Mathematics and Literature: Educators' Perspectives on Utilizing a Reformative Approach to Bridge Two Cultures

Suzanne J. Nesmith, Associate Dean/Assistant Professor of Education, Wayland Baptist University

Abstract

The existence of two distinct cultures within our society, the arts and the sciences, was introduced by physicist C. P. Snow in his 1959 Reed Lecture at Cambridge University and was further illuminated by Snow in *The Two Cultures, a Second Look* (1964). Lamenting the existence of the cultural chasm while also fearing a widening of the schism, Snow opened a dialogue with the hope of reconciliation between the cultures. Fifty years later, although the chasm still exists, numerous entities and individuals within the cultures work to formulate the means by which the cultures may be bridged, and, subsequently, the chasm narrowed and eliminated. The National Council of Teachers of Mathematics (NCTM) is one such entity, and leaders of the group have worked since the council's establishment in 1920 to research, promote, and improve the teaching and learning of mathematics through innovative, reformative approaches.

Reform-oriented curricula are built upon constructivist perspectives aimed at assisting students in utilizing their own unique backgrounds and experiences to develop a personal understanding of mathematical situations. One means of infusing personal experience into the mathematics curriculum, while also bridging the aforementioned cultures, is through the incorporation of children's literature, yet there exists great variance in the type, format, structure, and success of the methodology's implementation. Subsequently, while the reformative approach of mathematics literature integration presents as a means of building understanding by bridging the cultures of mathematics and the humanities, it is the educator's choices relevant to the approach which have the greatest impact on the outcomes of the approach.

Introduction

A fairly consistent, predictable way of teaching mathematics prevails in classrooms throughout the United States. Memorization of facts as well as the ability to follow rules, execute procedures, and plug in formulas is lauded, and only those students capable of absorbing, accumulating, and regurgitating received items of information in this manner excel in traditional mathematics classrooms (Battista 1994; Brandy 1999; Hiebert 2003). The teacher's role in traditional classrooms is to "provide clear, step-by-step demonstrations of each procedure, restate steps in response to student questions, provide adequate opportunities for students to practice the procedures, and offer specific corrective support when necessary," and the ultimate mathematical authority is the textbook from whence "the answers to all mathematical problems are known and found" (Smith 1996, 390-91).

In direct opposition to traditional mathematics' behaviorist approach, reform-oriented mathematics focuses on a constructivist perspective. While behaviorism emphasizes students' passive absorption of observable behaviors, constructivism asserts that individuals approach a new task with prior knowledge, assimilate new information, and, subsequently, construct their own meaning (Amit and Fried 2002). As children construct their own understanding based on the relationship between prior knowledge, existing ideas, and new experiences, they must be encouraged "to wrestle with new ideas, to work at fitting them into existing networks, and to challenge their own ideas and those of others" so as to subsequently enlarge the framework from which new ideas may be formulated (Battista 1994; Van De Walle 2007, 23). "Once one accepts that the learner must herself [*sic*] actively explore mathematical concepts in order to build the necessary structures of understanding, it then follows that teaching mathematics must be

reconceived as the provision of meaningful problems designed to encourage and facilitate the constructive process" (Schifter and Fosnot 1993, 9).

The National Council of Teachers of Mathematics, as well as other entities promoting mathematics reform, recognizes that the fate of the reform movement lies within the reality that teachers are key figures in effecting change in the ways mathematics is taught and learned in schools (Battista 1994; NCTM 1991). Altering the way educators teach, however, is difficult, and the more ambitious and drastic the instructional program, the more significant and substantial the change (Battista 1994; Hiebert 2003). Subsequently, if the chasm between the arts and the sciences, which was first addressed and enunciated by Snow in 1959, is to be bridged by reform-oriented approaches such as mathematics literature integration, one must delve the many fissures within the subculture of mathematics; the gulf between educators who actively promote change and those who accept and maintain the status quo within their mathematics classrooms, the gulf between traditional and reformative mathematics, and the gulf between approaches and beliefs relevant to mathematics literature integration. Only after these openings and cracks are recognized and addressed, can we stand on the edge of the bicultural abyss and, without fear of falling in, formulate a means of bridging the chasm between the arts and sciences.

The History of Mathematics Reform

Most reforms begin due to an element of dissatisfaction. Relevant to mathematics reform, the dissatisfaction grew from students leaving school with only minimal mathematical knowledge and skills, a dramatic decrease in the number of individuals desiring to pursue mathematically oriented careers, and, perhaps most relevant in today's high stakes accountability culture, students' poor performances on standardized tests (Amit and Fried 2002). However, these elements do not represent the broad realm of reform, nor do they allow for the representation of mathematics reform as a phenomenon involving "the whole complex of students, teachers, researchers, parents, and politicians" (Amit and Fried 2002, 355). To garner an understanding of society's continued and pervasive utilization of traditional mathematics' collection of obscure procedures and rules, and to fully realize the tenets of reform-oriented mathematics, it is necessary to examine the historical progressions that have transpired within the field of mathematics.

Mathematicians of the seventeenth century, such as Newton and Descartes, viewed mathematics as "a tool to organize, communicate, and convince others of their hypothesis." Their original intent, therefore, was not to establish math as an independent study. However, once science and technology expanded mathematical horizons, the refinement of mathematics into neat and logical categories occurred. Concurrently, computations became so complex as to necessitate the reductionism of mathematics; "complex problems were reduced to elemental principles and specific skills" and explicit, precise languages for each mathematical field evolved. What followed was the creation of formulas capable of creating reproducible solutions and the establishment of rules "for the efficient calculation of problems" (Brandy 1999, 2).

Mathematics curricula in the United States have not only been impacted by the evolution of mathematics throughout the centuries, but by events that are more recent as well. Originally designed to prepare "shopkeepers, farmers, and factory workers for the 1940's," mathematics curricula were drastically revised in the late 1950's due to the Sputnik space shot by the Soviets (Braddon, Hall, and Taylor 1993, 1). The *modern math era* of the 1960's was highlighted by an emphasis on precision and rigor followed by a process-driven, hands-on approach to teaching

and learning. The hands-on approach continued into the 1970's *laboratory mathematics period* as mathematics curricula began to include "lab materials, manipulative materials, and hands-on activities" (1). An increase in technological developments, as well as an understanding that the country required equal access to mathematics education for *all* peoples if the United States were to remain a competitive world leader, precipitated the *back to basics movement* of the late 1970's. The problem with this movement, however, arose not from its well-formulated intentions, but rather from the fact that "no one could agree on what the basics actually were in mathematics" (2). The National Council of Teachers of Mathematics stepped onto the stage early in the 1980's with the publication of *An Agenda for Action*. A primary focus of the document was on the importance of problem solving, yet the skill of problem solving proved very complex relative to both its teaching and its execution. By the late 1980's, NCTM stepped firmly into the reform arena with the development of *Principles and Standards for School Mathematics*. Classified as *the era of realization*, this period highlighted the need for reform in mathematics education while also spotlighting the ways and means by which students come to understand mathematics.

Published almost two decades ago, and revised in 2000, NCTM's *Principles and Standards* continue to guide a revolutionary reform movement in mathematics education. Relative to mathematics, reform focused constructivism represents the perspective that student's mathematical understanding requires the provision of time and opportunities to participate in a process of concept construction and active interpretation within meaningful contexts (Schifter and Fosnot 1993). Brownell (2004) posited that meaningful mathematical experiences were those connected with real life needs, and, similarly, Nunes claimed meaningful experiences were those which demanded "the thinking sustained by daily human sense" (1993, 23).

An additional element of constructivism's personalized, meaningful, meaning-making construct is its attendance to issues within the affective domain. When viewed through a traditional lens, mathematics is "a largely logical and narrowly rational business," and, based on this view, "education is an area where there is little room for our emotional lives" (Egan 1986, 17). However, reform-oriented mathematics appreciates that mathematics is not an inhuman activity, and according to Egan, the key to "rehumanizing it for children is to tie the computational tasks back to the human intentions, hopes, fears that generated them in the first place" (77). Smith (1996) asserted that it was not possible for anyone to actually teach mathematics; instead, effective teachers are those capable of stimulating student learning. Subsequently, the reconstruction of "curricula and teaching methods in light of a richer image of the child as an imaginative as well as a logico-mathematical thinker" reveal through the tenets of constructivism (Egan 1986, 17).

Barriers to Reform-Oriented Mathematics

Transformation of any type is difficult, and in addition to considering the tremendous scope and complexity of the transformation, a shift to reform- oriented mathematics must be viewed in light of the fact that the history of American education is characterized by Kennedy as "a history of reform efforts, most of which have left teaching unchanged" (1991, 3).

The reform movement in mathematics education necessitates within a majority of educators a realistic confrontation of the habits and assumptions of traditional instruction. Battista argued that because the beliefs, habits, and assumptions of these educators are incompatible with those of the reform effort, teachers may, both with or without their full cognizance and recognition thereof, "block reform and prolong the use of a mathematics

curriculum that is seriously damaging the mathematical health of our children" (1994, 1). Schifter and Fosnot (1993) similarly recognized the gap between current instructional practices and the new paradigm posed by the NCTM standards, and subsequently enumerated a list of impending barriers to mathematics reform.

The first potential barrier is that teachers are products of the system they are being asked to change. "The fact that their understanding is more rule-bound than conceptual, and more fragmented than connected, reflects the nature of the teaching and curriculum that they, like other American adults, experienced in elementary and secondary schools" (Ball 2003, 18). Teachers have at least 16 years of experience supporting their belief that following rules will lead students to the right answer, and most are successful products of this practice (Brandy 1999). Along a similar vein, another barrier is that in addition to reform being very different from the mathematics of their past, it is also very difficult. While Battista (1994) perceived potential difficulties in teachers' acquisition of the knowledge and competencies necessary to implement reforms, Perry and Dockett posited that, "one of the biggest challenges for mathematics education is in the area of learning how to develop a profound understanding of fundamental mathematics in adults who interact with the young children in their schools" (2002, 104). Additionally, when examining knowledge and competency acquisition difficulties associated with reform implementation, it is noted that, "the mathematical knowledge needed to enable effective teaching is different from that needed by mathematicians" (Ball 2003, 16).

Another potential barrier to reform is the current emphasis on textbooks for mathematics lessons. This practice undermines teachers' professional judgment regarding appropriate mathematical methodology as traditional texts "embody a transfer-of-information, drill-and-practice approach to instruction" (Schifter and Fosnot 1993, 13). Not only do textbooks support a rule-based view of mathematics, but state and district assessment programs are often designed to assess computation-centered instruction, thereby creating another impediment to reformative mathematics. District and school cultures may also hinder the adoption of reformative measures due to the fact that colleagues, supervisors, and administrators may claim to embrace the approach, yet may still harbor the assumption that good teaching means "ensuring that students get right answers," and they may also interpret the new approach "in terms of past reform movements whose premises are in conflict with this one" (14). This barrier may present as being insurmountable to educators because supervisors and administrators continue to evaluate teachers while often utilizing the traditional mathematics paradigm.

Literature Integration in Mathematics

The reform era began in 1989 when the National Council of Teachers of Mathematics published *Curriculum and Evaluation Standards for School Mathematics*, and "no other document has ever had such an enormous effect on school mathematics or on any other area of the curriculum" (Van De Walle 2007, 2). Since the time of its publication, NCTM has published three additional standards documents, yet the tenets of the 1989 *Curriculum Standards* have continued to serve as the framework for subsequent documents as well as maintain the vision of reform. As articulated below, the integration of children's literature within mathematics has the power and the potential to help students achieve each of the five mathematical goals outlined in *Curriculum and Evaluation Standards for School Mathematics* (Whitin and Wilde 1992).

1) Students should come to understand the value of mathematics through numerous, varied learning experiences that represent the cultural, historical, and scientific evolution of mathematics (NCTM 1989). Additionally, the following has been asserted:

> In its origin, in its development, mathematics requires full association with all types of human activity, mental and physical… mathematics has drawn inspiration from business, from religion, from law, from war, from politics, from ethics, from gambling, from metaphysics, from mysticism, from ritual, from play (look what a mathematical thing the children's game of hopscotch is), and not just from a 'sanitized' physical science. (Davis and Hersch 1986, 304)

Children's literature, through its natural ability to represent the integration of mathematics into other curricular areas, provides students with a unique perspective on mathematics' role in the development of these other domains (Leitze 1997; Whitin and Wilde 1992). Furthermore, by drawing attention to the mathematics that is entrenched in everyday life, literature reveals to students that mathematics is inherent in human thinking and is relevant to their lives (Haury 2001; Murphy 1999).

2) Mathematics curricula should relate to students' everyday lives and should be shared with students in a manner which builds their sense of self-reliance and allows them to become confident in their mathematical abilities (NCTM 1989). Stories, whose context is often represented through specific narrative situations, are understandable to children because "the mathematics to be learned is related to concrete actions of an identifiable person and their explanations of those actions" (Schiro 2004, 53). The use of literature has also been reported as a means of alleviating some of the math anxiety experienced by students through its provision of low-key, natural, open-ended, nonthreatening explorations of mathematical ideas (Jacobs and Rak 1997; Whitin 1992; Whitin and Wilde 1992). The reduction in anxiety subsequently serves to pave the way for student's increased mathematical confidence.

3) Problem solving skills are essential to the development of productive citizens, and mathematics curricula must develop children's mathematical problem solving abilities as well as their ability to apply the power and utility of mathematics (NCTM 1989). In mathematics literature, language and mathematics work together as both the story and the mathematical problem unfolds. "This shows children that real world mathematics problems can be 'messy' and have multiple solutions, and are not typically static, like those frequently seen in the textbooks" (Moyer 2000, 3).

4) Students need to learn mathematical symbols and ideas so that they can communicate with others mathematically. As students strive to express and expand their mathematical understanding through the communication of their ideas, they learn to clarify, refine, and consolidate their thinking (NCTM 1989). Mathematics is a communication system that can be used to describe and communicate our life experiences, yet Pimm (1995) further discerned that communication about mathematics requires genuine negotiation and sharing of meaning. Children's literature involving mathematics provides a common, natural context for the sharing of mathematics. Teachers and students are accustomed to using books as a springboard for discussions about other subjects; therefore, using mathematics literature employs already fertile ground for the promotion of discourse (McDuffie and Young 2003; Narode 1996). Mathematical discourse not only promotes children's oral language skills, but it also advances students' abilities to think and communicate mathematically (Moyer, 2000).

5) Traditionally, mathematics has been taught as a set of problems whose solutions were either right or wrong, yet the guidelines of the NCTM *Curriculum Standards* promote the valuing of students' reasoning processes as equal to their ability to find correct answers. Reasoning mathematically involves making conjectures, gathering evidence, and building a

supportive argument, and these skills are essential to the development of mathematical understanding. Kolstad, Briggs, and Whalen (1996) postulated that much of children's literature encourages investigation and provides students the opportunity to examine mathematical concepts in a nonthreatening manner, and when children are encouraged to question their explorations, they utilize hypothesizing, estimating, and computing. Oral storytelling also promotes reasoning as children listen, interpret, and reflect on the story's content. As posited by Countryman (1992), to know mathematics is to do mathematics, and this is possible only through the exploration, justification, representation, discussion, use, description, investigation, and prediction of mathematics in the world around us – and reading and writing mathematics are ideal for these processes.

Context of the Study

The study was conducted in elementary classrooms within a single school district, Proper ISD (a pseudonym), located in the southwestern United States in the city of Proper. Having a population of approximately 22,000 residents, the school district has an enrollment of approximately 6,100 students, and the district is composed of six elementary campuses, early childhood through grade four. Four females of two varying ethnicities with a range of teaching experience from 9 to 24 years were included in the study. The participants represented three elementary campuses, three grade levels, and embodied four distinct classroom organizational structures. The listing and exemplification of each participant's distinct characteristics are contained in table 1.

During the course of the investigation, a series of three semi-structured interviews were conducted with each of the four participants. Additionally, classroom observations of the participants occurred during scheduled mathematics times to allow for an in-depth, contextual study of the selected classroom teachers' math lessons when they were both incorporating and not incorporating children's literature. Artifacts requested of participants included weekly e-mailed lesson descriptions, lesson plans and student assignments specific to classroom observations, student assessments utilized during the course of the study, and a participant literature checklist. As an important element of the study related to the relationship between stated and actual utilization of reform-oriented measures, these articles provided "frequently mute but telling testimony to the tasks teachers believe important or feel obliged to emphasize" (Eisner 1991, 185).

Results

This study focused on the beliefs, attitudes, and experiences of elementary educator's which block or promote their utilization of reform-oriented mathematics, and how the relationship between these factors impacted the educator's utilization of the specific reformative approach of mathematics literature integration. In an effort to determine the ways, means, and frequency with which participants utilized reformative practices in their classroom as well as to explore the potential for pseudo-reforms, whereby participants expressed reform-oriented views but maintained a traditional mathematics classroom, classroom observations of participants were compared to their personally presented interview descriptions. Additionally, artifacts presented a means for further exploration and comparison of participant's expressed and exhibited degrees of reform and literature integration within their mathematics classrooms.

Barriers to reform

Consistent with the findings of Ball (2003), Battista (1994), Schifter and Fosnot (1993), Smith (1996), and others, numerous barriers to reform presented through participants' words and actions. The delineation of reformative barriers is contained within table 2.

Expressed/exhibited reform

Expressed and exhibited views towards specific reform-oriented classroom approaches and practices revealed the depth of the reformative barriers as well as each participant's desire and ability to overcome those barriers so as to create a reformative mathematics classroom. Examined holistically, findings herein revealed participants' expressed and exhibited mathematical perspectives along a reform oriented to traditional continuum. No participant demonstrated through words or actions a wholly reform-oriented "pedagogy that centers on conjecture, conceptual exploration, and discursive interchange" nor an exclusively traditional "pedagogical practice that emphasized memorization and computational routine conveyed through lecture, demonstration, or textbook" (Shifter and Fosnot 1993, 13). A summary of participants' expressed and exhibited degrees of mathematics reform is represented in table 3.

Literature integration

Based on participants' descriptions of a typical mathematics literature integration lesson, delineations of their perceptions relevant to the purposes associated with the approach, and classroom observations, determinations of participants' expressed and exhibited levels of literature integration were determined. Comparisons between previously delineated reformative perspectives and explications of the same relative to mathematics literature integration revealed the relationship between participants' mathematics reform levels in general and mathematics reform levels specific to literature integration. A summary of participants' general and specific reform beliefs is presented in table 3.

Conclusions

This study was designed to explore elementary educator's perspectives, abilities, and desires to utilize the reformative approach of mathematics literature integration as a means of bridging the cultures of science and the arts. With respect to reform orientations, there revealed no correlation between the age of participants, their years of teaching experience, and their ability or desire to implement reformative measures such as literature integration. Ann and Jo revealed as the most reform-oriented participants while Rose and Gail moved closer to, but did not reach, the traditional orientation endpoint. One conclusion that can be drawn from this delineated differentiation is that although all participants expressed numerous barriers to reform, Jo and Ann were the participants capable of overcoming these barriers so as to realize reformative measures; this capability was linked to these two participant's expressed interest in and pursuit of deeper mathematical understandings through participation in mathematics courses, conferences, and workshops. Subsequently, the depth of these participant's mathematical understandings relayed to increased reform orientations and reformative classrooms.

Comparisons between participants' expressed and exhibited mathematical reform perspectives revealed that Ann, Jo, and Rose all displayed parallels between their words and actions, yet Gail expressed a much higher degree of reform than was observed in her classroom. A possible reason for this inconsistency is that Gail articulated, during interviews, her misunderstandings of what constituted specific reformative measures. The conclusion underscoring this data is that confusion and misinterpretation of reform and reformative approaches produced heightened levels of expressed reform in Gail.

After delineating participants' general reform orientations, the same elements were determined specific to literature integration. Rose presented as the only participant with any discrepancy between her expressed and exhibited levels of literature integration; she exhibited a slightly higher level of reform within her mathematics literature integration than she expressed during interviews. It was determined that this incongruity was probably due to Rose's self expressed limited recognition of, experience with, and knowledge of mathematics literature integration. A subsequent conclusion drawn from this information is that general exhibited reform orientations almost paralleled specific literature integration exhibited reform levels and that exposure to and knowledge of the strategy had no major impact on participants' exhibited levels.

Implications

Examination of expressed and exhibited mathematics perspectives revealed that participants embraced the reformative approach of mathematics literature integration in varying degrees and with a multiplicity of attitudes, beliefs, and perceptions, thereby leading to numerous implications. Based upon the parallels between participants' exhibited general reform orientations and their exhibited specific literature integration orientations, the first implication to flow from these results is that educators' reform orientations are deep and reveal in numerous ways within their mathematics classrooms. While many factors may influence or potentially limit the integration of literature in mathematics, including the elements of curriculum, time, knowledge of literary resources, and availability of literary resources, the aspect that most affected participants' literature integration was their reform orientations. Participants high in reform levels formulated alternatives and devised means to overcome these influences so as to incorporate literature integration in its intended reformative manner. However, participants expressing lower levels of reform either succumbed to the reform barriers or modified the literature integration approach so as to present it in a traditional style.

Another study implication is that while literature integration has broad contextual variances, not all participants understood the mathematical underpinnings of this and other reformative approaches. Subsequently, misunderstandings relative to reform's constructivist nature must be revealed and resolved. NCTM released its original standards document in 1989, and 11 years later they released the current *Principles and Standards for School Mathematics*, yet many educators remain ignorant of what the document professes regarding principles fundamental to high-quality mathematics education.

Final Thoughts

Recognizing the dominating impact of traditional mathematical thoughts and methodologies on educators, all associated with and involved in educator preparation and professional development programs must remain firm in their belief that teachers at all levels desire classrooms wherein all students may come to recognize, understand, and utilize mathematics in a manner which allows them to face new quantitative scenarios with confidence and respect. The road to constructivist, reformative teaching and learning is arduous, for it is wrought with innumerable detours, shortcuts, and roadblocks. However, an awareness of these perils allows educators to arm themselves with the tools required to successfully navigate and complete the journey so as to fully realize that which should be the goal of all mathematics educators – mathematical proficiency that allows the entire citizenry to "participate fully and productively in society and the economy of the 21st century" (Ball 2003, 2). A goal analogous to that articulated by C. P. Snow over fifty years ago when he implored the bridging of the two cultures so that there may

subsequently follow communication between these cultures for the benefit and growth of all society's inhabitants.

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Table 1. Participant characteristics

Participant	Ethnicity	Campus	Years Teaching Experience	Grade Level	Classroom Structure	Self-Stated Level of Literature Integration
Ann	Anglo	Hilltop	20	4	Departmentalized math remediation	Medium
Gail	Anglo	Evergreen	9	4	Departmentalized	Medium-Low
Jo	Anglo	Hilltop	16	2	Self-contained	Medium
Rose	Hispanic	Channel	24	1	Self-contained bilingual	Low

Table 2. Barriers to reform

Participant	Traditional Experiences	Difficulty of Reform	Traditional Textbook or Program	Traditional Assessment	Focus on Correct Answers	Supervisor Misinterpretation of Reform
Ann	X	X	X	X		
Gail	X		X	X	X	
Jo	X	X	X	X		X
Rose	X		X	X		

Table 3. Participants' general and specific degrees of mathematics reform

Participant	General Mathematics		Specific Mathematics Literature Integration	
	Expressed Reform	Exhibited Reform	Expressed Reform	Exhibited Reform
Ann	High	High	High	High
Gail	Medium High	Low	Medium Low	Medium Low
Jo	High	High	High	High
Rose	Medium Low	Medium Low	Medium Low	Medium

Published by the Forum on Public Policy