Best practices in middle level mathematics teaching and learning

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Best practices in middle level mathematics teaching and learning

**Abstract**
The added pressure on students and teachers to do well in mathematics has placed a new emphasis on how best to teach math. This paper discusses the standards developed by the National Council of Teachers of Mathematics and how those standards can be implemented into classrooms in order to help students to increase their mathematical power. Although teaching to the standards would be a drastic change for many teachers with the proper professional development, standards-based math classes could be a reality that will help our students' mathematical understanding.
BEST PRACTICES IN MIDDLE LEVEL MATHEMATICS

TEACHING AND LEARNING

A Literature Review

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Wendy Sue Korte

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has been approved as meeting the research requirements for the Master of Arts in Education.

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Abstract

The added pressure on students and teachers to do well in mathematics has placed a new emphasis on how best to teach math. This paper discusses the standards developed by the National Council of Teachers of Mathematics and how those standards can be implemented into classrooms in order to help students to increase their mathematical power. Although teaching to the standards would be a drastic change for many teachers with the proper professional development, standards-based math classes could be a reality that will help our students' mathematical understanding.
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Practices in Middle Level Mathematics Teaching and Learning

Current legislation in education has increased the pressure on students and teachers to perform at higher levels. Students are currently expected to prove their proficiency in reading, math, and science, with technology soon to follow. Reaching a designated score on a written test is the way that most school districts are choosing to determine proficiency. The topic I am interested in researching is, how should I teach math in my sixth grade class to help the students score well on written tests, but also so that they learn and understand math?

There is a great deal of emphasis in the Cedar Falls school district on teaching reading so that students learn to read well and will, also, score well on the proficiency testing that will be reported to the public and to the government. It is difficult to dispute that having students become strong readers should not be an important goal for a school district. We all know how important being a proficient reader is. However, where does that emphasis on reading leave math instruction? There are a limited numbers of hours in the school day, and while scheduling time for math is expected, what is taught during that time may not be serving the students in the most productive fashion.

Many teachers in the elementary schools have not had much background in mathematics in their personal academic background. While that may not be a problem teaching primary math, when students enter the intermediate and middle grades, the effectiveness of the instruction may be compromised by the teacher's lack of background knowledge. Even with the proper background, there are many districts that do not offer teachers in-service in the latest research on the best teaching methods to teach students
Still, the scores students receive on written proficiency tests is how teachers and students are judged on their math abilities.

With this review of current literature, I hope to become more familiar with what to teach in my sixth grade math class and how best to teach those topics. When I was a sixth grade student, I did not like math and did not feel confident that I could be successful in math. It was not until I took a methods class in college that I began to feel better about myself as a math student. As a teacher, I want to reach out to all students, but especially to the students that feel as I did when I was in sixth grade. It is important to feel good about your capabilities as a student, and having a positive attitude about math in sixth grade is important. A vital part of that attitude is feeling that math is something that is useful and is something that is not impossible. My job as a teacher is to make math important and possible for all of my students. With this thought in mind, my review will attempt to answer the questions: What are the best practices for teaching and learning math in the middle grades? What are the best methods for assessing student learning in math? How do teachers adjust instructional methods to reach all students? What is the best way to prepare teachers to implement best practices in their classroom?

Methodology

My search for sources for this review began with a group that I consider as experts in the field of teaching mathematics, the National Council of Teachers of Mathematics (NCTM). This group includes elementary and secondary math teachers, as well as other professional educators, administrators and researchers. Their recommendations for how to improve mathematics instruction were published after years
of study. The NCTM has published many documents since the initial *Curriculum and Evaluation Standards for School Mathematics* were published in 1989. All of the additional publications were written to support teachers and their attempts to teach to the standards. These publications include *Professional Standards for Teaching Mathematics*, published in 1991, *Assessment Standards for School Mathematics*, published in 1995, *Principles and Standards for School Mathematics*, published in 2000, and an Addenda Series of books that are focused on specific topics in specific grade levels. This review began with the NCTM publications since the basis of a math curriculum should be the standards that were established by this group.

Other articles and publications that were chosen for this review were, for the most part, published within the last twelve years, since the standards were first published. Topics included the NCTM standards, how to assess or implement those standards in the classroom, and how best to prepare teachers to teach to the established standards.

Analysis and Discussion

*The Problem*

Teaching mathematics in today's society is a demanding job. The educational system designed to meet the needs of the industrial age is no longer meeting the needs of the information age that we experience now. As society changes, and the expectations for our children change, teachers need to be open to adjusting their teaching styles in order to help prepare students to meet those expectations. It is important for citizens of our society to be prepared to use information to solve problems, often by working cooperatively with others. Modern educational practices should also help to create
citizens that are lifelong learners, are informed community members, and to help to provide opportunities for all.

Reform of mathematics education seems to be something that has historically been ongoing. From the late 1950s to the early 1970s, “New Math” was a common curriculum choice. The failure of this change in emphasis to increase mathematical test scores by many students lead to a “back to basics” push (Kraus International Publications, 1993). This has, in turn, led to the most recent attempts to reform learning math. Throughout the changes, math continues to be the core subject in school that it is most acceptable to do poorly at. Many students hold the belief that math is only for a few students to be successful at and that only the brightest students will do well.

Traditional methods of teaching math, with the teacher in front of the classroom showing the students how to determine the correct answer using a defined method, is not an effective way for most students to understand mathematics (Zemelman, Daniels, & Hyde, 1998). There is a strong focus on rote memory of mathematics facts and algorithms, with little emphasis on applying the facts. Each student is expected to learn in the same manner and within the same time period as all other students.

Traditional math classes also have an element of competition ingrained in them because students are given the information needed to complete a task and then given a set amount of time to complete the task (NCTM, 1995). Each student works alone to get the correct answer. The work is then corrected, and, in many cases, a score is assigned. These scores, along with scores of tests that are given periodically, are used to determine a student’s grade in math. The grades given show which students can do math and which
cannot do math. Although logic tells us that this method of teaching math is not effective for all students, the vast majority of math teachers still teach this way.

The NCTM (1989) believes that all students are capable of learning math, but need to learn different mathematics, and more of it, than is being taught in most school districts at the current time. To accomplish this, math curricula and instruction will need to be revised significantly. The five main goals of the NCTM for kindergarten to twelfth grade students is that they will include the following:

1. Learn to value mathematics by having a variety of experiences related to the historical and cultural importance of math.

2. Learn to reason mathematically by making conjectures and supporting them through evidence. Sound reasoning should be valued as much as the ability to get the answer correct.

3. Learn to communicate mathematically by learning the symbols and terms of math and being able to explain their thinking either orally or in written form. This is best done in the context of solving problems.

4. Become confident in his or her mathematical abilities by understanding that doing math is a common activity that everyone has the ability to do.

5. Become mathematical problem solvers by being involved in a classroom that focuses on solving problems. In turn they will be able to transfer this skill to their daily lives.
The Standards

The original *Curriculum and Evaluation Standards for School Mathematics* publication, published by the NCTM in 1989, designated standards in thirteen topics that math educators should focus on in the middle grades. These standards propose a broad mathematics curriculum for students. Computation is important, but is not the main focus of the recommended curriculum. Although there are thirteen standards, they should not translate into thirteen chapters in a math book or thirteen separate units of study. Integration of the topics throughout the curriculum is the ideal. Seldom, in our daily lives, do we have one specific type of problem to solve at a time. Generally, we need to use a variety of strategies and skills in our day-to-day existence, and that is what the NCTM suggests to teachers when teaching math in our classrooms. Problems that utilize knowledge about several math topics helps math seem more relevant and realistic to the students. It is important for students in the middle grades to have a positive experience with math, since these are the years that their feelings about math are solidified, and they are beginning to plan for their future study of mathematics.

A later publication by the NCTM, *Principles and Standards for School Mathematics*, published in 2000, has combined several of the thirteen standards into one area. The standards involve the following topics: Numbers and Operations, Algebra, Geometry, Measurement, Data Analysis and Probability, Problem Solving, Reasoning and Proof, Communication, Connections, and Representations. This publication offers more information on how best to implement the standards into our classrooms. Focusing on
each of these standards helps to give a better understanding of what an ideal mathematics classroom would look like.

The Numbers and Operations standard focuses on understanding numbers and number systems (NCTM, 2000). This area of study has typically been the cornerstone of most math curricula. Computation has been the most important thing students needed to learn to be successful in math class for many years, and it still is important. Knowing addition, subtraction, multiplication, and division facts makes many other parts of math easier. This standard, though, goes farther than just knowing how to do computation problems on a piece of paper. Zemelman, Daniels, and Hyde (1998) note that application of the basic facts should be the goal of the math curriculum. It is not enough for the students to just know the facts; it is crucial that they also know when to use certain operations. Using estimation and mental math falls under this standard, and are important skills for students to focus on. These skills are contingent on a student’s basic knowledge of numbers and facts.

Developing a student’s number sense is an important part of their mathematics education (NCTM, 1989). Number sense is exactly what it sounds like it should be. Students with number sense understand number meanings and are able to develop multiple relationships between numbers. They understand the relative magnitude of numbers, are able to detect errors in computation, understand the relative effect of operations on numbers, and have a desire to make sense of numbers. Students with number sense usually will look at the whole problem before looking at the details in order to get the general idea of what is required to solve the problem. Although some
students seem to have this ability naturally, number sense is something that must be developed over time. Teachers can assist students in developing number sense by making a conscious effort to help students make connections while working on mathematics. Giving students many opportunities to work with numbers helps the students to develop an important intuition about numbers that will help them to solve problems (Zemelman, Daniels, & Hyde, 1998). Encouraging students to use their own strategies to solve problems is another way teachers can help guide students. Offering many experiences using and manipulating numbers with partners and with small groups gives students opportunities to hear what others are thinking and will increase number sense.

Students should enter the middle grades with a basic understanding of fractions, decimals and percentage (NCTM, 2000). Continued work with rational numbers should be a big part of the math curriculum in the middle grades. Building on the student’s basic knowledge will help them to observe that the same number can be written in many ways, and also determine which form, fraction, decimal, or percent, to use for the most effective representation. Using a variety of models to help students understanding of rational numbers is important. Using fraction strips, number lines, 10 x 10 grids, and other objects helps to offer concrete experiences for an abstract idea. Having this basic knowledge will help the student as more complex ideas are presented. The transition from using mathematical operations with whole numbers to using those operations with rational numbers should be an easy one if the student has a strong understanding of those numbers.
The NCTM (2000) recommends a much stronger focus on algebra in the middle grades than is common in most current math curriculums. MacGregor and Stacey (1999) noted five aspects of number knowledge that are important for learning algebra. They include the following: understanding equivalence, recognizing number operations and their relationships to each other, understanding important properties of numbers, describing patterns, and being able to use a wide range of numbers, including large numbers and fractions. In order for learning algebra to be successful, students should enter the middle grades with the understanding of how numbers work. Strengthening the student’s intuitive knowledge of number properties and increasing their abilities to see relationships in number patterns will help the student be able to transit into using symbols to express those patterns. Algebra is very difficult to learn without a strong background in number operations and properties. The effects that operations have on numbers, including large numbers, fractions, and decimals, are important concepts to have if we expect students to be successful in algebra. Recognizing the relationships among the operations and which should be used to solve a problem is an important step in solving all kinds of problems and vital when dealing with algebraic equations. Being comfortable using the operations with a variety of numbers is another important understanding to have for success in algebra. Understanding equivalence, and how that can be translated into an equation, is one of the most vital understandings that we assist students with that will help them be successful in algebra.
The algebra standard calls for students to be able to study patterns and make generalities using tables, graphs, words, and symbols (NCTM, 2000). Students should become more comfortable with the relationships with these representations and understand the advantages and disadvantages of each. It is important that students begin using variables, and learn about how variables can be used in different ways, not always just as a place holder for an unknown number. The study of algebra should include using models to help with students understanding. Students should be able to generate and recognize equivalent expressions. This is an important skill when solving for variables. The study of algebra in the middle grades should include analyzing change that is at a constant rate. The NCTM emphasizes that algebra, as well as other mathematics topics, should be integrated within the math curriculum.

Geometry is the third standard focused on by the NCTM in the *Principles and Standards for School Mathematics* publication (2000). Like algebra, this publication recommends that more emphasis be placed on geometry than most curriculums do currently, and also that geometry be integrated into other areas of the math curriculum. The study of geometry should include activities that help students strengthen their abilities to create mental images of mathematical relationships and patterns. Mental images play an important role in all aspects of math. The ability to build and use mental images and transform them, helps to increase the students thinking flexibility and will help to increase their ability to devise solutions to problems (Wheatley & Reynolds, 1999). The ability to use spatial sense, developed in a strong geometry curriculum, should allow students to solve problems in a more image-based way.
Regular opportunities to construct images to solve problems helps students solve other problems that they are unfamiliar with and should, in turn, help students feel more confident in their abilities to solve problems that they have not been exposed to previously.

In the middle grades, the study of geometry should include examining the features of two and three-dimensional shapes and making generalities by noting what is common and different about the shapes (NCTM, 2000). Working with congruent and similar shapes should help students learn to analyze characteristics and discover relationships. The study of lines of symmetry of shapes is also emphasized. Using transformations such as flips, turns, and slides should help develop and increase spatial visualization and also encourage development of the student’s reasoning skills. Many middle grade students are able to deal with abstractions, but concrete work is still important in order to build a strong understanding of the concepts. Hands-on materials, such as geoboards, dot paper, cardboard strips, and even computer software help improve most students’ ability to visualize. The use of coordinates to help with the study of the properties of geometric shapes, such as congruence and similarity, is important. The NCTM (2000) recommends an activity based geometry curriculum to help increase the student’s geometric reasoning, with much of the work being done with a partner or in small groups.

Measurement, the next standard determined by the NCTM (2000), should be tied closely to the study of geometry. Both are learned best when students are able to use concrete materials to discover relationships within, and between, the disciplines
(Zemelman, Daniels, and Hyde, 1998). Students should bring diverse experiences with measurement to the middle grade classroom. Each student should have formal and informal measurement experiences, both from activities at school and at home. Most students have spent time measuring with non-standard units such as paper-clips, their shoes, and other items, in the early grades and should have had experiences with standard units, as they got older. As students grow, what they are measuring also becomes more complex, starting with length and weight and moving on to area, mass and rates of speed. The measurement standards emphasize the importance of selecting the appropriate type of measurement unit for what is being measured, and also states that the use of customary and metric units is necessary. Students should be able to understand the relationships among the units of measure and be able to convert from one particular unit to another one within the same system. It is important for students to be able to estimate when actual measurement is not possible, so providing activities to reach this goal should be a priority. Students also need to learn that measurements are approximate and that a small amount of error in all measurement is acceptable. Hands-on experiences are important for all of measurement, even for area and volume. The formulas that students are taught to help solve for area and volume should be meaningful, not just memorized. Using concrete materials for this more advanced measurement is a way to increase the chance that students will develop a deeper understanding of what area and volume actually are measuring.

Data Analysis and Probability is another standard that educators should consider when planning their math curriculums (NCTM, 2000). Students entering the middle
grades should have previous experience collecting and representing data. Teachers in the middle grades need to build on this knowledge in several different ways. At this point in their education, students should be instrumental in the collection of the data for any activities. Zemelman, Daniels, and Hyde (1998) state that students will learn better through real-world problem-solving situations, rather than something that the teacher contrives for them. Students should formulate research by determining what question they would like to have answered or what problem they would like to study. They should hypothesize what the outcome of their research might be and decide on the sample that will be polled and how the data should be gathered. After the data is collected, students should decide the best way to represent their findings to communicate the information in the most appropriate way. Analyzing the data and comparing it to the hypothesis that was made should help the students to develop an appreciation for real-world studies and how they can assist in solving problems. At the middle grade level, a good share of the data should compare the same information from different populations, and the students should be able to use the data to compare the populations, looking for relationships among the data. From this information, inferences should be able to be made about the differences in the populations and why those differences may occur. New questions to study may even rise from this information.

An important part of the study of data for students in the middle grades should include becoming familiar with the use of the mean, median, and mode in order to describe the center of the data. Understanding what each of these numbers shows is
important for the student’s understanding of data and what that data can help to show us. It is also important to understand how changes in the data will change the mean, median, and the mode. Knowing how to figure the range of the data and what it shows is also another important part of analyzing data.

Using probability to make predictions and test conjectures is also part of this standard. Looking at the results and interpreting them is an important part of this area of study. Students should learn that large discrepancies between the predictions and outcome of the activity must be taken seriously if the sample is large enough.

Problem solving, the next standard recommended by the NCTM (2000), should not be an isolated part of a good math curriculum, but should involve all of the other areas of mathematics. In fact, problem solving should be an integral part of entire curriculum for the middle grades because it provides a context for applying math in other areas of education (Zemelman, Daniels, and Hyde, 1998). This is a realistic way for students to experience the power of math. Successful problem solvers believe in their abilities to solve the problem and are willing to take the necessary time to work through the problem. They know that there is more than one right way to solve a problem and they are able to apply knowledge from other disciplines in different contexts. Good problem solvers assess their progress as they are working and adjust their strategy while working, if necessary. Many times problem solving failures are because of the student’s ineffective use of what they already know. Helping students find an effective plan to solve problems is a way that teachers can assist students in developing their problem solving abilities. Students must first understand the problem
in order to know what the problem is, and what information should be used. Many strategies can be used to actually solve the problem, although some will help to solve the problem in a more effective way than others. Deciding which strategy would be best to use for the particular problem would be the next step in solving the problem. Some widely used strategies for problem solving include the following: working backwards, guess and check, finding patterns, drawing diagrams, listing possibilities, and creating equivalent or easier problems. Overtly teaching these strategies is important if teachers expect the students to use them, although many times the students are already using these strategies without knowing that the method they are using to solve problems has a specific name. One of the most important steps in problem solving, one that is often overlooked by students, is determining if the solution to the problem makes sense once the students have solved the problem. This final step of problem solving is one that is often skipped, but is valuable in determining real understanding by the student.

Teachers help students' problem solving skills improve by not only teaching strategies, but also by the choices they make in the problems they select for the students to solve. Problems should come from the students' lives, if possible, to help them be more relevant to the student. They should be chosen to help the students think systematically, integrate multiple topics, and should sometimes include not enough, or too much, information to solve the problem. Allowing the students to choose or create the problems is a good way to create even more interest by the students. Students help each other become better problem solvers by working
together, so planning for many partner and small group activities is another valuable thing that teachers can do to help students become successful problem solvers. Students need to reflect on their work and explain the strategies that they used and the solutions they got. Communicating their thinking, either in writing or orally, helps the student to solidify their problem solving skills and gain confidence in their abilities. Krulik and Rudnick (1999) suggest having students write a summary explaining how they solved the problem, why they chose the method they did to solve it, and what the results were. This summary helps the teacher to better understand the student’s thinking, and also forces the student to reflect on, and clarify, their ideas and thought processes. According to Krulik and Rudnick, teachers can extend the problems by encouraging the students to find another method to solve the problem and also by changing a condition of the problem to determine the effect it would have on the solution.

The focus on problem solving in current math curricula is a result of the NCTM standards. Why is problem solving important? The goal of all math curricula should be to produce students that understand math. Practicing computation and learning skills and operations is only helpful when the students are able to apply this information to new contexts. Demonstrating the ability to use prior math knowledge in new contexts is one vital way that students can show their understanding of math concepts. Problem solving requires students to make many decisions, such as what information is valuable and how the information should be used to solve the problem.
This process helps students to enhance their problem solving techniques and builds students' self-confidence.

The NCTM (2000) lists Reasoning and Proof as the next standard. Reasoning is an integral part of mathematics and should be thought of as a fundamental skill students should do on a daily basis. Middle grade students should have already experienced the fact that math consists of patterns and have begun to be able to make generalities from those patterns. The problems chosen for students should require students the chance to generate and organize data, make conjectures, find the patterns, and evaluate the conjectures. All ages of students should investigate conjectures using concrete materials, including calculators. Working with others offers students the opportunity to discuss the problem and develop and use their inductive and deductive reasoning skills.

One way that teachers can help students improve their reasoning skills is to be certain that they spend time reflecting on their solutions in problem solving situations. Simply finding the solution does not go far enough to encourage reasoning skills. Expanding the activity to give the student an opportunity to create new problems using similar situations, find other solutions, if possible, use the solution to make generalities, and to have the student self-assess is a way to develop students' reasoning skills. Having the student reflect on the problem by writing a summary paragraph about the problem and its solution is another way for the student to improve his or her reasoning abilities, and ties directly into the next standard.
Although Communication is listed as a separate standard, it is mentioned as a key factor in a student’s ability to learn the math included in all of the other standards (NCTM, 2000). Communicating, either orally or in a written format, gives the students an opportunity to solidify their thinking and reflect on their own understanding. Students can try out new vocabulary and justify their conjectures. Listening to others, or reading other’s explanations, can benefit the student by offering them a chance to reflect on another student’s understanding.

Children’s literature can be used, even in the middle grades, to help foster discussion and understanding. Patricia S. Moyer (2000) comments that children’s literature can provide a real-world context for mathematical concepts. This context may help make learning the concept easier and more interesting to the student. She also notes that promoting mathematical discussion in other areas of the curriculum will help increase students’ abilities to communicate mathematically through the course of their lives.

Communication is an essential element of a classroom where the students are asked to reason and think. In order to have successful discussions, it is important to build a sense of mutual trust and respect in the classroom, among all of the students and the teacher. Students must feel free to express their ideas, and know that it is acceptable to make mistakes and be unsure about how to accomplish a task. Students need to be given opportunities to share the strategies they used and ask each other questions for clarification. All students should participate and the teacher should monitor the discussions, making sure that the focus remains on the thinking required,
rather than just on what the right answer is. Incorporating discussion into math class, especially if it is about authentic tasks, will help to increase interest and focus for the students. The teacher is involved in the discussion process by posing a question that will challenge the student’s thinking, and then monitoring the discussion to be certain that the students are addressing the problem and being respectful of each other. There may be times the teacher may need to ask a student for clarification, reword the question, or even model a strategy to assist the students. Simply asking a student “why?” may help the student reflect further, thus increasing their reasoning abilities and helping them solidify their thinking. Teachers need to be certain that all students are participating. The student’s role in classroom discussions in math is to make sense of what the problem is asking and listen to, respond to, and ask questions of the teacher and the other students. One side-benefit of this type of communication in a mathematics class is that students learn that the teacher is not solely responsible for the teaching and learning; the students share the responsibility for their own learning.

Writing about mathematics in the classroom is another excellent way for the student and teacher to communicate (NCTM, 2000). Writing in math class not only helps students reflect on their thinking, but it also helps to improve the students writing skills because the student is writing for a purpose that is different than what is usually thought of. Writing can come in many forms, such as math journals, commenting on assignments, explaining how a solution was found, writing comparisons of procedures, learning logs, formal papers about a topic in math, and math autobiographies. The primary goal of the writing assignments should be to
require the student to reflect on their understanding and solidify their thinking. Math journals are a good way for the student to express their attitudes about math and communicate with the teacher any successes or misgivings they may have.

Summarizing a problem, the solution, and how the solution was achieved is another way to use writing in math class (Krulik & Rudnick, 1999). This form of writing helps the students clarify the problem and the process they used to solve it. There are times that the student may have misunderstandings that may not show up until they are forced to reflect on what they are doing by writing a summary. Writing gives students a chance to use mathematical vocabulary that they may not use, otherwise.

The NCTM (2000) has also listed Connections as a separate standard, although making connections is mentioned often in the other standards. Students will be more successful in math when they are able to look for, and make, connections among the skills they are learning. Looking for connections between mathematics class and life outside of school is important for students. Seeing the relevance of studying math should heighten the student's motivation to learn the skills necessary to be successful in math class. Math has many isolated facts and rules. If students fail to use their prior knowledge, to see that new facts and rules are connected to others they are familiar with already, then they will have a difficult time understanding math.

Teachers can help students build the necessary connections by using problems that are related to problems that have already been mastered, and by using classroom discussions to point out the connections directly. Connecting math to other parts of the entire curriculum is an excellent way for the teacher to make math seem more
relevant to the students. Using children’s literature is a natural way to help students make the connection between math and the world they live in. There are many pieces of literature that will allow students to see that math can be a natural part of their everyday experience. Although some teachers may feel that the use of literature to make math connections is for primary grades, even middle grade students enjoy reading or listening to a piece of literature that uses an interesting context to explore mathematical ideas.

Representation, the final standard discussed in the *Principles and Standards for School Math*, refers to diagrams, charts, symbols, and other ways that help us to communicate math (NCTM, 2000). Representations are central to the study of math and it is important that students are able to use them properly in order to represent the information given in problems and their solutions. Making the connection between the concrete and the mental representations is vital for students, in order for them to solve problems well. Students are able to deepen their understanding of mathematical concepts as they compare, create, and use a variety of representations. Teachers can help students increase these understandings and connections explicitly through questions that require the student to reflect directly on what the representations mean. It is important for students to learn which representations are the best in helping them organize their thinking and in their communication with others.

**Assessment**

As mathematics educators change the focus of the curriculum they teach, a change in assessment practices must follow. It is obvious that a change in the vision
of school math would necessitate different forms of assessment of the students. The NCTM published a document in 1995, the *Assessment Standards for School Mathematics*, to assist teachers with the matter of assessment. The six Assessment Standards proposed in this publication are designed to build on the Evaluation Standards that were already written in the *Curriculum and Evaluation Standards for School Mathematics* publication in 1989.

Many educators think of assessment simply as testing. Assessment is the process of collecting evidence about a student’s knowledge and understanding, and then using that evidence to make inferences about that knowledge. This allows the teacher to then make decisions about future teaching and learning activities (Zemelman, Daniels, and Hyde, 1998). Assessment should be an ongoing, daily process, and students should be given feedback so that they are aware of what they are doing well and what still needs to be practiced (NCTM, 2000). Teachers need to plan for assessment as they would plan for a lesson. What is the purpose of the assessment, and what will the methods and criteria be? Once the procedures have been selected and carried out, the data needs to be interpreted and some sort of action taken based on the inferences drawn.

Assessment can take many forms and has several purposes behind it. A main reason for assessing students is to monitor their progress in relation to the math goals that have been set and to provide feedback on that progress (NCTM, 1995). Helping students to set and strive toward reaching math goals is important. Then, communicating openly with students about the expectations, and if their work is
meeting the set criteria, helps students to become more independent as learners. Using a variety of assessment tools allows students the opportunity to show what they have learned and understand. Self-assessment is a valuable way for students to reflect on their learning.

Assessment should also be used by teachers to make long and short-term instructional decisions for their mathematics classes (NCTM, 1995). When teachers understand what students know, it is easier to make important curricular choices. Using evidence from the student’s work helps the teacher to identify appropriate content, pacing, and sequencing. It should also help the teacher with appropriate questioning, and assist in planning instruction that is responsive to the students’ curricular needs.

Evaluating a student’s overall achievement in math is another purpose of assessment (NCTM, 1995). Periodically, student work is examined and the report on that assessment is shared with parents, administrators, and people outside the district. This type of assessment should also be consistent with the reforms being proposed. We should be comparing students to the criteria being set, rather than other students, and assessing overall mathematical understanding, rather than individual skills. Using a variety of assessment forms is necessary, in order to offer multiple sources of information to draw valuable conclusions from. Currently, however, people outside the school district write many of the assessments that are given to students for this purpose. These assessments are often timed, so the tests require rapid responses, and most do not contain the balance in the types of tasks included to follow the reforms
being proposed by the NCTM. At this time, there is a strong emphasis on scoring well on this form of assessment. This often forces the students and teachers to focus on teaching and learning the types of tasks necessary to be successful on this assessment, rather than on the recommended standards.

Another purpose of assessment is to help schools evaluate their math programs (NCTM, 1995). Using the student performance data assists educators in evaluating how well the curriculum meets the criterion that has been established. Possible shifts in focus can be determined by evaluating student overall achievement.

The NCTM has written six assessment standards to assist teachers in making appropriate choices in assessing their students' mathematical understanding. The first standard states that the assessment should reflect the math that each student needs to know and should be able to do (NCTM, 1995). Students are apt to believe that only the items being assessed are important, so teachers should be certain to not only practice, but to also assess, mental math skills (Cohen and Fowler, 1999), math vocabulary, and other topics that are deemed important. The assessors should be familiar with the math curriculum being taught, how students learn, and should have actual knowledge of the mathematics. The assessment should allow the students to solve realistic problems that will give them the opportunity to use the procedural skills and knowledge that they have acquired. These problems may use math that has been previously learned, but put into unfamiliar situations, forcing the students to become more flexible in their understandings. Using reasoning skills and making connections through problem solving should be a part of assessment. Learning to communicate
clearly about mathematics through the use of correct terminology is also an important part of learning and understanding math, and should be assessed. Finding the solution to a problem is important, but being able to give reasons and explain procedures demonstrates a greater understanding than simply solving the problem.

The second standard states that assessment should be a way to help enhance learning for the student (NCTM, 1995). Students are able to demonstrate their strengths and determine the areas in which growth still needs to occur. The knowledge of where students are in their understanding supports further learning by providing valid information for both the teacher and the student as to what should be next in instruction. There are a variety of assessment forms that some may not see as an assessment, such as teacher observation, journals, drawings, portfolios, written papers, projects, and oral comments the student makes during classroom discussions. Each of these forms can provide a different way of assessing what the student understands. Having the students assess themselves, possibly through the use of rubrics, is one way to encourage them to reflect on their own work and learning. Assessment should be something that is ongoing, not a disruption in the routine. Classroom instruction should not stop for assessment.

Another standard for assessment written by the NCTM (1995) is that assessment should help to promote equity, not determine who can and cannot do math. The focus of our math instruction and assessment in the classroom should be on each student learning math. Having high expectations for all students should help students strive for understanding, even when some students have not been successful in math class in
the past. Traditionally, math instruction and assessment have expected all students to learn mathematics in the same way, solving problems in a set fashion. Differences in the way students think has been largely ignored. The NCTM reform of mathematics calls for assessment to allow for multiple approaches to the same problem, since students show what they know in a variety of ways. Assessors that are open to alternative strategies and solutions encourage students to be creative in their thinking. Each student is then able to develop mathematical thinking that is useful to them in a variety of situations.

The NCTM (1995) recommends that assessment be an open process in the next standard. It is important that all students are aware of what mathematical understandings and procedures will be assessed and what process will assess them. Something that is crucial is that all students must be given the necessary time to learn what will be assessed, before the assessment. Teachers and students should both be active participants in the assessment procedure, and modification to the process may be necessary, so flexibility is important.

The fifth Assessment Standard states that assessment should help to promote valid inferences about the students’ mathematical learning (NCTM, 1995). Making judgments about what the student knows, based on a variety of sources, is an important part of what teachers do daily. Using relevant and adequate resources, and trying to minimize bias, allows the teacher to make important curricular decisions that will determine the direction math instruction will go.
The final standard states that assessment should be a coherent process (NCTM, 1995). It is vital that assessment is aligned with the curriculum and daily instruction in the classroom. There needs to be a balance among a variety of appropriate assessment activities to help students learn. Communicating what students have learned and understand is crucial to the student.

**Professional Standards**

The ultimate goal the NCTM reforms call for, by writing the Curriculum and Evaluation Standards, is to develop mathematical power in all students. In order for this to occur, teachers need to be aware of the standards, and must structure their classrooms, and teach, in a way that allows for the math instruction that is most beneficial to the students’ learning. The *Professional Standards for Teaching Mathematics*, published in 1991, provides guidelines for teachers. The NCTM has established standards for teaching math, evaluating the teaching of math, professional development of teachers of mathematics, and also for the support and development of math teachers. Several assumptions were the basis for the standards in this publication. Educators need to assume that all students can learn to think mathematically and develop the power to use math in their lives. Also, what students learn is directly connected to how they learn it. An important assumption that educators need to keep in mind is that teaching is a complicated process. It cannot be reduced to a recipe that is always going to work with every student. Finding one right way to teach to every student is impossible.
Six standards have been established for teaching math in order to help students gain the mathematical understanding they need to be successful. The first is that teachers need to be certain to choose tasks that are worthwhile (NCTM, 1991). Each task should take into consideration the content that is being taught, and encourage mathematical reasoning and development of the appropriate skills. Practicing those skills in the context of a real-life problem helps to promote the idea that math is something that is useful to the student. The students need to be considered when choosing an appropriate task. Keeping in mind what the students already know, what needs to be learned, and even student interests will assure the tasks chosen will help the students reach the content goals. It is also important for the teacher to be aware of how students learn best when choosing tasks for instruction. Using a variety of strategies helps to assure a successful lesson.

The next three standards involve discourse in the math classroom (NCTM, 1991). Discourse involves communication in the classroom, and is a central element to what students should learn about math. Discourse includes the ways of representing math. It includes thinking, talking, listening, and writing about math. The teacher’s role in discourse in the mathematics classroom is the next standard in the **Professional Standards for Teaching Mathematics** publication. Teachers should pose questions to the students that challenge the student’s thinking and encourage mathematical reasoning. Asking them to justify and clarify their thinking, either orally or in writing, forces the student to reflect on their thinking. Simply asking the student , "Why?" helps them to focus on what they truly understand. Listening to the students’ ideas,
without directly evaluating the correctness of their comments, allows the teacher to
develop an awareness of what the students understand and does not understand.
Teachers need to decide when it is best to let the students struggle with a concept,
allowing them to work it out on their own, and when to clarify and provide
information for them. A strong commitment by the teacher to encourage every
student to participate is another important role for the teacher. Monitoring discussion
and participation allows each student a chance to share their ideas.

The next standard deals with the student’s role in classroom discourse (NCTM, 1991). Teachers need to promote classroom discourse that allows each student to
communicate mathematically. Students should listen to and respond to each other
with respect, whether they are working with a partner or in small or large groups.
They should be initiating some of the questions, and presenting solutions that will help
them to solidify their thinking, as well as convincing others of the validity of their
solutions. Students should be allowed to use a variety of tools to solve problems,
relying on mathematical evidence to determine the validity of their solution. As they
work, students should continue to make connections to other topics in math and to
their lives.

The third standard dealing with discourse has to do with the tools students and
teachers can use to enhance discourse in the classroom (NCTM, 1991). Allowing
students to use the tools that are most meaningful to them will help them to develop
the necessary understanding to be able to communicate and validate their thinking.
Whether the tools are concrete materials, calculators, pictures, diagrams, graphs,
computers, or a variety of others, students should be encouraged to use them to find a way to solve the problem. There are times, if the student is struggling with a concept, that the teacher may chose to encourage a certain tool to help the student develop the necessary understanding. Certain representations may be more helpful than others in building a particular concept and that may be a way to reach a student that is struggling.

The fifth standard for teaching math states that a teacher should create an environment that promotes the development of the mathematical power of each student (NCTM, 1991). The math classroom should focus on making sense of mathematical ideas. Students should be expected to work hard, developing their math skills and understandings. The teacher needs to provide the structure and the time in order for the students to explore ideas through a context that develops each student’s math skills. The classroom should be equipped with the materials to facilitate learning. Students should be working independently, as well as collaboratively. Students should be encouraged to take risks to help deepen their understandings and should be required to explain and justify their ideas. Each student should be respected for the ideas that they share, even if those ideas may exhibit a misunderstanding of a concept. There will be times that the student will discover their error as they communicate.

Teachers should be constantly analyzing their teaching and what the students are learning, states the sixth teaching standard (NCTM, 1991). The analysis of what the students are learning and the instruction by the teacher is interconnected, and analysis
should be ongoing. Teachers should observe students working to assess what they are learning and examine the effect of the task on each student’s understanding. This will ensure that every student is being given the chance to learn and is being challenged. As the teacher observes the students and assess their understandings, the lesson may need to be adapted to be certain that it achieves the goals that were initially set. As teachers analyze the lesson they will be able to comment on the student’s learning and be able to make decisions on any follow-up lessons. An important part of the analysis should be to consider how the students feel about math and how well they are functioning in math class. It is important for students to have confidence in their abilities and understandings in order to be successful in math class. Expectations for the type of math instruction have changed, so the type of grading requirements will need to change, also. Teachers need to determine a system that will work efficiently for them, because keeping records of student work is an important part of analyzing the math instruction. Long and short-range plans to best instruct the students can be made as the teacher observes and analyzes the student’s work.

**Evaluation of Instruction**

Improving the way we teach math is a major element in reaching the goal of having each student gain mathematical power. Deciding what should be taught and how it should be taught is an important step, but evaluating the instruction is just as crucial. Evaluation should play a role in the professional development of each teacher and several assumptions should be made when considering teacher evaluation (NCTM, 1991). One of those assumptions is that the evaluation process should be
used to improve teaching and enhance the professional growth of the teacher. Teachers are the key to good instruction and their ability to make good decisions will make the difference between strong and weak instruction. The more the teacher understands math and how students learn, the better the instructional decisions will most likely be. Other assumptions that need to be made about teacher evaluation is that what teachers learn from the evaluation process is directly related to how the evaluation is conducted. Simplistic evaluations will not be helpful to teachers. There are many aspects to good teaching, so there should also be many aspects included in the teacher evaluation. It is also important to remember that evaluation is helpful not only to beginning teachers. All teachers should be able to look at their teaching and find an aspect that could be improved upon in order to help all students learn mathematics.

The evaluation standards in the *Professional Standards for Teaching Mathematics* (1991) publication include eight standards to contribute to the teacher's professional development, and also to consider where the focus of those evaluations should be. The first standard is on evaluating teaching comments on the importance of the evaluation being cyclical in nature (NCTM, 1991). The cycle begins with the collection and analysis of data concerning the evaluation of the teacher's instruction. The evaluation should include areas in which improvement can be made, and parts of the instruction that was effective. From this data, a plan for improvement can be made. The plan should include what can be done by the teacher to help math instruction improve and a timeframe for the plan to be carried out. The goal should
always be for the teacher to become a better teacher. After a sufficient amount of time for the plan to be implemented another evaluation can be scheduled to assess how well the plan has worked for the teacher.

The second standard for evaluating math teaching states the important role the teacher should play in their own evaluation (NCTM, 1991). Math teachers should be given the opportunity to analyze their own teaching and be involved in each step of the process. Teachers that are able to discuss with their supervisor the goals that they had for the lesson and analyze the instruction, rather than strictly being told what was observed by the supervisor, are much more likely to learn from the evaluation process. Being more involved in the evaluation will force the teacher to reflect on their teaching, and the result will most likely be a plan that will encourage the teacher. Another way that teachers can improve their teaching is to be able to observe and work with peers. Colleagues can be an important resource for teachers in their quest to become better math instructors.

Evaluation of mathematics teaching should come from a variety of sources and from more than one observation, states the third evaluation standard (NCTM, 1991). Part of the evaluation should be on the goals and expectations that the teacher has for the students, and then, the plans the teacher has for achieving those goals. An analysis of classroom instruction should be done more than once. It should include a teacher analysis of the lessons evaluated by the supervisor. In some cases, a teacher may have a portfolio that will include samples of lesson plans, assessments, and other sources that shows evidence of students' understanding of the math lesson taught.
The following five standards provide the framework for the evaluators and the teachers to know what should be observed during math instruction (NCTM, 1991). These teaching evaluation standards are based on the curriculum standards that were established in the original *Curriculum and Evaluation Standards for School Mathematics* publication in 1989 and include not only content standards, but process standards as well. The first of these standards states that evidence of students understanding the math concepts, procedures, and connections should be provided (NCTM, 1991). In order to do this the teacher needs to show knowledge of math concepts and procedures and be able to demonstrate the connections between math topics as well as math and the student's daily life. Teachers must have the background mathematical knowledge to answer questions and to plan tasks that will help all students learn. The teacher should plan tasks that will engage the students in activities that will promote the learning of concepts, procedures, and connections that are vital to mathematical understanding. Tasks should show how many mathematical concepts and procedures are interrelated. This will help to show students the value of math in their lives. Engaging students in discourse to extend their mathematical understandings of the concepts, procedures and connections should also be demonstrated by the teacher.

The second standard in this section states that teaching math should include problem solving, reasoning and communication (NCTM, 1991). The essence of mathematics is problem solving. Using reasoning skills to solve problems and then communicating the results should be what math curricula is about. Teachers should
model and emphasize the various aspects of problem solving, mathematical reasoning, and communication in math during instruction. A variety of strategies to solve problems should be modeled and the results of the problems should be verified, with generalities being made when possible. Teachers should choose tasks that engage students' reasoning and problem solving skills. Students should then be required to communicate their learning in a variety of forms, written and oral, in order to expand and validate their understandings.

It is essential that the teacher foster a disposition toward math in all students, the next standard states (NCTM, 1991). Evaluation of the teacher should provide evidence that students are confident and flexible math students that understand the value of math in our society. The teacher should show a love for math and actively engage the student in appropriate, real-world tasks that will show the value of math. Connections are the key to the students believing that math is valuable to them in their lives. Students should be expected to challenge the ideas of others and ask questions. They should receive nonjudgmental written and oral comments from the teacher about their work.

Evaluating the assessment practices of the teacher is what the next standard discusses (NCTM, 1991). A math teacher should demonstrate that a variety of methods are used for assessment of the student's mathematical understandings in order to give a clear picture of the student's strengths and where growth still needs to occur. The assessments should be based on what was being taught and how it was taught. They should also take into consideration the maturity level and cultural
background of the students being assessed. Each student’s disposition to do math and mathematical understandings should be assessed so that the teacher can plan what the next step will be in math class.

The final teacher evaluation standard deals with the teacher’s ability to establish an environment that encourages all students to become the best math students they can become (NCTM, 1991). In this type of environment, students are respected for their ideas and abilities. They are encouraged to take risks to solve problems and then to validate their solutions. Expectations for each student should be set high, but the students need to understand that it is their responsibility to work to learn the mathematical ideas. The teacher needs to be certain to select tasks that allow the students to build new understandings based on what they already know through active involvement in the task. The sequence of the instructional tasks should be based on what the students understand already. The idea that math is a subject that can be worked on either individually or by collaborating with others should be demonstrated by the teacher with the selection of tasks. Each student should be expected to participate in the tasks.

Professional Development

Teaching math is a complex task that requires a myriad of understandings and skills. Teachers must have knowledge of mathematics, knowledge of the students they are teaching, and knowledge of the best methods to teach math. A teacher brings many experiences to their teaching and must be aware of the many influences on the way they
think about math. These influences will affect their attitude toward math, and will affect the way they teach mathematics.

The NCTM determined that several basic assumptions needed to be made in order to determine the standards for teacher professional development in math (NCTM, 1991). The first of these assumptions is that knowledge of the Curriculum and Evaluation Standards is what should be the driving force behind determining the Professional Development Standards. Teachers need to be aware of, and teaching to, the curriculum standards established by the NCTM in 1989.

Another assumption made by the NCTM is that a teacher's experiences impact their knowledge, beliefs, and attitudes toward math and the teaching of it (NCTM, 1991). The teaching they see and experience influence teachers. Models that are provided them through their own educational experiences, as well as the influence that colleagues provide, generates the basis of how to teach mathematics.

Teacher education is an ongoing process that requires the integration of theory and practice. Successful teaching of mathematics requires teachers to not only study math, but also study the best methods to teach it to others. As different strategies to teach math are being implemented, the teacher should consider the research behind the strategies.

The final assumption the NCTM is making when determining the Professional Development Standards is that there are specific development needs, depending on the level of math being taught, and it is important that those needs are considered in all facets of professional development (NCTM, 1991).
The first of the six standards the NCTM has established for professional development is that math education instructors should model good math instruction (NCTM, 1991). The experiences that math teachers have while learning math, and while learning to teach math, have a strong influence on the way that they will, in turn, teach math. There may be times that professional development experiences will challenge their prior thinking about math, and require the teacher to rethink what math is and how they are teaching it. Instructors of math educators should model good instruction by trying to create an environment that uses worthwhile tasks to encourage reasoning and discourse. This type of instruction should help teachers develop ideas of what successful strategies look like in a classroom.

The second Professional Development Standard states that mathematics teachers should develop knowledge of the content and of the discourse of math (NCTM, 1991). Knowledge of math includes many things, including the understanding of specific concepts, procedures, and processes. Connections to other subjects are vital in understanding math, as is learning ways to reason and solve problems. Another key to understanding math is the ability to communicate mathematically with others. The ability to communicate increases the chances of understanding and will help the teacher to gain confidence in their own mathematical abilities. Confidence and comfort in math affects the choices that teachers make in what and how to teach math, so it is important that instructors of math educators help to foster a deep understanding and confidence in each teacher's mathematics knowledge.
The third standard notes the important role that understanding students as learners plays in teaching math (NCTM, 1991). Professional development should incorporate the latest research on student learning and the most recent methods in teaching math. Respect for the students as individuals is crucial because many influences affect how each student learns math. These influences include such things as the student’s age, ability, interest in, and experiences with, math. Ethnic and socioeconomic influences are also important when the teacher considers each student. Teachers need opportunities to examine how students think about math in order to make the best decisions about what tasks would be best in teaching specific content. Knowledge about how students best learn will provide teachers with the necessary direction for effective instruction.

The fourth professional development standard deals with the teacher’s ability to use and evaluate instructional materials and resources, as well as using appropriate instructional strategies and procedures (NCTM, 1991). It is important that math teachers have the tools necessary to teach each student the math that is required of them. This standard focuses on the ways that teachers help their students learn and develop a greater understanding of math, so that math is something that is useful to them. Teachers must be familiar with a variety of representations in order to help each student construct a representation that is useful to them. The classroom environment should encourage questions and interaction and students should be allowed time to work together to help shift some of the responsibility for learning away from the teacher to the student. Assessment should be aligned with instructional goals and results of those assessments should be used in future planning.
The next standard helps to promote the importance of each teacher continuing to
develop as a teacher of mathematics (NCTM, 1991). The identity of the individual as a
teacher develops over time and is built by the many experiences the teacher has with
students and colleagues, and with their own learning. It is important that teachers are
given the opportunities to observe and analyze a variety of approaches to teaching
mathematics. Allowing them to focus on things such as classroom environment, tasks
used for learning, class discourse, and assessment methods helps teachers to examine,
and possibly change, assumptions they may have about the best way to teach math. It is
important that teachers are given the opportunities to work in a variety of settings with a
diverse group of students; working with individuals, as well as large and small groups of
students. Another important way to enhance teaching is by giving opportunities to math
teachers to interact with other math teachers. Discussions with colleagues and
supervisors are an effective way to improve and enhance teaching.

The sixth Professional Development Standard determined by the NCTM (1991) is that
teachers should be active in their own professional development in a variety of ways.
Teachers should be at the forefront of the change in mathematics education and be
responsible for improving instruction. This requires teachers to be familiar with and
discuss issues in math and in teaching math with colleagues and supervisors.
Participating in workshops and taking courses is important, but also necessary is
reflecting on what is learned at the workshops. It is only through this reflection that it
then becomes possible for the teacher to use new approaches and strategies in the
classroom. Mathematics teachers must get involved in professional organizations that are
specific to math. It is also important that they become involved in planning district wide curriculum and professional development specific to math.

Conclusions and Recommendations

The need for a change in the way that we teach math is evident. We have many students that are not successful in our mathematics classrooms and that is not acceptable in this society. After reading the standards set by the NCTM, it seems only logical for us to incorporate those standards into our classrooms. In fact, our classrooms and math curricula should be designed with the standards as the focus. In order to do this, there will need to be a change in philosophy for many people, including math educators, administrators, parents, legislators, and even the students.

The redesigned classrooms should focus on a student’s understanding of numbers and how they work by using realistic problems. Computation is important, but should not be the main focus. Being able to use numbers and algorithms to solve problems should be emphasized. Problem solving should be integrated into all aspects of the mathematics classroom, not taught as a separate part of math. More focus should be placed on geometry and algebra in the middle grades.

Students should be encouraged to work with others and to communicate their ideas about math, both orally and in written form. The teacher should be sure to establish an environment that allows students to ask questions and, even, fail to get the correct answer. It is important that students know that there is more than one way to solve problems. Ultimately, students need to take charge of their own learning and develop the
mathematical power necessary to be successful in math, not only in school, but also in society.

Teachers are responsible for making the mathematics classroom one that will allow students to grow as mathematicians. Creating an environment of learning is important, as is choosing appropriate tasks and having the knowledge to answer any questions the students may have. Teachers should analyze their teaching to be certain that lessons are leading all students in gaining mathematical power. Another important part of the standards-based classroom is having the materials that are necessary, such as calculators, to best teach the content.

Professional development for teachers is the key to implementing a standards-based math curriculum into our schools. Teachers need training in how best to teach the skills that are recommended by the NCTM. Some teachers lack the background knowledge in math that is necessary to teach the skills at their level. In-services to teach mathematics may be something that school districts will need to consider, along with content specific work with teachers. Allowing time for teachers to collaborate with colleagues and to observe effective mathematics classrooms will be an important part of how districts could best implement a standards-based math curriculum. Most teachers are willing to put in the time that is necessary to help students become the best students that they can be and to reach a deeper understanding of math so that they can, ultimately use it in the real world.
References


