. Our job has just began, however, because while the students are thinking and talking, we must observe what they are doing, listen to their conversation, and ask probing questions. ... We should plan how to use their work as part of the lesson and how to craft discussions around what we are observing (p. 508).

Thus far, this paper has examined various challenges, which the pessimist may argue are barriers, to assessment reform implementation. The remainder of the paper is devoted to examining what can be done to facilitate teacher implementation of assessment reform ideas and provide for an optimistic future.

Provision of Teacher Education, Resources, and Support

Many teachers have not been trained to teach and assess in ways consistent with NCTM's Standards yet they are being asked to create opportunities for learning and assessing mathematics that they have likely never experienced nor observed. Russell & Corwin (1993) indicate that in order for assessment reform to "work," it is necessary to reeducate, provide resources for, and support teachers as they attempt to expand and deepen the content of their mathematics programs and to develop a pedagogy in which students are challenged to think mathematically and assessed in ways consistent with NCTM's Standards documents.

A first step in constructing ways to assess mathematics that takes the ideas of the NCTM Standards seriously will indeed require new learning. Lappan (1997) states, "There is a need to begin at ground level and build teacher support systems that can educate and assist teachers in changing their minds and their practice to encourage more powerful mathematics and mathematical thinking for students" (p. 211). If a teacher is going to have the attitude, "I'm going to still instruct using 'chalk and talk,' but every now and then I'll give students an open-ended problem to do for homework and have them pass it in because that's what I know I should be doing," then that teacher's assessments will probably "flop."

Teachers need a lot of background knowledge in order to carry out quality classroom assessment. Joyner & Bright (1998) indicate that they need to have a deep understanding of mathematics, have a firm grasp of the curriculum they teach, and know how what they teach fits into broader curriculum goals (p. 62). Additionally, they need to understand the ways that mathematical ideas develop in students' minds and the kinds of strategies that students bring to the senior high classroom. So too, they need to know how to gather information from students and then to make inferences from that information.

Encouraging teachers to take advantage of opportunities for professional development is mandatory. "Examples of successful professional development efforts show that over time teachers can reform their practice and build new classroom environments in which students learn to engage with mathematics in more active ways" (Lappan, 1997, p. 208). Such professional development may come in many forms including university courses, mathematics institutes, in-service days, and local, regional, and national conferences. Additionally, however, professional development often results as teachers circulate with other teachers in informal settings (e.g. student mathematics league competitions provide a local example for this informal discussion).

Undoubtedly, teachers need a variety of opportunities to learn. Determining accessible ways to connect with teachers in other schools -- to watch them assess, to talk with them about what they do, to share ideas, questions, and frustrations can enhance such learning. Ball (1992) offers some feasible suggestions: "Can networks be established that make ongoing professional exchanges feasible, cheap, and not time-intensive? Can video footage from different kinds of math classes be developed and made available in ways that would be productive -- and consistent with the idea of supplementing teachers' work and ways of thinking? Can multiple kinds of exemplars and data be made easily available -- opening the proverbial classroom door to offer practitioners opportunities to learn and to build a sense of professional community?" (p. 17).

Additionally, I firmly believe that it is important for teachers to have the opportunity to do mathematics together, at an adult level, on a regular basis, and to reflect with peers about their own learning of mathematics and its implications for their teaching. In fact, the APEF curriculum can be one of the tools that supports teachers as they rethink their mathematics teaching; new items can invite teachers into mathematics and into the world of student thinking about mathematics, thus, inviting teachers to open the doors of their classrooms to NCTM's vision of mathematics and, consequently, NCTM's vision of assessment.

We must say goodbye to the days when teachers worked in relative isolation, seldom sharing their methods and innovations with others; collaborative ventures are important. For instance, discussing the scoring of assessment "instruments" will help teachers build upon what constitutes a thoughtful, well-constructed student response. So too, conversing with other teachers about examining assessments to learn about students' thinking processes will prove insightful.

Undoubtedly, change requires clear direction and guidance. However, it should be noted that rigidity could be a setback. Shulman (1983) indicates that initiatives for change "must be designed as a shell within which the kernel of professional judgement and decision making can function comfortably" (p. 501). He argues that such initiatives cannot determine directly teachers' actions or decisions, and he concludes that they can, at best, "profess a prevailing view, orienting individuals and institutions toward collectively valued goals, without necessarily mandating specific sets of procedures to which teachers must be accountable" (p. 501). NCTM (1991) acknowledges these concerns:

> Because teaching mathematics well is a complex endeavor, it cannot be reduced to a recipe for helping students learn. Instead, good teaching demands on a host of considerations and understandings. Good teaching demands that teachers reason about pedagogy in professionally defensible ways within the particular contexts of their own work. The standards for teaching mathematics are designed to help guide the processes of such reasoning, highlighting issues that are crucial in creating the kind of teaching practice that supports the learning goals of the Curriculum and Evaluation Standards for School Mathematics (p. 22).

Ball (1992) indicates that this kind of teaching is hard, and "no one is going to produce a system, or a formula, or a program that can produce it. There are no recipes for helping students construct useful and worthwhile understandings of mathematics" (p. 15). Porter (1989) suggests that NCTM's Standards merely create a "context of direction" for change. Teachers are professionals who must make professional judgements based on experience, insight, and skill. Shulman (1983) points out that good teachers must work within a repertoire of possibilities, making decisions in the context of competing concerns and demands. Richardson (1990) notes that the content-specific nature of teaching practice creates a challenge for those who work for significant change in schools.

Thoughtfully constructed assessment materials and articles describing assessment would comprise useful resources for new ways of working with students within secondary school mathematics classrooms. Quite simply, however, there are too many demands on the Government of Newfoundland and Labrador resources to fully fund extensive professional development programs and/or provide elaborate resources. Therefore, teachers have to work together to help each other. It would be easy for teachers to give up and say that the province doesn't care if mathematics assessment reform is successful because it has not provided schools with enough money to do the professional development necessary to facilitate reform implementation. If Newfoundland educators respond in this way, it is almost certain that mathematics education in Newfoundland will remain in the era of skill and drill assessments. Whatever resources the province provides, Newfoundland schools must work to expand those resources to assure that teachers gain the skills and understandings they need to build upon the success of assessment reform implementation. Teacher initiatives are critical -- we must not remain locked into a model dominated by skill and drill assessments.

Conclusion

A comment like "math is the easiest subject to teach and correct" often permeates through many staff rooms. Indeed, there may be some validity in this statement if mathematics is taught from the traditional "set of skills" perspective and assessed solely through paper-and-pencil tests. However, if students are effectively "taught" and assessed in an active student-centered classroom, mathematics instruction and assessment can be very challenging.

Paper Two pointed out that NCTM's assessment reform ideas primarily center around assessing a student's ability to reason, communicate, and solve problems in an effort to improve instruction and facilitate student growth and learning. These ideas cannot be mechanically implemented; thus, it becomes necessary for teachers to reverse their mentality that assessment is not an interruption that marks the end of a learning cycle.

Amidst apparent turmoil, optimism can surface and there are things that can be done to build and sustain supportive attitudes and structures in order to facilitate the implementation of assessment reform. Reports from the National Research Council (1993) suggest that society recognizes a problem of graduating students who cannot think for themselves or solve problems; and, undoubtedly, having society "on-side" and being able to communicate with business and industry for practical ideas about assessment is beneficial.

Undoubtedly, there are "roadblocks" to assessment reform implementation. However, it is possible for teachers to overcome challenges as they steer in the direction of the NCTM Standards documents even though, at times, it may be necessary for them to "back track" if the road becomes too "bumpy" or a chosen direction leads to unfruitful circumstances. Nonetheless, despite potential "rough terrain," the end result of using alternative assessment "instruments" in the classroom will prove beneficial to teachers and students alike.

References

Acquarelli, K. & Mumme, J. (1996). A renaissance in mathematics education reform. Phi Delta Kappan, 77 (7), 478-482.

Atlantic Provinces Educational Foundation. (1995). Foundation for the Atlantic Canada mathematics curriculum. Halifax, Nova Scotia: Atlantic Provinces Educational Foundation.

Ball, D. (1988). Unlearning to teach mathematics. For the Learning of Mathematics, 8 (1), 40-48.

Ball, D. (1992). Implementing the NCTM standards: Hopes and hurdles. East Lansing, MI: National Center for Research on Teacher Education. (Eric Document Reproduction Service No. 352 264).

Ball, D. (1997). From the general to the particular: Knowing our own students as learners of mathematics. Mathematics Teacher, 90 (9), 732-737.

Brown, C. (1999, February 9). Discussion on mathematics assessment in Education 6630 at Memorial University of Newfoundland, St. John's, Newfoundland.

Burrill, G. (1997). Choices and challenges. Mathematics Teacher, 90 (6), 506-511.

Cohen, D. & Ball, D. (1990). Relations between policy and practice: An overview. Educational Evaluation and Policy Analysis, 12, 347-353.

Dickey, E. (1997). Challenges of teaching mathematics today: How can school leaders help? NASSP Bulletin, 81, 1-10.

Joyner, J. & Bright, G. (1998). Recommendations and starting points. In G. Bright & J. Joyner (Eds.), Classroom assessment in mathematics (pp. 59-77). Lanham, Maryland: University Press of America.

Knapp, N. & Peterson, P. (1991). What does CGI mean to you? Teachers' ideas of a research-based intervention four years later. Chicago: American Educational Research Association.

Lambdin, D. (1993). The NCTM's 1989 evaluation standards: Recycled ideas whose time has come? In N.L. Webb (Ed.), Assessment in the mathematics classroom: 1993 yearbook of the National Council of Teachers of Mathematics (pp. 7-16). Reston, VA: National Council of Teachers of Mathematics.

Lappan, G. (1997). The challenges of implementation: Supporting teachers. American Journal of Education, 106 (1), 207-239.

McDiarmid, G., Ball, D., & Anderson, C. (1989). Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. East Lansing: National Center for Research on Teacher Education, Michigan State University (Issue Paper No. 88-6).

National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1991). Professional standards for school mathematics. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (1993). Measuring up: Prototypes for mathematics assessment. Washington, DC: National Academy Press.

Nespor, J. (1987). The role of beliefs in the practice of teaching. Journal of Curriculum Studies, 19, 317-328.

Norwood, K. (1994). The effect of instructional approach on mathematics anxiety and achievement. School Science and Mathematics, 94 (5), 248-254.

Porter, A. (1989). External standards and the pros and cons of telling teachers what to do. Educational Evaluation and Policy Analysis, 11, 343-356.

Richardson, V. (1990). Significant and worthwhile change in teaching practice. Educational Researcher, 19 (4), 10-18.

Romberg, T. (1993). How one comes to know: Models and theories of the learning of mathematics. In Mogens Niss (Ed.), Investigations into assessment in mathematics education: An ICMI study (p. 109). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Russell, S. & Corwin, R. (1993). Talking mathematics: "Going slow" and "letting go." Phi Delta Kappan, 74 (7), 555-558.

Shulman, L. (1983). Autonomy and obligation: The remote control of teaching. In L. Shulman & G. Sykes (Eds.), Handbook of teaching and policy (pp. 484-504). New York: Longman.

Smith, J. (1996). Efficacy and teaching mathematics by telling: A challenge for reform. Journal for Research in Mathematics Education, 27 (4): 387-402.

Spillane, J., Thompson, C., Lubienski, C., & Reimann, C. (1995). The local government policy system affecting mathematics and science education in Michigan: Lesson from nine school districts. Michigan Statewide Systemic Initiative Policy and Program Review Component, College of Education. Michigan: Michigan State University.