A COMPREHENSIVE LITERATURE REVIEW AND CRITIQUE ON THE DIFFERENCES AND EFFECTS OF IMPLEMENTING TRADITIONAL AND REFORM MATHEMATICS CURRICULA

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Abstract

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History shows that there has often been discussion and debate regarding the best teaching practices. Pedagogical differences among mathematics educators has especially come into the forefront over the past several years. There has been a push to incorporate a more constructivist approach to mathematics instruction across the United States. Mathematics educators supporting the philosophy of constructivism advocate a transition from traditional textbooks and practices to reform teaching materials.

Constructivism is a philosophy of learning focused on how people best learn information, understand it, and are able to recall it to use at a later time. Constructivism is rooted in brain theory and its basis relies on the belief that through the addition of new data a person's current base of knowledge on that topic is modified. The new information is assimilated into what is already known about the topic. Constructivists believe that people are continually creating and developing their ideas as they are modifying their understanding based on new data. Its educational applications lie in creating classroom activities and experiences that continually build on prior knowledge. It is important that

new information not only coincides with a person's current knowledge base, but also challenges their current understanding so they can refine and enrich their understanding of an idea.

In regards to mathematics instruction, this theory and its application has evolved into teaching resources and instructional practices known as reform mathematics. The focus in reform mathematics is problem solving, student-discovery, hands-on activities, and critical thinking. Students participate in group discussions and activities. It is a priority to continually build upon students prior knowledge on a topic so they can best retain and recall information. Information has been learned in a way that the brain has assimilated it, allowing the information to be accessed later and used for problem solving. Engaging students in the classroom by giving them real-life math problems and interesting activities is at the core of reform mathematics. This style of teaching differs from what is considered traditional math instruction.

Currently, the traditional approach is the most prevalent technique used in education in the United States. Traditional math instruction focuses on the teacher who disseminates all information to the student. There is typically no student-discovery process involved. Quite often only one algorithm is taught when solving a math problem. In mathematics education from primary through secondary school, there is a focus, almost solely, on basic skills. Hands-on activities, projects, and problem solving are not central to this teaching style. Traditional instruction does not embody the constructivist approach to educating students.

The purpose of this study was to describe the historical transitions from traditional to reform mathematics and the implications of reform mathematics for today's

teachers in the 21st century. This study identified how the teaching of reform mathematics has affected student learning. The researcher compared and contrasted the advantages and disadvantages of traditional and reform mathematics instruction through a comprehensive review and critique of the research and literature. Based upon critical analysis of the research and literature, the researcher has made conclusions and recommendations.

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CHAPTER 1
Introduction

"The essence of mathematics is not to make simple things complicated, but to make complicated things simple." -S. Gudder

While the idea exists that the study of mathematics can be a complicated endeavor, there are many math educators that strive to teach the subject, perhaps simplifying it, so it can be understood by all students. In the search to find the best practices to reach all students, there are many approaches that can be utilized. The options range from a traditional approach to teaching math to a constructivist approach. These two pedagogical styles are, essentially, on opposite ends of a continuum. While these teaching styles vary greatly, both approaches are implemented throughout the United States (Crawford & Snider, 2000).

Traditional math instruction holds that "students learn by absorbing clearly presented ideas and remembering them, and that teachers offer careful explanations followed by organized opportunities for students to connect, rehearse, and review what they have learned" (Kilpatrick, Swafford, & Findell, 2001, p. ix). This teaching method focuses on the teacher who disseminates all information to the student. There is typically no student-discovery process involved. Quite often, in mathematics, only one algorithm is taught when solving a problem. Traditional education relies on direct teacher instruction, recitation, memorization, and logical analysis (Ravitch, 2000). Basically, this is the teaching approach that most people have experienced in their educational background.

In contrast to the traditional view is the constructivist approach. Reform math instruction relies on constructivist pedagogy. Integral to constructivist theory is the idea that we are continually generating a new set of rules that better accounts for what we perceive is occurring (Brooks & Brooks, 1999). Based on a constructivist approach the focus in reform mathematics is problem-solving, student-discovery, hands-on activities, and critical thinking. Students participate in group discussions and activities which are centered around real-life math problems. Students are encouraged to construct deep understandings of important concepts (Hiebert et al., 1997).

Reform oriented mathematics educators are also considered to promote standards-based instruction. The National Council of Teachers of Mathematics promotes the focus on standards to give individual school districts a guide to use in order to design a coherent curriculum and to promote continuity in mathematics education throughout the nation (Mann, 2000). An area in the NCTM Standards that has received criticism from traditional mathematics professionals is encouraging use of technology in the classroom. Centrally, it is the increased use of calculators at all grade levels that is of the most concern. The question arises whether the students will be as strong at basic skill work as they should be if allowed to rely on a calculator when working on mathematics, especially during their elementary education.

Although there are a variety of teaching styles utilized in our nations schools today, it is evident that the most pervasive is the traditional approach (Goodlad, 1984). The American classroom is dominated by teacher talk. Student-initiated questions and interaction among the students are atypical (Brooks & Brooks, 1999). Often the information teachers relay to students is taken directly from school district textbooks.

While it is possible to use incorporate primary sources, cooperative group work, or interactive discussion, most teachers rely heavily on textbooks (Ben-Peretz, 1990).

To assess which pedagogical methods develop and guide students' learning best is not a simple task. Research results can help narrow the scope of what seems to be working and to assess where students are in their learning. Depending on what the goals and expectations are of the researchers and an individual's preset notion of what they believe is true, a wide array of information can be inferred from the research and assessments.

There does appear to be one study conducted at an international level that is considered especially reliable. This study was administered by the TIMSS International Study Center at Boston College and the National Center for Educational Statistics (National Education Goals Panel, 2002). The Third International Mathematics and Science Study (TIMSS), is currently the most extensive and far-reaching comparative study of mathematics and science conducted. It shows the United States falls below average internationally in mathematics at the middle-school level (Schmidt, 2000). These results were found in 1995 with the TIMSS and also in 1999 with the TIMSS-R (for repeat), revealing a disturbing pattern. Along with research data there are also other indications that show the need for enhancement and cohesiveness in teaching practices in the United States. American employers currently spend more than $25 billion each year on remedial education for their employees-most of whom have come from a public school background (Kearns, 1989).

Statement of the Problem

There is an increasing recognition among educators that math instruction in the United States needs to improve on many levels. Both the traditional and reform approaches to math instruction are currently being debated for their effectiveness. Examining educational theories that are currently at work in our nation is necessary in order to assess their pedagogical value.

Purpose of the Study

The purpose of this study is to describe the historical transitions from traditional to reform mathematics and the implications of reform mathematics for today's teachers in the 21st century. This study identifies how the teaching of reform mathematics has affected student learning. The researcher also compares and contrasts the advantages and disadvantages of traditional and reform mathematics instruction through a comprehensive review and critique of the research and literature. Based upon critical analysis of the research and literature, the researcher formulates conclusions and recommendations.

Definition of Terms

In order to provide an appropriate framework for the comprehension of material contained in this study the following definitions of terms are provided for the reader.

NCTM: is the National Council of Teachers of Mathematics, a professional organization of mathematics educators.

Standards: the National Council of Teachers of Mathematics has designed and published a set of national mathematics standards that are to be used as a guide for school districts and states when writing curriculum. The NCTM standards are considered as statements of criteria for excellence in school mathematics programs.

Pedagogy: refers to the profession of teaching and the theories of how to teach.

Standards-based: activities, materials, textbooks, or teaching methods based on the NCTM Standards.

Reform: a pedagogical teaching style which encourages a constructivist approach to teaching and learning, focusing on real-life application of mathematics skills.

Constructivist: a theory of learning focusing on active involvement of the learner in order to give them the opportunity to construct a basic framework of knowledge to then be able to add more information as it is learned in context.

Traditional: a pedagogical teaching style that relies heavily on drill and practice of computational skills, distributed mastery, and negligible application of mathematics skills.

Chapter 2

Review of Literature

Introduction

In this chapter the researcher reviewed the body of literature and research related to traditional and reform approaches to mathematics instruction. The investigation of literature on the topic of these two pedagogical styles provided a framework for understanding the dynamics and issues promoting the employment of the strategies, methods, and approaches, as well as the development of conclusions and recommendations.

Traditional Instruction

Traditional instruction stems from an assemblage of school practices that were thought to be the *natural* way of conducting school (Oakes, 1985). In a typical classroom today you will find one teacher, 25 to 35 students, a chalkboard, books, and a lock-step curriculum (Rorinson, 1992). Most classrooms in the United States follow a traditional approach to instruction (Schoenfeld, 1985). Gallagher and Pearson (1989) reviewed several studies on classroom practices and found that instructional practices have remained about the same from about 1893 to 1979. According to Ravitch (2000), education in America since the seventeenth century has been based on a traditional liberal arts curriculum. The traditional curriculum for student instruction started with basic reading, writing, and arithmetic, and then followed with the study of history, science, literature, math, and Latin. Memorization, drill and practice, and recitation is common-place in a traditional classroom. These practices have been utilized for many years and are seen as “an integral part of the way schools are. As a result we don’t tend to think critically about much of what goes on” (Oakes, 1985, p.5).

In a traditional mathematics classroom the teacher is typically the person doing all of the talking, students work solely from problems in their textbook, individual desks are in straight rows (not in groups), and rarely are students working together or completing projects. Commonly the teacher will show students examples of how to solve a certain type of problem and then has them practice this method in class and in homework (Battista, 1999). The mathematics covered is almost identical to what most adults were taught when they were children. The type of teaching prevalent in many American classrooms today more closely resembles the traditional model of teaching than a constructivist approach (Schoenfeld, 1985). Students spend most of their time trying to learn computational procedures.

A key tenet in traditional mathematics education is the fundamental principal of distributed mastery. Distributed mastery is the idea that mastering pieces of a subject will lead to mastery of a bigger whole (Schmidt, McKnight, & Raizen, 1997). The basic theory behind this mathematics teaching philosophy is that a person must learn skills first before they can ever be applied to a real situation. Unfortunately, says Battista (1999), one of the disadvantages of spending all of their time on skill work is that few students develop any understanding of why the computations work or when they should be applied.

Often integral to the traditional approach to educating students is evidence of tracking. Tracking refers to separating students into instructional groups on the criterion of assumed similarity in ability (Oakes, 1985). This practice is typically utilized in middle and secondary school. Students are sorted into categories so they can be assigned to classes that teachers feel they are best suited for. Students are selected to go into the college preparatory courses or to follow the vocational track. The vocational track courses are often the classes that cover basic skills and consist of low-level coursework (Bottoms, Presson, & Johnson, 1992). Educators who follow this practice believe strongly that students learn better in groups with other students that are like them and also when students are placed into courses with similar abilities they will be easier to manage (Oakes, 1985).

Reform Instruction

In an effort to address the issue of teaching so students can learn with understanding, reform mathematics instruction has been gaining support. Advocates of reform believe that new teaching techniques in mathematics not only assist students in learning mathematics in a meaningful way, it also empowers them in their learning process. Many reform approaches encourage students to take a proactive approach to their learning and education (Addison Wesley Longman, 1999). This push towards math reform is based, largely, on the constructivist theory about learning.

Constructivists believe that people are continually adding to their knowledge base by assimilating the new with the old. When new information is added to old information the only way to be able to recall and use the data at a later time is for the brain to reorganize the information. Jean Piaget (1886-1980), a Swiss psychologist, described learning "as the modification of students' cognitive structures as they interact with and adapt to their environment" (as cited in Tompkins & Hoskisson, 1991, p.3). Teachers who subscribe to this belief change their role as the sole "information-giver" in their classroom, to a leader and facilitator of activities, discussion, and resources. Instead of solely dispensing knowledge, they engage their students with experiences in the classroom that require them to add onto their current knowledge base by modifying their cognitive structure. According to Smith in his book Comprehension and Learning (1975), the cognitive structure is the organization of knowledge in the brain and knowledge is organized into category systems called schemata. Within the schemata are three components: categories of knowledge, the features determining what constitutes a category and what will be included in each category, and a network of interrelationships among the categories. It is analogous to a filing system where as a person learns they add new files and as they learn more about a topic the file grows thicker. Constructivists propose that students are not merely the passive recipients of knowledge; they are constantly reshaping their lives as they learn (Harmin, 1994).

Advocates of reform state that basic facts and skills are still important, but it is just as important to know how to apply those skills (NCTM, 2000). Teachers encourage children to not only utilize traditional algorithms for computing, but to create their own procedures for computing. Regardless of the algorithm they choose, children’s computational procedures need to be both efficient and correct (Campbell, Rowan, & Suarez, 1998). The development of efficient, correct procedures to solve problems requires careful instruction and focuses on developing understanding. According to NCTM (2000), practice is important, but practice without understanding is a waste of time. Using their skills helps children to become more confident and competent in using them. According to Resnick and Omanson (1987) and Wearne and Hiebert (1988) research indicates that if children memorize mathematical procedures without understanding, it is difficult for them to go back later and build understanding. This is supported by Kamii and Dominick (1998) affirming that when children memorize without understanding, they may confuse methods or forget steps. The development of numeric reasoning may be hindered by requiring the memorization of specific algorithms.

Historically, the focus on number has been the foundation of mathematics education in the United States (Reys & Nohda 1994). Through the standards, NCTM believes that basic number sense and computational fluency is crucial in developing a strong understanding of our number system. In The Learning Gap (1992), Stevenson and Stigler state that in the United States "…the weakness is not limited to inadequate mastery of routine operations, but reflects a poor understanding of how to use mathematics in solving meaningful problems" (p.50).

In contrast to traditional pedagogy, reformers do not believe that students should be held back from learning higher level math because they may not yet know all the basic facts or are not yet proficient with computation. The practice of tracking is not encouraged in order to achieve equity and excellence through high expectations for all students (Oakes, 1985). They believe that schools should provide support for children to continue working on basic facts and computation while instruction on other mathematics topics takes place. The other topics include measurement, statistics, geometry, and algebra. These topics provide the opportunity to apply their skills and to learn more advanced mathematics.

Research Information

In the search for the ideal mathematics curriculum a school district should follow, looking at the available research can give a quantitative analysis that avoids purely anecdotal information. Both traditional and reform supporters can benefit from looking over factual information from a variety of sources. Many people make assumptions one way or another without necessarily substantiating their beliefs with facts. One way to compare similarities or differences in the effectiveness of curriculum programs is by looking at current state-mandated standardized mathematics tests. Many textbook companies do use the various state-mandated standardized tests already given by school districts in order to compare outcomes from using traditional versus reform textbooks. Although many evaluations of standards-based mathematics programs have been limited to field studies conducted by the developers of the curricula, these studies can provide initial trends in data concerning student achievement. The following information embodies direct comparisons between traditional and reform mathematics curricula in a variety of school districts, grade levels, states, and even nations, through a combination of state-mandated testing, field testing by textbook companies, and federally funded testing.

In Pittsburgh, Pennsylvania, the effects of a reform mathematics curriculum were recently evaluated (Briars & Resnick, 2000). The Pittsburgh public school system adopted the new standards-based system in 1992. The program adopted includes content and performance standards, standards-based assessments, standards-based instructional material, and standards-based professional development for educators and administrators. Briars and Resnick carried out the study examining the impact of *Everyday Mathematics* on achievement when implemented as part of a systemic change in the Pittsburgh public schools. Their study compared scores on a statewide test from 1996, 1997, and 1998 for all fourth-grade students in the school district. The Iowa Test of Basic Skills and the New Standards Reference Examination were used to assess mathematics achievement. They found overall improvement during this time period in all competency levels. The competency levels were designated as skills, concepts, and problem-solving. Schools that were categorized as strong implementers of standards-based programs demonstrated significantly higher gains than weak implementers, even in schools with large numbers of poor and minority students. The most dramatic increases were achieved by the 1998 group of fourth graders, the first group to experience the standards-based program from kindergarten through fourth grade.

Carroll (1997) reported positive results on the mathematics standardized test used in Illinois for students using the *Everyday Mathematics* program (a standards-based program at the elementary level) in the Chicago area, compared to students in a suburban county not using the program and also compared to state scores. The standardized test consisted of 60 multiple choice questions. Schools with the greatest number of disadvantaged students scored both above the comparison school and the state. Also, Carroll reported higher test scores for students who had experienced *Everyday Mathematics* since kindergarten than for students who had been in the program for only one or two years. In the same study, Carroll made another comparison between one district using the *Everyday Mathematics* program and similar districts not using the program. School districts were considered similar on the basis of school size, per pupil spending, and student demographics. Third-grade students using *Everyday Mathematics* scored significantly higher on the Illinois state-wide test than three of the four comparison districts and did not differ significantly from the fourth district (Carroll, 1995). In another study, Carroll and Porter (1994) found that fourth-grade *Everyday Mathematics* students scored as well on traditional items as they did on reform- oriented items on the Illinois standardized test. Carroll (1996) also found that in a comparison of performance on 25 mental computation problems administered at the fifth-grade level, students in a class using *Everyday Mathematics* outperformed the students in traditional classes on all but one of the problems.

Recently, the Massachusetts standardized tests were used by Riordan and Noyce (2001) to conduct a study using test results from the Massachusetts Educational Assessment Program (MEAP) administered between 1992 and 1996, and results from the 1999 Massachusetts Comprehensive Assessment System (MCAS). Comparison schools were chosen based on reform-oriented instruction versus a more traditional instructional style. The groups were then aligned based on predictors that determined the groups would be expected to perform similarly on the statewide test. The two standards-based mathematics programs implemented in Massachusetts were *Everyday Mathematics* at the elementary level and *Connected Mathematics* at the middle school level. The traditional mathematics programs were most commonly *Addison-Wesley, Houghton-Mifflin,* and *Scott Foresman* at the elementary level and *Heath, Addison-Wesley, Prentice Hall*, and *Houghton-Mifflin* at the middle school level. The study was designed to compare the two standards-based programs against a range of curricula that represent the instructional norm in Massachusetts. The goal of the study was to examine the impact of curriculum on student achievement. Riordan and Noyce found there were statistically significant differences between students who were taught with standards-based curriculum like

Connected Math (grades six through eight) or *Everyday Mathematics* (kindergarten through fifth grade) compared to a more traditional curriculum. They also found that the longer a school implemented a standards-based program there was a greater score advantage for students. Generally, *Everyday Mathematics* and *Connected Mathematics* students consistently outperformed traditionally taught students. There was no student group for which exposure to a traditional curriculum resulted in a significantly higher score than exposure to a standards-based program. With few exceptions, students in the standards-based programs outperformed their counterparts in the traditional mathematics programs in all four areas of mathematics tested (number sense, patterns and functions, geometry, and statistics) and on all three types of test questions (multiple choice, short answer, and open response). There were also positive score differences for Black and Hispanic students, and free and reduced-price lunch students in schools using standards-based programs. Furthermore, the study found that standards-based programs were effective for all students, not just those at the bottom, middle, or top of the achievement spectrum.

In a study comparing 8th grade students from five Minneapolis schools that were fully implementing *Connected Mathematics* (a standards-based program for grades six through eight), Winking, Bartel, and Ford (1998) found that most 8th grade students significantly outscored their counterparts in comparison schools on the state basic standards tests, specifically the CAT/5 Math Concepts Sub-test and the Minnesota Basic Standards Tests. Schools that were only partially implementing the standards-based mathematics program were modest or neutral in gain compared to students not using *Connected Mathematics*. O’Neal and Robinson-Singer (1998) examined the progress of students in eight *Connected Mathematics* pilot school districts one year after implementation for the Arkansas Statewide Systemic Initiative. They found that statewide standardized test score gains in mathematics were positive and statistically significant for students using the *Connected Mathematics* program. Also, students in almost all participating school districts made gains in mathematics test scores on the Stanford-9 test.

Not only do middle-school children seem to benefit from standards-based curriculums, but elementary students are also performing well on standardized tests and growing in their understanding of number sense. Wood and Sellers (1997) compared students who had received two years of standards -based instruction and other students who had used a more traditional textbook in their class. The students in the reform-oriented class room performed better on norm-referenced standardized tests in grades one through four and demonstrated greater conceptual understanding in place value, numeration, and multiplication skills. In a similar comparison study in England, Boaler (1998) found that students from the traditional classroom were less able to apply their math skills to real life situations than the reform taught students. The students taught through the reform methods outscored the comparison school students on tests and applied mathematics problems.

The QUASAR Project is a national study of middle school mathematics reform in economically disadvantaged communities (Stein, Grover, & Henningsen, 1996). This study presented data with reference to students using a variety of standards-based curricula and concluded that even teachers whose background characteristics did not differ from most middle school teachers' could be successful in setting up and delivering tasks that required high-level mathematical reasoning. The QUASAR Project also provided evidence that the nature of the mathematical tasks used in the classroom effects student learning outcomes (Riordan & Noyce, 2001). Stein, Grover, and Henningsen found that “the construct of the mathematical task was found to be a useful focusing device-one that served to highlight mathematical content and processes” (1996, p. 484).

In an effort to accurately compare American students to students internationally in mathematics and science, the Third International Mathematics and Science Study was developed and implemented in 1995 (TIMSS), and then again in 1999 (called the TIMSS-R). The Office of Educational Research and Improvement (OERI) of the U.S. Department of Education, the National Science Foundation (NSF), and the National Center for Education Statistics (NCES) worked with the International Study Center (ISC) at Boston College to develop the study (NCES, 1999). There was a need in mathematics education for reliable and timely data on mathematics achievement of American students compared to that of students in other countries. The TIMSS and TIMSS-R are considered to have significant, reliable, and timely data. According to NCES, TIMSS involved 42 countries at three grade levels (grades 4, 8, and 12), while TIMSS-R collected data in 38 countries at the eighth-grade level to provide information about change in the mathematics and science achievement of American students compared to those in other nations over the last four years.

The results of this cross-nation study have been notable. Of the 23 nations that participated in both the TIMSS and the TIMSS-R , the U.S. eighth-graders scored significantly lower than fourteen nations and below the international mean in 1995, and in 1999, the U.S. again scored below the international mean (Gonzales et al., 2000).

Unfortunately, results from TIMSS-R show no increase for U.S. students in mathematics from the TIMSS study in 1995, four years later (Schmidt, 2000). According to William Schmidt, executive director of the U.S. National Research Center for TIMSS at Michigan State University, “The results indicate that U.S. mathematics education in the middle grades is particularly troubled” (as cited in Mann, 2000, p. 2). U.S. fourth graders scored somewhat above the international average and eighth graders scored below it. Schmidt sees this as a “clear signal” that the discrepancy is not with the U.S. students, but the system. The researchers cite low expectations for student achievement, insufficient professional development, and shallow repetitive curriculums as signs of a poor math education system. Through the research they found that middle school mathematics curriculums in America, “tend to include all topics every year and just keep repeating them, compelling teachers to rush through lessons in a superficial manner (as cited in Mann, 2000, p.2). The research study noted that in the United States there is approximately a 75 percent overlap in math content annually between 4th and 8th grades, resulting in only 25 percent of content that is new each year. In the high achieving countries the majority of classroom time is spent on learning new material and reviewing only part of the time. The statistics reveal the vast difference between high achieving countries and the United States with regard to the percent of new content covered each year in mathematics classes. This is based on the TIMSS finding that countries with higher math achievement explore fewer topics each year. Since less topics are covered, they can be studied in greater depth. According to Luther Williams, who heads the National Science Foundations Education and Human Resources Directorate, “The TIMSS results confirm that educators in other countries demand a greater depth of education for elementary and middle-school students than do their counterparts in the United States. They simply demand more of every student" (as cited in "Lacking a clear focus," 1996).

The TIMSS study includes information about math education systems where student achievement is high. According to Glenda Lappan, president of NCTM and a professor in the department of mathematics at Michigan State University, "educators should make sense of what TIMSS tells us so that we can make a difference in what we do in the classroom" (as cited in Mann, 2000, p.2). *A Splintered Vision* (Schmidt, McKnight, & Raizen, 1997), prepared by the U.S. National Research Center for the TIMSS, states that there is no clear vision in the U.S. regarding a focused, cohesive curriculum. Every state implements its own curriculum standards without having a common place to go to in order to design a strong mathematics curriculum. The study also included a data analysis of 491 curriculum guides and 628 textbooks from around the world. They found that mathematics curricula in U.S. schools are unfocused in comparison with those in other countries studied. U.S. math curricula are unfocused in several respects: topics covered, repetition, emphasis, variations among states, and defining the *basics.* Mathematics curricula in the U.S. consistently cover far more topics than is typical in the countries that are stronger in mathematics. In the U.S., the practice is to cover many more topics than other countries do in first and second grade and then repeat these topics until seventh grade. Then, at the high school level in grades nine and eleven, the U.S. offers fewer topics than other countries. This tendency to retain topics over many grades may reflect the traditional approach of distributed mastery. According to Schmidt et al. (1997), "U.S. curricula lack a strategic concept of focusing on a few key goals, linking content together, and setting higher demands on students" (p. 5). Mathematical instructional practices in the U.S. define the "basics" taught at the eighth grade level as arithmetic, fractions, and a small amount of algebra. The "basics" taught internationally among top countries, including Japan and Germany, at the eighth grade level were defined as algebra and geometry.

To further show the difference of instructional focus on an international level, Stigler and Hiebert (1997) found that the most common goal of U.S. lessons was to teach students how to do something, whereas the most common goal of Japanese lessons was to enhance student understanding of mathematical concepts. Compared to Japanese teachers, American teachers spent more time reviewing and less time presenting new material in their classrooms (Riordan & Noyce, 2001). According to a summary appearing in the National Research Council's report *Everybody Counts* in 1989, average students in other nations often learn as much mathematics as the best students in the United States. The National Research Council reported that data from the Second International Mathematics Study (SIMS) shows that the performance of the top 5 percent of American students is matched by the top 50 percent of students in Japan.

While leading nations like Japan, Singapore, and China, introduce and integrate geometry, algebra, and other mathematical topics much earlier in the elementary curriculum (Stigler et al, 1990), the U.S. K-8 mathematics curriculum has focused on arithmetic (Flanders, 1987). In U.S. schools algebra and geometry have generally been delayed until high school and have often served to "filter" students from taking further mathematics classes (Silver, 2000). Geometry and measurement are topic areas in which U.S. students have performed quite poorly on national and international tests. On the

TIMSS assessment, geometry and measurement were the weakest performance areas for U.S. 8th graders (Beaton et al., 1996). While U.S. students begin school recognizing basic geometric shapes, little progress is made in building their comprehension of or their ability to apply geometric concepts (Carroll, 1998). In the Fourth National Assessment of Mathematical Progress, 90% of the 7th grade students who took part could identify simple geometric shapes. However, less than one third of the 7th graders could identify properties of angles and triangles or solve missing angle measurements (Lindquist & Kouba, 1989). In a different study, Stigler, Lee, and Stevenson (1990) found that Japanese and Taiwanese 5th graders consistently outperformed U.S. 5th graders on all questions requiring analysis of geometric properties and relationships. Only on questions of simple recognition, such as identifying a parallel line or square, did U.S. students' scores even approach those of their Asian peers. Results of international studies suggest that the cause of this deficit lies in the U.S. curriculum, not in students' developmental capabilities (McKnight et al., 1987; Stigler, Lee, & Stevenson, 1990).

Standards

Controversy has erupted in several states regarding the use of "standards-based curriculum" in mathematics. Standards-based mathematics curriculum is usually interpreted to mean curriculum aligned with the content standards prepared by the National Council of Teachers of Mathematics (NCTM) (Bay et al., 1999). Otherwise known as the NCTM standards, these documents are considered the most widely used of all school subject standards in the United States. The NCTM standards recommend that mathematics curriculum should place an emphasis on problem solving, reasoning, making connections between mathematical concepts, communicating mathematical ideas and providing opportunity for all students to learn (NCTM, 1989; 1991; 1995; 2000). The standards also encourage the teaching of certain mathematical content, including algebra, geometry, trigonometry, statistics, probability, discrete mathematics and calculus (NCTM, 1995). Standards-based math is sometimes referred to as "new" math. This may give the impression to people who are unaware what standards -based is actually referring to that educators, administrators, researchers, and other mathematics professionals are creating a new type of math.

The goal of creating national standards for mathematics was to provide sound professional guidance to educators, policy makers, and parents. Internationally, many countries already have and utilize national mathematics standards (Stigler & Hiebert, 1999). This ensures that the schools in that country are all striving towards similar goals for education. The United States however rests much of the responsibility for curriculum decisions at the state and local levels. This policy allows for flexibility in decision-making by each school-district. The United States does not have a national curriculum (Stigler & Hiebert, 1999). Prior to NCTM creating guidance for professionals through the standards, the variance between states' curriculums, guidelines, and expectations was incredible. NCTM (2000), in response to questions about what American students should be learning and the best educational practices for teachers, delineated six themes to focus on to generate high quality math education: equity, curriculum, teaching, learning, assessment, and technology. Along with these six principles, NCTM (2000) created a set of ten standards that emphasized content and process standards. Content standards describe the content that student should be learning in a high quality mathematics curriculum. The content standards are number and operations, algebra, geometry, measurement, data analysis and probability. The process standards describe ways of acquiring and using content knowledge. The process standards include problem solving, reasoning and proof, communication, connections, and representations. The ten standards are applicable from prekindergarten to grade twelve (NCTM, 2000).

Textbooks

Many people do not realize that much of the curriculum that has been used in mathematics classrooms is not defined by courses of study or suggested programs but by the grade level specific textbook that is used in the classroom (Apple, 1998). Even thought as much as 75% of classroom time and 90% of homework time is spent using these materials at the elementary and secondary levels people do not know very much about the textbooks they are relying on (Goldstein, 1978).

Since there is no official federal sponsorship of specific national curricula in the U.S., textbook companies must try to incorporate information, exercises, and activities that represent what they think a majority of school districts will be looking for when they purchase textbooks. The goal for textbook publishers is to create a textbook that appeals to as many schools as possible in order to make a profit in this highly competitive market. It is expensive to produce texts; therefore, it is advantageous to combine as many topics and ideas into one textbook so multiple school districts with different guidelines are interested in their product. It takes years to write and produce a textbook; publishers want to know that their text series will sell before they are willing to commit large sums of money to produce them (Keith, 1981). In several states, textbooks that will be used in major subject areas must be approved or recommended by state committees or agencies. If a school district in one of these states chooses a textbook on this approved list they are often reimbursed for part of the cost. The amount of money a school district can recover can be significant. Publishers know that it is important to get their tests on the approved lists if they want to sell a high volume of books. Accordingly, a textbook company will gear their books' contents and design to those particular state adoption agencies (Apple, 1998). Texas and California are two states that fall into this category. Sales to these two states alone can account for over 20% of the total sales of a text series. Often textbooks are designed with these state's guidelines in mind. School districts purchasing books may expect that all textbooks conform to their state's math standards, however, a text series content and style are influences predominantly by the political and ideological climate of primarily southern states (Apple, 1998).

Historically, there has been a variety of mathematics textbooks used throughout the world (Mendez, 2001). In these books there does seem to be documentation that encourages mathematical dialogue between the teacher and the student. This mode of teaching is prevalent in the textbooks written according to NCTM's standards. Increased mathematical communication is one of the goals in mathematics reform. Dating as far back as 5 BC there has been mathematical dialogue. In Plato's Meno, Socrates engaged in a conversation with his student to help him find a solution to a math problem (Fauvel and Gray, 1987). This idea of mathematical dialogue is quite different from the perspective of teaching using a traditional approach. During medieval and renaissance times a student was expected to receive knowledge from the teacher and not to ask questions. Arithmetic teaching was mainly done through lecturing, rote memorization, and drill (Karpinski, 1965; Swetz, 1987). Even though these approaches were the most common during this period, some textbooks written in the 10th century have been found to be written in the dialogue format (Smith, 1951). Comenius, a 17th century Czechoslovakian educational reformer, recommended writing textbooks in the form of dialogue. Comenius cited the works of Plato and Cicero as historical precedents for this format (Comenius, 1967).

In America, beginning in the 17th century, commercial textbooks were prevalent. Arithmetic textbooks were not in dialogue format and presented rules that were to be memorized and not understood (Cohen, 1985). Then in 1821, a new style of textbook was written focusing on a student-centered approach to education. Warren Colburn encouraged teachers to allow their students to develop their own methods of problem solving and never to directly show how to perform an operation, but to guide the student if they needed help (Mendez, 2001). William Milne in his textbook Progressive Arithmetic, provided skill work for the student and also wrote "…the book is not merely a book of exercises. Each new concept is carefully presented by questions designed to bring to the understanding of the pupil the ideas he should grasp, and then his knowledge is applied" (1906, p. 4).

Until the 1940's textbooks in the United States promoted the use of three different subtraction algorithms: decomposition, equal additions, and the Austrian method (Ross, 1999). At this time, William Brownell (1939) conducted a study to determine which method was the most beneficial to use. The decomposition method was determined to be the best one to use and became the preferred method of subtraction in the United States. People were concerned at the time that this method was detrimental to learning because it was too easy and students wouldn't need to rely on their memorization skills (Ross, 1999). The other two methods of subtraction virtually disappeared from textbooks at this point.

Currently textbooks, designed with reform techniques, commonly use collaborative group-work , discovery learning, and writing exercises. According to textbook publisher Addison Wesley Longman (1999), these methods have become popular not only with reform oriented educators, but with traditional instructors as well. Standards-based textbook programs are those written specifically to fulfill not only the content standards, but also the pedagogical approaches that the NCTM standards advocate (Riordan & Noyce, 2001). Compared to mathematics instruction commonly observed in American classrooms today, standards-based curriculum programs place less emphasis on memorization, manipulating numbers, and less time devoted exclusively to skills development (Goldsmith, Mark, & Kantrov, 1998). Though less emphasis would be placed on skill development, basic facts and computation are still important (NCTM, 2000). NCTM states that children still need to know how to add, subtract, multiply, and divide. They also need to know their addition, subtraction, and multiplication facts, as well as understand fractions, decimals, and percents. The difference between what is encouraged between traditional instruction and standards-based instruction is that it is just as important to know all the facts as it is to be able for students to apply their knowledge in real-life, and also understand basic principles of probability, measurement, statistics, and geometry. Teachers are encouraged to set up problematic situations so students can investigate and discover solutions.

According to Williams (“Lacking a clear focus,” 1996) the TIMSS study showed that U.S. textbooks make minimal demands on students and represent a limited notion of what should be discussed as *basic topics.* He also noted that American schools retain the same topics in the curriculum much longer than schools in other countries, suggesting that U.S. elementary and secondary schools may repeat the same math and science subjects grade after grade. The belief that American textbooks cover topics “a mile wide and an inch deep” may be most apparent by comparing the number of topics presented in grades five through eight (Schmidt, McKnight, & Raizen, 1997). In grades five through eight, the U.S. expects between 27 to 32 topics to be taught each year. This far exceeds the international median of 21 to 23 topics each year for each of these grades and contrasts sharply with the 20 to 21 topics intended by the highest achieving TIMSS countries (Cogan & Schmidt, 1999).

In an effort to evaluate the content of middle school mathematics textbooks, the American Association for the Advancement of Science (AAAS) conducted a study through Project 2061 basing their analyses on a variety of benchmarks consistent with standards developed by NCTM (AAAS, 1999). AAAS conducted the study with the understanding that textbooks are a critical link to implementing a school district's curriculum and it is important that curriculum materials are aligned with district and state standards. While many textbooks claim to be aligned with standards, few educators have the opportunity to analyze textbooks to see how closely they are aligned to their district math curriculum guidelines.

Technology

One of the major changes, and most controversial, in the transition from traditional mathematics instruction to reform instruction is the increased use of technology. Technology, in this case, refers to four-function, scientific, and graphing calculators; computers; Internet; and software. The use of technology need not be limited to these listed, but may include other instruments, such as data probes, depending on what items the educators have available to them in their school district. Many parents and even teachers are apprehensive at the thought of incorporating new technology into the mathematics classrooms at all grade levels. They are afraid that students will not learn basic mathematical skills and will become dependent on technology to the point of not being able to solve simple computations in their daily lives on their own (Pomerantz, 1997). Most adults think back to their childhood and remember mathematics as consisting primarily of performing long, tedious computations and doing algebraic manipulations using paper and pencil, looking up values in tables, memorizing formulas, and endlessly drilling the skills they had learned. With this background adults may view the integration of technology in mathematics classrooms as a way to nullify the hard work associated with doing long computational work and algebra problems by hand. These assumptions however do not take into account research that is currently available.

According to Campbell and Stewart (1993) research has shown that calculators can aid in “stimulating problem solving, in widening children’s number sense, and in strengthening understanding of arithmetic operations.” They can also help students learn mathematical basics, such as numbers, counting, and the meaning of arithmetic operations. Students show greater ease in problem-solving when using calculators, since they focus less on computational recall and algorithmic routines and more on the other parts of the problem solving process. Appropriate calculator use also “promotes enthusiasm and confidence while fostering greater persistence in problem-solving.” According to Heid (1988) the appropriate use of calculators does not result in the atrophy of computational skills; instead, it provides an impetus and opportunity for students to focus on conceptual learning. Students who learn paper and pencil techniques in conjunction with the use of calculators or other technology, and are tested without calculators, perform as well as, or better than, those who do not use technology in class (Gilliland, 2002).

Contrary to what people may presume regarding the use of technology in mathematics classrooms, research shows that calculator use does not diminish student's math skills (Lott, 2002). Results from the 2000 National Assessment of Educational Progress (NAEP) show that eighth graders who had unrestricted use of calculators in their mathematics classroom had higher average scores than the students whose teachers restricted calculator use in their classrooms (Braswell et al., 2001). Also, eighth graders who reportedly used calculators on classroom tests had higher average NAEP scores than students whose teachers did not permit the use of calculators on their classroom tests. For eighth and twelfth grade students taking the NAEP a positive association was found connecting higher frequency of classroom use of calculators with higher test scores. Hembree and Dessart's (1992) meta-analysis of studies on four-function calculators determined, "The preponderance of research evidence supports the fact that calculator use for instruction and testing enhances learning and the performance of arithmetical concepts and skills, problem solving, and attitudes of students" (p. 30).

Mathematics education does not simply consist of rote computation, memorization, endless drills, tedious manipulations, or solely learning and performing algorithms (Pomerantz, 1997). This way of viewing mathematics belies the problem solving, pattern recognition, logic and reasoning skills, number sense, abstract thinking, discovery, construction of relationships, and reasoning from data that also needs to be addressed in mathematics curricula. Opponents of reform math claim that math curriculum should focus solely on computational skills, quite often this is how they were taught. President of NCTM, Johnny W. Lott, notes, "Reports today saying the curriculum must change to emphasize computational skills are no more valid now than in 1973. The difference is now we have NAEP results from many years to prove it” (p. 2).

Computations and algebraic manipulations are merely a means by which a student gets to the mathematics; they are not an end to themselves (Pomerantz, 1997). The integration of technology into classrooms can allow teachers and students more time to focus on the non-computational parts of the problem-solving process, since the real mathematics is not found in the low-level manipulative procedures (Campbell & Stewart, 1993). Educators have the option when students are solving more complex problems to allow the use of calculators. When students practice mental math skills or carry out simple calculations, they do not use calculators (Gilliland, 2002).

With technology available that can do more than simple arithmetic, it is necessary to ensure materials are developed that enrich learning experiences in mathematics (Smith, 1998). In order to bring this technology into the classroom in a valid, worthwhile way takes time, and requires access, money, and expertise. Trained personnel and professional development are necessary to facilitate educators in deciding when and how to incorporate technology effectively in the regular classroom. Ideally, with enrichment of the curriculum as the impetus for adding technology, there are several areas in which the integration of technology can be beneficial. According to Smith, technology can be used as tools for expediency, amplifiers for conceptual understanding, catalysts for critical thinking, and vehicles for integration. This theory is supported by the study *Handheld Graphing Technology in Secondary Mathematics: Research Findings and Implications for Classroom Practice* (Burrill, 2002). The Burrill citation reports:

> Students who use handheld graphing technology have a better understanding of functions, of variables, of solving algebra problems in applied contexts, and of interpreting graphs than those who did not use the technology…. No significant differences in procedural skills were found between students who use handheld graphing technology and those who do not. This indicates that extensive use of the technology does not necessarily interfere with students' acquisition of skills (p. v).

This empirical study was conducted by an independent group of researchers in order to gather data on the impact of calculators in classrooms.

NCTM has long supported and encouraged the use of technology in classrooms to help children understand mathematics. In its 1986 position statement *Calculators in the Mathematics Classroom*, NCTM recommended that test writers, authors, and teachers integrate calculators into school mathematics at all grade levels. This included use of calculators to do homework, classwork, and assessment. In 1989, NCTM reiterated their position in *Curriculum and Evaluation Standards for School Mathematics* on the integration of calculators into the classroom and during testing. They also advised that appropriate calculators should be accessible to all students at school and at home. Again confirming their status on calculator use in 1998, NCTM, in its position statement *Calculators and the Education of Youth*, continued its support by elaborating that instruments designed to assess students' mathematical understanding and application must acknowledge students access to and use of calculators. Most recently in 2000, NCTM's *Principles and Standards for School Mathematics* continued to advocate the appropriate use of calculators in learning and teaching mathematics at all grade levels.

Specifically, the Technology Principle (NCTM, 2000) states, “Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (p.373).

Hand-held calculators have been around for three decades. The first hand-held four-function and scientific calculators appeared in the early 1970’s (Usiskin, 1999). By the early 1980’s hand-held calculators became cheaper and more affordable. While hand-held calculators are inexpensive they are not prevalent in elementary mathematics classrooms (Flores, 2002). Contrary to what people may believe, integration of computers, Internet, and quality software in the regular classroom has been slow. Generally, people can conceptualize the educational advantages of having access to the scientific and graphing calculators at the high school level. Students can work at higher levels of math focusing on generalizations and abstractions (NCTM, 2000). They can also make and test hypotheses. However, technological advancement will not only affect high school level classes, but the middle and elementary levels, too. According to Flores (p. 308, 2000), at the elementary level, technology can be used “to enhance a concrete, experimental approach to mathematical topics, enabling students to have greater success with a more symbolic, abstract approach later in school”. Calculators were in daily use in 60 percent of 8th grade classrooms by 1996 (Gilliland, 2002). NCTM, in its 1998 *Calculators and the Education of Youth* recommended “the integration of calculators into the school mathematics program at all grade levels.”

Currently, the level of calculator use is more frequent in high school mathematics courses in the U.S. as compared to middle and elementary use. According to Dion et al. (2001), in *A Survey of Calculator Use in High Schools*, a survey conducted with 4,568 schools, the prevailing policy was to allow the use of calculators during classroom learning activities and tests. Regarding the specific use of scientific and graphing calculators, this same survey showed that 99.9% of the schools indicated that they either require or allow calculators for some part of their college preparatory mathematics sequence. The researchers indicated that Algebra 1 was to be considered the start of the college preparatory mathematics sequence. More than one third of the sample reported that they require scientific calculators regardless of the course level. Compared with graphing calculators, scientific calculators are more frequently required in algebra 1 (30% vs. 18%) and geometry (33% vs. 12%) for classroom learning activities and homework. The percentage of high schools in the sample requiring a graphing calculator generally increases with each course level: algebra I (18%), geometry (12%), algebra II (42%), and precalculus/trigonometry (70%). During classroom tests, 40% to 50% of schools always allow scientific calculators for tests. Graphing calculator use during tests varied by class level: algebra I (22%), geometry (26%), algebra II (37%), and precalculus/trigonometry (54%). Only a small number of schools in the sample never allow calculators for tests: algebra I (5%), geometry (2%), algebra II (1%), and precalculus/trigonometry (less than 1%). This research contrasts with Maroney’s 1990 survey which found that approximately 70% of the urban and rural schools permitted the use of calculators. Maroney also found that the number of schools allowing the use of calculators during classroom tests was more conservative at 25.9%. Through research it is apparent that calculator use has been increasing at the high school level, becoming an integral component of the mathematics curriculum across America.

While educators are incorporating the use of calculators into their classroom, there seems to be a question about the extent to which teachers have implemented the use of calculators in classroom assessment. This refers not simply to using a calculator on a classroom test, but the actual number of problems on a test that are calculator active. Calculator active problems are those items for which a calculator is very helpful or necessary to solve. Senk, Beckman, and Thompson (1997) explored the extent of purposeful, calculator active problems that are built into classroom assessments. The teachers in the study indicated that calculators had influenced the design of the tests and almost every teacher in the study permitted students to use calculators during tests. However, the researchers found that few problems on the assessments actually required calculators to solve them. The mean percentages of calculator active items were at 8% for scientific calculators and 3% for graphing calculators. Therefore, many test items given in the assessments were either neutral or inactive with respect to the implementation of calculators (Dion et al., 2001). This would seem to counter the effort and time spent in the classroom integrating technology. If the advancement of technology is an inevitable progression and if mathematics educators deem it important enough to incorporate technology use in their classrooms then it should also impact the design of the assessments within that curriculum.

It is not only in classrooms where mathematics educators are taking a look at mathematics assessment integrated with technology. The SAT II: Mathematics Level IC and Level IIC Tests include many calculator active problems, about 40% and 60%, respectively, as was recommended in NCTM's Curriculum and Evaluation Standards (1989). Dion et al. (2001) notes the variance in the percentage of calculator active problems in the SAT II assessment as compared to the current level of calculator active items on classroom assessments (40% and 60% versus 8% and 3%). The students taking the SAT tests are presented a greater percentage of calculator active problems to solve, even though few educators challenge their students with calculator active problems in classroom assessment. Integration of calculator-based mathematics into the curriculum would seem to be advantageous for students.

NCTM (2000) believes there are advantages in using the calculator as one of several tools for learning and teaching mathematics. However, the association believes that technology cannot be a replacement for a mathematics teacher or for basic mathematical understandings and intuitions. The ultimate goal is for the teacher to enhance their mathematics curriculum with technology in a prudent manner. Integrating technology into the classroom in an effective manner will then lead to assessing the students in a way that incorporates technology in a relevant way. When decisions are made to integrate technology into the classroom in a meaningful way it is necessary to support the educators with professional development in these areas. Technology can only be added in an effective manner if connections are made to the curriculum in a coherent and compatible way.

Professional Development

An integral component to implementing any change in curriculum is staff development. School districts and state departments of public instruction already require educators to engage in professional development activities each year. Teachers can acquire these hours through a number of different options including inservice days, college courses at either the graduate or undergraduate level, or workshops. Educators are continually adding to their knowledge base through these activities. Often new topics in education are explored and discussed allowing them the opportunity to continually be aware of current research relevant to instructional pedagogy and improving classroom practices. In order to effectively improve mathematics instruction in the United States it is necessary to provide professional development that supports standards, assessments, and accountability (Cohen & Hill, 2001). According to Kennedy (1998) the content of professional development workshops is important and that programs focusing on subject-matter knowledge as well as how students learn that content has a positive impact on how successfully that information will be incorporated into the classroom. The focus in quality professional development programs is not on teaching behaviors but on student learning of the subject matter.

Countries that consistently have strong math students also carefully plan professional development programs for their educators. More specifically, these countries do not plan generic activities for teachers at any grade level or subject matter, as is more typical in the United States (Schmidt, 2002). These high-performing countries continually focus their professional development programs on subject-matter information and how to teach it. Top nations encourage their educators to deepen their knowledge of the structure of their particular subject area and level. To effectively instruct students, teachers must have a strong understanding of mathematics. They need to know what the subject matter consists of, know how to develop students understanding of mathematics and be able to delineate levels of student understanding.

According to Schmidt (2002), there is a strong connection between what is taught in U.S. classrooms and the textbook used in that classroom. Textbooks are relied on and used as a main resource by a majority of teachers in the United States. The correlation between reliance on textbooks and what teachers teach is a remarkable .95. Interestingly, this correlation is similar to that of other countries. This data shows us the strong influence the textbook has regarding the type of instructional approach that is used in a classroom. This data confirms the importance of having access to quality instructional materials. The reliance on district textbooks may dictate the necessity to have professional development programs that can tie in the use of these instructional tools. Teachers will be more likely to effectively use these tools if shown how to successfully implement them and could lead to a coherent, cohesive curriculum in a school district (Schmidt, Houang, & Cogan, 2002).

In a review of studies looking at curriculum-based professional development, Grover Whitehurst, an assistant secretary in the U.S. Department of Education, presented research for the White House Conference on Preparing Tomorrow's Teachers (2002)., He stated that one out of seven teacher characteristics that could increase student achievement was participation in professional development programs focused on academic content aligned with a standards-based curriculum. Along with focused professional development, Whitehurst emphasized the importance of peer collaboration. In top-performing countries it is expected that teachers share ideas and discuss activities that seem to help their students understanding of mathematics. It is encouraged to duplicate discussions, activities, or projects from other educators if they have been successful in the classroom. In contrast, in the United States the idea of being innovative and creative is predominant and sharing ideas may lead to what is regarded as copying ideas, and not as an opportunity to share and utilize good ideas and practices in order to improve teaching methods.

NCTM (1998) believes that educators need to have access to sound professional development programs. This is especially true when many teachers are not accustomed to implementing a standards-based curriculum. Studies suggest that all teachers can improve their teaching practices and increase student achievement when supported by good curriculum and focused, subject-matter professional development programs (Whitehurst, 2002). The best professional development courses offered for mathematics educators need to not only focus on content, but also how students should be learning that content (Kennedy, 1998). According to the North Central Regional Educational Laboratory (NCREL), in order to provide sound professional opportunities for educators, local and state policymakers must deem professional development as important and continue investing in their school districts (NCREL, 2000).

Another component in making the most of professional development is to allow the educators themselves to help in realigning offerings to meet the needs of faculty in their own school district. The NEA Foundation for the Improvement of Education (NFIE), created and supported by the National Education Association (NEA), believes that when the educational staff play leadership roles in creating professional development opportunities for the members of their school district professional development can reach its full potential ("Using data," 2003). Teachers and administrators working collaboratively can identify and provide professional development offerings that are pertinent and timely for their school district.

Chapter 3

Conclusions, Analysis, and Recommendations

Conclusions

Mathematics education in the United States has a documented history of constantly changing and evolving. The ultimate goal of sometimes opposing pedagogical approaches is to determine the most beneficial way to educate students who will become intelligent and reasonable decision makers. One way to evaluate the most effective teaching practices is to conduct studies and look at available research in mathematics education. While there is research available from a multitude of sources there isn't always a clear, definitive answer to the perfect way to teach mathematics. Every teacher has their own teaching style. Knowing this we can search for ways to improve instructional practices that benefit students and can be assimilated into an educator's teaching style. One way to do this is to provide mathematics curriculum materials that are researched-based, quality programs.

Analysis

After looking at available research and information about mathematics education the researcher was able to compare data and evaluate relevant material. It is apparent that the results from field comparisons, state standardized testing, and international mathematics achievement tests show an abundance of favorable analyses towards the math programs based on the NCTM standards. Research studies report the success of certain features and practices common among standards-based programs. Student achievement at all ability levels and across a variety of socioeconomic backgrounds can be linked to the instructional practices in schools that have adopted a standards-based approach to teaching mathematics. Many of the research studies provide evidence that the nature of mathematical tasks used in the classroom influences students learning outcomes. The research suggests that students can learn more advanced mathematics at earlier grades and, remarkably, not at the expense of traditional skills.

Math programs that are implemented in districts encouraging professional development for educators do indeed result in improved math performance, including understanding concepts and basic skills. The data shows improvement made not in just single domains of mathematics but in all areas of mathematics. The standards-based programs seem to provide a common, sequential, rigorous curriculum to large, diverse groups of students. This review of literature supports the notion held by proponents of standards-based curriculum, that curriculum itself can make a significant contribution to improving student learning.

The incorporation of technology into American classrooms can have a tremendous impact on learning and teaching. The possibilities are infinite for technology to alter the way children learn mathematics and the way that teachers and schools conceptualize teaching. It also has the capability to make more mathematics accessible to diverse populations. Research shows that calculator use does not weaken student’s mathematical abilities. In fact, children who are accustomed to using calculators in class and on tests do as well as or better than students who do not have access to calculators in their classroom on comparison tests.

An important issue with respect to calculator use in the classroom is the ability for educators to be able to distinguish between mathematical ability and calculator proficiency of their students. Does the introduction of calculators into the mathematics curriculum necessarily invite students to learn keystrokes rather than math concepts? Will students focus more on computation more than problem solving with an increased use of technology in their classroom? There appears to be no significant research that suggests that calculator use at any level is detrimental to mathematical development or that paper and pencil arithmetic is essential or even particularly beneficial for later mathematical development.

While educators, parents, administrators, and policy makers discuss the most beneficial teaching styles and textbook programs to use in their school district, there is information and research available that can help guide them. Relying on anecdotal information and making assumptions about particular mathematics programs because they appear different from what has traditionally been done in a school district will not serve students well and will unnecessarily polarize people in these leadership roles making decisions. It does seem clear through available research that mathematics programs based on NCTM's standards do increase student understanding of basic skills, problem solving, and number sense. It is important for all students to have access to a quality mathematics education program. In other countries all students are expected to master the mathematics curriculum by putting time and effort into their studies (MSEB, 1989). It may be necessary for some of these students to request extra help, support, and encouragement through their teachers, tutors, and parents. Mastery learning is not expected to be easily accomplished for all students and should be challenging for most students.

Research indicates that when students are active in constructing their own mathematical understanding, the information is retained and can be recalled for later use.

Students taught with a more hands-on approach, through discovery, discussions, cooperative group work, and technology can score as well as their peers on basic skills and better on problem-solving and conceptual items. To ensure improved mathematics education for all students in the United States curriculums need to be imbedded with high-quality, relevant experiences and challenge all students to high achievement. Students learn best when they are intellectually challenged (Lacampagne, 1993). When all students have the opportunity to learn math with understanding they will become better problem solvers.

Recommendations

Based upon the comprehensive review of literature, the following recommendations are offered:

1. It is recommended that educators, administration, parents, and school board members consider mathematics program decisions on the quality of the textbook series they are considering and regard the alignment of the textbook curriculum, school district curriculum guide, and NCTM's standards as imperative. A standards-based framework on which to build a foundation may increase student learning to the level of high-achieving U.S. school districts and nations.

2. It is recommended that based on the literature and research comparing the traditional approach to teaching mathematics and the standards-based reform approach, educators, administrators, school board members, and parents, interested in creating a curriculum that is cohesive, produces strong math students, and is challenging to all levels of students, should consider and support incorporating standards-based materials into their school district.

. It is recommended that priority is given to investing time and funding to high quality professional development programs. Teachers will benefit from ongoing and engaging professional development opportunities that assist them in gaining mathematical understanding that will create a sequential, thought-out district mathematics program. Educators need to constantly increase their ability to improve their instructional practices. Attending workshops, inservices, speakers, college courses, that can be applied directly to their classroom practices will result in the best implementation of the acquired content.

. It is recommended that the appropriate use of technology in the classroom be encouraged at all grade levels and content areas of mathematics. Primary through secondary students can improve their level of understanding and delve into more difficult and interesting mathematics problems through the use of technology. Assessments used by teachers should genuinely include some calculator active problems that reflect knowledge gained in the classroom.

. It is recommended to educators to focus not only on the basic skills of arithmetic solely through skill work , but to incorporate real-life problems and events into their classroom instructional time to allow their students to apply their math skills in a real world way. In order to become better problem solvers and critical thinkers students must be given the opportunity to learn in that manner.

6. It is recommended that to grow in mathematical ability at a district, state, or nationwide level, it is beneficial to look at and assess ways to improve mathematics instruction at all grade levels. Individual performance tests, state-standardized tests and international studies can be used as a guide in our search for improvement. Ultimately,

educating our children to grow up to be functional, reasonable, and discerning citizens are our goal as educators, administrators, and parents.

REFERENCES

Addison Wesley Longman. (1999). *AWL Developmental Math Reform Forum*. Retrieved October 20, 2002, from http://www.mathreform.com/

American Association for the Advancement of Science. (1999*). Project 2061: Few middle school math textbooks will help students learn*. Washington, DC: Author.

Apple, M. (1998). The culture and commerce of the textbook. In L. E. Beyer & M. W. Apple (Eds.), *The curriculum: Problems, politics, and possibilities* (2nd ed., pp.157-176). Albany, NY: State University of New York Press.

Athappilly, K. (1983). A computer-based meta-analysis of the effect of modern mathematics in comparison with traditional mathematics. *Educational Evaluation and Policy Analysis, 5*(4), 485-93.

Battista, M. T. (1999). The mathematical miseducation of America's youth*. Phi Delta Kappan, 80*(6), 424-433.

Bay, J. M., Reys, B, J., Reys, R. E. (1999). The top 10 elements that must be in place to implement standards-based mathematics curricula. *Phi Delta Kappan, 80,* 503-506.

Beaton, A. E., Mullis, I., Martin M.O., Gonzalez, E.J., Kelly, D.L., & Smith, T.A. (1996). *Mathematics achievement in the middle school years: IEA's Third International Mathematics and Science Study.* Chestnut Hill, MA.: Center for the Study of Testing, Evaluation, and Educational Policy.

Ben-Peretz, M. (1990). *The teacher-curriculum encounter: Freeing teachers from the tyranny of texts.* New York: State University of New York Press.

Boaler, J. (1998). Open and closed mathematics: Student experiences and understanding. *Journal for Research in Mathematics Education, 29*, 41-62.

Bottoms, G., Presson, A. & Johnson, M. (1992). *Making high schools work through integration of academic and vocational education.* Atlanta, GA: Southern Regional Education Board.

Braswell, J.S., Lutkus, A.D., Grigg, W.S., Santapau, S.L., Tay-Lim, B., & Johnson, M. (2001). *The Nation's Report Card: Mathematics 2000* (NCES Report No. 2001-517). Washington, DC: National Center for Education Statistics.

Briars, D. J., & Resnick, L. B. (2000). *Standards, assessments--and what else? The essential elements of standards-based school improvement* (Report No. CSE-TR-528). Los Angeles, CA: National Center for Research and Evaluation. (Eric Document Reproduction Service No. ED450137)

Brooks, J. G., & Brooks, M. G. (1999). *In search of understanding: The case for constructivist classrooms.* Alexandria, VA: Association for Supervision and Curriculum Development.

Brownell, W. A. (1939*). Learning as reorganization: An experimental study in third-grade arithmetic*. Durham, NC: Duke University Press.

Burrill, G. (2002). *Handheld graphing technology in secondary mathematics: Research findings and implications for classroom practice*. Dallas, TX.: Texas Instruments.

Campbell, P. F., & Stewart, E. L. (1993). Calculators and computers. In R. Jensen (Ed.), *Early Childhood Mathematics* (pp. 251-268). New York: Macmillan.

Campbell, P. F., Rowan, T. E., & Suarez, A. (1998). What criteria for student-invented algorithms? In L. J. Morrow (Ed.), *The teaching and learning of algorithms in school mathematics* (pp. 49-55). Reston, VA: National Council of Teachers of Mathematics.

Carroll, W. M. (1995). *Third grade* Everyday Mathematics *students' performance on the 1993 and 1994 Illinois state test*. Chicago: University of Chicago School Mathematics Project.

Carroll, W. M. (1996). Mental computation of students in a reform-based mathematics curriculum. *School Science and Mathematics*, 96, 305-311.

Carroll, W. M. (1997). Results of third grade students in a reform curriculum on the Illinois state mathematics test. *Journal for Research in Mathematics Education, 28,* 237-242.

Carroll, W. M. (1998). Geometric knowledge of middle school students in a reform based mathematics curriculum. *School Science & Mathematics, 98*(4), 188.

Carroll, W. M. and Porter, D. (1994). *A field test of fourth-grade* Everyday Mathematics. Chicago: University of Chicago School Mathematics Project.

Cogan, L. S., & Schmidt, W. H. (1999). What we've learned from the TIMSS: Middle school math reform. *Middle Matters, 8,* 2-3.

Cohen, P. C. (1985). *A calculating people*. Chicago: University if Chicago Press.

Cohen, D., & Hill, H. (2001). *Learning policy: When state education reform works.* New Haven, CT: Yale University Press.

Comenius, J. A. (1967). *The great didactic*. (M. W. Keatinge, Trans.). New York: Russell & Russell. (Original work published 1649)

Crawford, D.B., & Snider, V.E. (2000). Effective mathematics instruction: The importance of curriculum. *Education & Treatment of Children, 23*(2), 122.

Dion, G., Harvey, A., Jackson, C., Klag, P., Jinghua, L., & Wright, C. (2001). A survey of

calculator usage in high schools. *School Science & Mathematics, 101*(8), 427.

Fauvel, J. & Gray, J. (1987). *The history of mathematics: A reader*. London: MacMillan.

Flanders, J. R. (1987). How much of the content in mathematics textbooks is new? *Arithmetic Teacher, 35*, 18-23.

Flores, A. (2002). Learning and teaching mathematics with technology. *Teaching Children Mathematics, 8*(6), 308.

Gallagher, M., & Pearson, P. D. (1989). *Discussion, comprehension, and knowledge acquisition in content area classrooms* (Tech. Rep. No. 480). Champaign, IL: University of Illinois, Center for the Study of Reading.

Gilliland, K. (2002). Calculators in the classroom. *Mathematics Teaching in the Middle School, 8*(3), 150.

Goldsmith, L. T., Mark, J., & Kantrov, I. (1998). *Choosing a standards-based mathematics curriculum*. Newton, MA: Education Development Center.

Goldstein, P. (1978). *Changing the American schoolbook*. Lexington, MA: D. C. Heath.

Gonzales, P., Calsyn, C., Jocelyn, L., Mak, K., Kastberg, D., Arafeh, S., et al. (2000). *Pursuing excellence: Comparisons of international eighth-grade mathematics and science achievement from a U.S. perspective: 1995 and 1999* (NCES Report No. 2001-028). Washington, DC: Government Printing Office.

Goodlad, J. (1984). *A place called school*. New York: McGraw-Hill.

Harmin, M. (1994). *Inspiring active learning: A handbook for teachers.* Alexandria, VA: Association for Supervision and Curriculum Development.

Heid, M. K. (1988). Calculators on tests: One giant step for mathematics education. *Mathematics Teacher, 81*(9), 710-713.

Hembree, R., & Dessart, D.J. (1992). Research on Calculators in Mathematics Education. In J.T. Fey (Ed.), *Calculators in Mathematics Education, 1992 Yearbook of the National Council of Teachers of Mathematics* (pp.22-31). Reston, VA.: National Council of Teachers of Mathematics.

Hiebert, J., Carpenter, T., Fennema, E., Fuson, K., Wearne, D., Murray, H., et al. (1997). *Making sense: Teaching and learning mathematics with understanding*. Portsmouth, NH: Heinemann.

Kamii, C., & Dominick, A. (1998). The harmful effects of algorithms in grades 1-4. In L. . Morrow (Ed.), *The teaching and learning of algorithms in school mathematics* (pp. 130-140). Reston, VA: National Council of Teachers of Mathematics.

Karpinski, L. C. (1965). *The history of arithmetic*. New York: Russell & Russell.

Kearns, D. (1989, December 17). Improving the workforce: Competitiveness begins at school. *The New York Times*, p. 2.

Keith, S. (1981). *Politics of textbook selection*. (Tech. Rep. No. 81-A7). Stanford, CA: Stanford University, Institute for Research on Educational Finance and Governance.

Kennedy, M. (1998). *Form and substance in inservice teacher education* (Research Monograph No. 11). Madison, WI: University of Wisconsin-Madison, Wisconsin Center for Education Research.

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). *Adding it up: Helping children learn mathematics.* Washington, DC: National Academy Press.

Lacking a clear focus, US science and mathematics courses cover many subjects but provide little depth. (1996). *Advanced Materials & Processes, 150*(6), 47.

Lacampagne, C. B. (1993). *State of the art mathematics: Transforming ideas for teaching and learning*. (OERI Publication No. OR 93-3044). Washington, DC: Government Printing Office.

Lindquist, M.M., & Kouba, V.L. (1989). Measurement. In M. M. Lindquist (Ed.), *Results from the Fourth Mathematics Assessment of the National Assessment of Educational Progress* (pp. 35-43). Reston, VA: National Council of Teachers of Mathematics.

Lott, J. W. (2002). *How are your math students doing?: A President's Message.* Retrieved December 8, 2002, from http://www.nctm.org/news/president/2002-11president.html

Mann, L. (2000). Recalculating middle school math. *Association for Supervision and Curriculum Development*, *42*(1), 1-8.

Maroney, J. M. (1990). *Calculator survey report: The use of calculators in urban and rural schools.* New York and Princeton: College Entrance Examination Board and Educational Testing Service.

Masini, B., & Taylor, J. (2000). New evidence links curricula and instruction to mathematics achievement. *Policy Issues*, 7, 1-7.

Mathematical Sciences Education Board. (1989). *Everybody counts: A report to the nation on the future of mathematics education*. Washington, DC: National Academic Press.

McKnight, C. C., Crosswhite, F. J., Dossey, J. A., Kifer, E., Swaford, J. O., Travers, K. J., et al. (1987). *The underachieving curriculum: Assessing U.S. school mathematics from an international perspective*. Champaign, IL: Stipes.

Mendez, E. P. (2001). A history of mathematical dialogue in textbooks and classrooms. *Mathematics Teacher*, *94*(3), 170-173.

Milne, W. J. (1906). *Progressive arithmetic: First book*. New York: American Book Company.

North Central Regional Educational Laboratory. (2000). Professional development and student achievement. *Learning Point. 2*(1). Retrieved June 10, 2003, from http://www.ncrel.org/info/nlp

National Council of Teachers of Mathematics. (1986). *Calculators in the mathematics classroom*. Reston, VA: Author.

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

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

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

National Council of Teachers of Mathematics. (1998). *Calculators and the education of youth*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1998*). Professional development of teachers of mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Education Goals Panel. (1999). *Third international mathematics and science study-replication (TIMSS-R).* Retrieved December 12, 2002, from http://www.negp.gov/issues/publication/othpress/timss.html

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

Oakes, J. (1985). *Keeping track: How schools structure inequality*. Binghamton, NY: Yale University Press.

O'Neal, S. W., & Robinson-Singer, C. (1998). *The Arkansas Statewide Systemic Initiative pilot of the Connected Mathematics Project: An evaluation report*. Retrieved December 12, 2002, from http://www.math.msu.edu/cmp/ArkRep.html

Pomerantz, H. (1997, December). *Parents, calculators, and kids: What parents should know about the benefits of calculator use*. Paper presented at the Superintendents Forum, Dallas, TX.

Ravitch, D. (2000). *Left back: A century of failed school reforms*. New York: Simon & Schuster.

Resnick, L. B., & Omanson, S. F. (1987). Learning to understand arithmetic. In R. Glaser (Ed.), *Advances in Instructional Psychology* (Vol.3, pp. 41-95). Hillsdale, NJ:Lawrence Erlbaum Associates.

Reys, R., & Nohda, N. (Eds.). (1994). *Computational alternatives for the 21st century: Cross-cultural perspectives from Japan and the U.S.* Reston, VA: National Council of Teachers of Mathematics.

Riordan, J., & Noyce, P. (2001). The impact of two standards-based mathematics curricula on student achievement in Massachusetts. *Journal for Research in Mathematics Education, 32*(4), 368-398.

Rorinson, M. A. (1992). Mastery learning in public schools: Some areas of restructuring.

Education, *113*(1), 121.

Ross, S. & Pratt-Cotter, M. (1999). Subtraction from a historical perspective. *School Science & Mathematics, 99*(7), 389-393.

Schmidt, W. H. (2000). *Paying the price of "no change"*. Retrieved December 12, 2002, from Michigan State University, U.S. TIMSS Research Center Web site: http://ustimss.msu.edu

Schmidt, W. H. (2002). The benefit to subject-matter knowledge. *American Educator, 26*(2), 8.

Schmidt, W. H., Houang, R., & Cogan, L. (2002). A coherent curriculum. *American Educator*, *26*(2), 1-18.

Schmidt, W.H., McKnight, C.C., & Raizen, S.A. (1997) *A splintered vision: An investigation of U.S. science and mathematics education*. Dordrecht, Netherlands: Kluwer.

Schmidt, W. H., McKnight, C. C., Valverde, G. A., Houang, R. T., & Wiley, D.E. (1997). *Many visions, many aims: A cross-national investigation of curricular intentions in school mathematics*. Dordrecht, Netherlands: Kluwer.

Schoenfeld, A. H. (1985). *Mathematical problem solving*. Orlando, FL: Academic Press.

Senk, S. L., Beckman, C. E., & Thompson, D. R. (1997). Assessment and grading in high school mathematics classrooms. *Journal for Research in Mathematics Education. 28*(2), 187-215.

Silver, E.A. (2000). Improving mathematics teaching and learning: How can principles and standards help? *Mathematics Teaching in the Middle School, 6*(1), 20-23.

Smith, D. E. (1951). History of mathematics (Vol. 1). New York: Dover Publications.

Smith, F. (1975). *Comprehension and learning: A conceptual framework for teachers*. Toronto, Canada: International Thomson.

Smith, J. P. (1998). Graphing calculators in the mathematics classroom. *ERIC Digest.* Columbus, OH: Office of Educational Research and Improvement. (ERIC Document Reproduction Service No. ED433183)

Stein, M. K., Grover, B. W., & Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *American Education Research Journal, 32*, 455-488.

Stigler, J. W., Lee, S. Y., & Stevenson, H. W. (1990). *Mathematical knowledge of Japanese, Chinese, and American elementary school children*. Reston, VA: National Council of Teachers of Mathematics.

Stevenson, H. W., & Stigler, J. W. (1992). *The learning gap: Why our schools are failing and what we can learn from Japanese and Chinese education.* New York: Touchstone.

Stigler, J. W., & Hiebert, J. (1997). Understanding and improving classroom mathematics instruction: An overview of the TIMSS video study. *Phi Delta Kappan, 79*(1), 14-21.

Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. New York: The Free Press.

Swetz, F. J. (1987). *Capitalism and arithmetic*. La Salle, IL: Open Court Publishing.

Tompkins, G. & Hoskisson, K. (1991). *Language arts: Content and teaching strategies.* New York: Macmillan..

Using data about classroom practice and student work to improve professional development for educators. (2003). *NEA Foundation for the Improvement of*

Education, *5*, 1-12.

Usiskin, Z. (1999). Groping and hoping for a consensus on calculator use. *Mathematics Education Dialogues*, *2*(3), 1

Wearne, D., & Hiebert, J. (1988). A cognitive approach to meaningful mathematics instruction: Testing a local theory using decimal numbers. *Journal for Research in Mathematics Education, 19,* 371-384.

Whitehurst, G. J. (2002). *Research on teacher preparation and professional development.*

Paper presented at the White House Conference on Preparing Tomorrow's Teachers, Washington, DC. Retrieved June 21, 2003, from http://www.ed.gov/inits/preparingteachersconference/whitehurst.html

Winking, D., Bartel, A., & Ford, B. (1998). *The Connected Mathematics Project: Helping Minneapolis middle schools students "beat the odds": Year one evaluation report*. Report submitted to the National Science Foundation as part of the Connecting Teaching, Learning, and Assessment Project. East Lansing, MI: Unpublished technical report.

Wood, T., & Sellers, P. (1997). Deepening the analysis: A longitudinal assessment of a problem-centered mathematics program. *Journal for Research in Mathematics Education*, *28,* 163-186.