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Manipulatives: Are they necessary for middle level learners?

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Manipulatives: Are they necessary for middle level learners?

Abstract
Educational leaders continually search for ways to improve the quality of learning for that special group of students we call middle level. Middle schools have worked to establish a unique program for making the transition from elementary to high school for young adolescents between the ages of ten and fifteen. Students at this age often make firm decisions about how and whether to continue their study of mathematics. Nowhere is the teaching of mathematics more challenging than during these years of transition (Leitzel, 1991 ).

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MANIPULATIVES:
Are They Necessary for
Middle Level Learners?

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Submitted to the
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MANIPULATIVES: ARE THEY NECESSARY FOR MIDDLE LEVEL LEARNERS?

Introduction

Educational leaders continually search for ways to improve the quality of learning for that special group of students we call middle level. Middle schools have worked to establish a unique program for making the transition from elementary to high school for young adolescents between the ages of ten and fifteen. Students at this age often make firm decisions about how and whether to continue their study of mathematics. Nowhere is the teaching of mathematics more challenging than during these years of transition (Leitzel, 1991).

Middle level instructors have a history of being the stepping stone for the high school experience. Many perceive the task of the middle school to be one of preparation for high school. Teachers at this level need to know how the mathematics they teach follows from elementary school mathematics and how it leads to the secondary curriculum. They need a breadth and
depth of experiences which go considerably beyond the 
preparation of elementary teachers but which are quite 
different from that expected for teachers at the secondary level 
(Leitzel, 1991). Middle level teachers have often received 
criticism for gaps which have occurred in the students' 
mathematical learning (NCTM 1982).

Piaget (cited in Smith 1981) tells us that children develop 
intellectually in four stages; the sensorimotor, the 
preoperational, the concrete operational, and the formal 
operational. Students commonly found in the middle schools 
are in the second, third, and fourth stages of learning. 
Mathematics classes during these middle school years are 
traditionally large-group oriented with explanations and 
occasional demonstrations provided by the teachers. Students 
are then expected to apply the lesson through completion of 
pencil and paper assignments. Could there be other options 
which will provide a bridge between the various stages of 
leaning? One possibility is the use of multiembodiments. 
"Multiembodiments" refers to the presentation of concepts in as 
many different ways as possible. Research suggests that the
use of different modes of representation will promote meaningful learning, retention, and transfer of mathematical concepts. There has been mixed research on the use of multiembodiments in math (Suydam & Higgins, 1977).

There appear to be some ambiguous feelings on the part of mathematics teachers regarding the need for manipulatives in the middle school years. A review of research by Suydam (1984a) suggests that the use of manipulatives will enhance the level of achievement in mathematics. This enhanced level of achievement was found in a variety of topics, grade levels, achievement levels, and ability levels of students. Manipulatives have, for sometime, been an integral part of lower elementary and supplemental programs for students with learning problems. However, the use of manipulatives in the middle school is sometimes neglected. Mathematics teachers tend to stop using manipulatives long before they should, which means that it has probably been years since any given middle school student has seen or used them. A common attitude of both teachers and students in the seventh and eighth grades is that these students have outgrown the need
for any type of a manipulative to aid them in the solving or understanding of mathematics problems. Middle school students have been "taught" that concrete models are childish and unnecessary (Schultz, 1984).

Middle school teachers may also feel unsure about how to use manipulative materials in their classrooms. Many teachers have little or no training in the incorporation of manipulatives. Using manipulatives involves a set of teaching strategies which are often not modeled in teacher preparation (Schultz, 1984). We have fears that classroom control may need to be sacrificed and principals, parents, and colleagues may not see the benefits of manipulatives and manipulative activities.

Time is another possible drawback to the incorporation of manipulatives. A classtime of forty to sixty minutes is not always adequate to present a theory and allow students to explore with the use of manipulative materials. Students need time to explore algorithms with manipulatives in order to reason, hypothesize, formulate, verify, and perform the mathematical functions. Teachers are accountable for the learning which occurs in their classrooms and extended time
spent on activities and concrete experiences can decrease the number of mathematical concepts that can be reasonably be taught.

Purpose

The purpose of this study is to examine possible gaps associated with middle level mathematics and how the use of manipulatives throughout the middle school years may be a potential or partial solution for these gaps. The values and limitations of incorporating manipulatives as recommended by the National Council of Teachers of Mathematics Standards will also be examined.

What The NCTM Standards State

Documents from the National Council of Teachers of Mathematics tell us that there is a tremendous burden on middle level instructors. These pressures exist for all teachers, but the impact for middle grade mathematics teachers is different from that of any other level. The burden is different for teachers of middle grade mathematics because all too often expectations encompass remedial teaching of the arithmetic of
the elementary school along with readiness for the study of algebra for every student (NCTM, 1982).

Few teachers in the middle grades receive specific preparation and certification to teach in grades 5 through 8. Those with elementary preparation often have five semester hours of mathematics and those with secondary preparation have an undergraduate major or minor in mathematics but almost no training in methodology and content appropriate for middle level teaching. They are not prepared to handle the unique situations which middle schools present. Even though many states have introduced certification of endorsements for the middle-grade level, specialized mathematics experiences for teachers at this level are not common. The breadth of mathematical experiences needed by teachers of the middle grades is enormous, but the depth of study appropriate for them is not necessarily the same as that expected for mathematics majors (Leitzel, 1991).

The NCTM (1980) standards state:

to be an effective teacher of middle grade mathematics is to be an
individual responsive to a variety of mathematical requirements and pressures from both school and nonschool sectors of society. These influences include but are not limited to--

* the preservation of mathematics as an important component of our scientific culture;

* the development of future consumers of mathematics, be these consumers, sociologists, tool and die makers, physicists, linguists, marine engineers, insurance adjusters, or dieticians;

* the recognition and encouragement of mathematical talent, despite awesome variations in individual differences among the students;

* the development of users of elementary mathematical techniques, including the ability to express relationships in a
variety of ways, to compute numerically, to solve a broad range of problems, to reason abstractly, and to evaluate results. (p. 3)

Foundations of Learning Theory

Piaget (cited in Smith, 1981) reports that children evolve through four stages of learning. There is a gradual process from one stage to the other. The first stage is the sensorimotor which occurs from birth to approximately two years of age. Children in this stage learn through touching, seeing, hearing, and tasting things. The manipulation of objects is necessary to achieve understanding during this stage.

The second stage is the preoperational which occurs from two to seven years of age. Children in this stage begin using language as a form of symbolism. They use the spoken word instead of touching to learn and understand.

Sometimes around the age of seven, many children enter the concrete operations stage. Children in this stage are capable of making generalizations about what they know and have experienced. The concrete operational child is able to
perform operations with concrete experiences. Smith (1981) states, "They are still unable to perform mental operations such as reversibility and seriation in purely verbal terms. Such mental processes occur at the highest hierarchical level, the formal operations stage" (p. 25).

The formal operations stage begins to emerge sometime between the ages of eleven and twelve. A child in this stage can hypothesize and think on a purely abstract-verbal level. They are able to function completely in the world of formal logical thought. A formal operations child needs to explain and provide proof and reasons for what he does (Barta, 1977).

Every child must pass through these four stages of cognitive development. According to Barta (1977), "The stages are the result of successive equilibriums in the assimilating and accommodating processes and are dependent on the interaction between maturation and experience" (p. 15). There are many factors which affect the age at which each stage is achieved. Depending on the kinds of experiences and environment a child is raised in, the actual chronological age when he/she attains the formal operational level of cognitive
growth can differ by a number of years. "Studies have shown that children in limited experiential cultures and environments can be impeded from making this significant intellectual transition from concrete operational thinking to manipulative cognitive abilities characteristic of the formal operations stage" (Adler cited in Smith, 1981, p. 25). Children who have been identified as "underprivileged" probably have not begun the transition into formal operational thought by the age of eleven or twelve.

Children in grades 5-8, are approximately eleven through fourteen or fifteen years old and fall into preoperational, concrete operational, and formal operational stages of development depending on the schema in which they are operating. These years are transitional years not only in physical growth, but also in intellectual development. "One must not be misled to interpret Piaget's theory as implying that maturation of the nervous system is sufficient for the development of formal thought" (Lawson & Wollman, 1975, p. 2). Studies show that by the age of fifteen, approximately half of the students have use of the formal operations stage in some
processing. As a result, a few students in middle schools are functioning at the preoperational level, a few at the formal operational level, and a majority are in the concrete or transitional phase (Zimmerman, 1988). In fact, studies of university students indicate that only approximately half of college freshman have achieved the formal operations level of thinking.

Heddens (1986) divides this transition stage into two levels -- semiconcrete and semiabstract. The semiconcrete level is a representation of a real situation; pictures of real items are used rather than the items themselves. The semiabstract level involves a symbolic representation of concrete items, but the symbols or pictures do not look like the objects for which they stand. Tally marks might be used to represent the idea of automobiles, for example.

Some children have little difficulty assimilating new knowledge, while others need additional time to think. During this thinking time, teachers very often continue to present material, leaving the child still assimilating with an ever-widening gap. Some kind of provision must be made for
bridging this gap. It is, therefore, very possible that real understanding of some mathematical concepts demands formal operations. Couple this with the fact that the majority of middle school students have not fully attained the formal stage of development, and one might infer that there is little hope for effective teaching of many basic mathematical ideas in these grades (Juraschek, 1983). In spite of these discouraging observations, students have experienced success when provided with manipulative materials to substitute or represent symbols. "This belief that manipulative materials do indeed enhance the learning of mathematics has gained much validity from theories such as those suggested by Bruner, Diens, and Piaget" (Fennema, 1973, p. 350).

Teachers indicate that they believe manipulative materials should be used in mathematics instruction. However, this is not always the case. First-grade teachers report rather frequent use of manipulative materials. But teachers from grade 2 on indicate less and less use of materials (Suydam, 1984). It is almost a cliche to say that in order to learn, children must experience and be active. "Being active involves
investigating problem situations, posing possible solutions, looking for cause-effect relations, noting results of various actions, and being able to make generalizations" (Copeland, 1984, p. 19).

According to Zimmerman (1988), Reys has compared the learning theories purported by psychologists. He has compiled the following statements based on the theories of most of the learning psychologists.

1. Concept formation is the essence of learning mathematics.

2. Learning is based on experience.

3. Sensory learning is the foundation of all experience and thus the heart of learning.

4. Learning is a growth process and is developmental in nature.

5. Learning is characterized by distinct, developmental stages.
6. Learning is enhanced by motivation.

7. Learning proceeds from the concrete to the abstract.

8. Learning requires active participation by the learner.

9. Formulation of a mathematical abstraction is a long process.

(p. 552)

It is not being contended that manipulatives are the cure-all for bridging the gap between concrete and abstract thought. Research has shown that the sensible use of concrete materials is effective in teaching mathematics (Heddens, 1986). A teacher must guide children to develop skills in thinking. Fennema (1973) states that,

The use of materials does not automatically ensure that mathematics learning will follow. The most important reason for using manipulative materials in teaching is to make the abstract world of mathematics meaningful. This is done when such
materials are used to enhance the relationship between symbols and reality. However, children should at some point learn to operate efficiently and effectively with symbols that represent the abstract nature of mathematics. (p. 350)

In genuine learning the child regulates his own activities, decides what needs to be learned, sets his own pace, and selects certain kinds of activities (Barta, 1977). But is this always the case? A teacher must find the appropriate strategy which will lead her students to an understanding of the concept rather than "rote" learning which is quickly forgotten.

With the majority of middle level students in the transition stage between concrete and formal operations, it would seem most logical that a combination of introducing a concept and reinforcing it with concrete objects would be the best choice. Piaget saw the teacher as providing a learning situation that provoked the desired learning by the child (Hillger, 1988). This includes not only the use of concrete objects but the use of "how" and "why" questions and less emphasis on the "what"
questions. This questioning technique can help students bridge the gap between the concrete experiences provided to the abstract level of thinking required to verbalize the concept.

Teachers need to ask crucial questions that guide children to think through the mathematical concepts being studied. Questions asked by teachers can reveal new directions of thought, encourage children to continue their current line of thought, or provide clues that will stimulate thinking when progress has been temporarily blocked (Heddens, 1986). Teachers can become a catalyst stimulating their students to use thought-processing skills to internalize the formal thought based on concrete experiences.

Teachers have a responsibility to find the appropriate strategy which will lead their students to an understanding of the concept being taught. If the majority of students in the middle level grades are in the concrete or transitional phase, it would be most logical that concepts be introduced and/or reinforced with the use of concrete objects (Zimmerman, 1988).
Holden (1987) tells us of the special benefits of manipulative objects,

Manipulatives let students see and even touch the components of an abstract problem. This lets them form a mental picture of the problem they're working on. Manipulatives help students build a concrete language for talking about math concepts. Manipulatives encourage students to gain confidence in their ability to figure things out. (p.53)

Manipulative materials do not teach mathematics by themselves. It is the use by the teacher and the guidance of the students' use that determines effectiveness of manipulative materials (Holden, 1987).

Textbooks have continued to dominate the classroom not only in mathematics, but in other areas as well. The text has continued to influence the direction that most lessons take. Completion or near completion of textbooks has long been stressed by many educators and administrators. Teachers are
to expose their students to as many concepts as possible and hope that they "catch on" to some of them. It takes longer to teach a lesson using manipulatives, so teachers may be discouraged from using them. In addition, manipulatives must be prepared before the lesson adding to teacher preparation time (Zimmerman, 1988).

Many students and teachers are under the impression that manipulatives are only for primary grade students or low-ability students. Middle school students feel that they have definitely "outgrown" manipulatives (Schultz, 1984). Research done by Schultz (1985) shows that this is not so. Schultz (1985) found that when seventh grade students were provided with the opportunity to use manipulatives, after appropriate instruction in their use, students improved their test scores significantly. The largest improvements were found for average and above average students. Schultz also felt that the fact that the manipulatives were available but not required was of significant importance. By using the materials voluntarily, not because of any assignment to do so, students internalized their
use and did not think of them as some external thing forced on them.

Schultz's (1985) findings in a problem solving unit were as follows: the above average ability group showed the greatest improvement from 23% to 76.9%, the average group from 19.2% to 65.2%, and the below average group from 2.7% to 37.5% correct of the problems covered. She found while observing the students that there was an inclination toward certain types of models over others. Concrete models were used 77% of the time, pictorial models, 43.7%, and time symbolic models 21.8% of the time. The more concrete the model, the more it was used. Students had the greatest problem-solving success (61.1%) when concrete models were used. This study reiterates what Shores and Underhill (1977) found when first grade students were provided with manipulative materials to help with the solving of addition and/or subtraction problems. They found students who were provided with instruction and opportunity to use manipulative materials scored significantly higher on posttests than the
control group which received only traditional instruction and no manipulatives.

Schultz (1985) further observed that "some students felt manipulatives provided them with confidence to do problems." This increased confidence helped motivate students toward learning mathematics. The ability to figure things out on their own can increase student self-esteem. When questioned about the use of manipulative materials, students responded with a variety of both positive and negative comments. Some felt the materials were helpful while others felt that it was just easier to use pencil and paper. The latter attitude and others similar to it are difficult to overcome. If the study accomplished anything, it caused many of the students with this "hard line" attitude to have a change of heart when it came to actual practice (Schultz, 1985).

The Teacher's Role When Manipulatives Are Used

Middle level educators of mathematics have a responsibility to meet the needs of their students. Concepts should be developed through the use of concrete objects. These concrete experiences will provide the students in either the
concrete or transition stages of cognitive development with a base upon which abstract learning can be built. Manipulatives are tools which help to provide this necessary base. The manipulation of objects in itself is a mindless act. Along with external manipulation, there must be an internal thought process. When teachers include concrete activities in their lessons, they must take care that the activity is fresh but not so new that students fail to build upon their existing knowledge (Holden, 1987).

In the middle school setting, a variety of manipulatives are available for use. For most adolescents learning about whole numbers, using a number line or base ten blocks would not be too abstract.

Fractions are an area where more caution is necessary. The relationship between the numerator and denominator is sometimes difficult for students. The use of cuisenaire rods, fraction bars, paper folding, rulers, and grid paper are beneficial even if they are only used for a brief period of time. Driscoll (1984) states that "this procedure leads the children through concrete manipulation of fractions to oral naming of
fractions, which, research indicates, should precede the symbolic representation of fractions" (p. 461). Berlin and White (1986) found that the use of computer-assisted instruction can lead to a higher level of mathematics achievement. This was the basis upon which Ball (1988) completed a study of the use of concrete materials and computer software to teach fractions. The computer-assisted learning was designed to help students make the transition from the concrete to the symbolic after concrete fraction bars had been used.

When teaching ratios and/or probability and statistics, the use of dice, cards, or spinners provides students with a concrete experience. They can play simple games and analyze the experience prior to completing paper and pencil seat work.

Geometry is more realistic for students when they are provided with rulers, protractors, and compasses. They can make polyhedron models to use with area and volume activities. Students can determine the volume of some regular solids through immersion. This method could be compared
with measuring the polyhedron and using a formula.

Geoboards are excellent for area and perimeter along with the Pythagorean theorem and learning about polygons. One should provide students with irregular polygons and have them use area formulas for rectangles, squares, and triangles to make determinations and comparisons (Zimmerman, 1988).

When manipulatives are used in a classroom, the role of the teacher changes. The teacher becomes a coach or facilitator in the learning process instead of the distributor of information. Some of the same techniques used in cooperative learning are applied in this setting. The teacher questions and guides rather than leads students. This can involve students separately or in small groups. This role change can be more demanding and difficult when compared to the traditional role of lecturing and demonstrating before a mentally passive group of students (Zimmerman, 1988).

Time has been a consideration when it comes to the use of manipulatives. Teachers have felt that using manipulatives uses more classtime than they can afford. It is true that extra time is spent in the beginning stages of developing a concept
when using manipulatives, but it has also been found that less
time is needed for reviewing and reteaching. The total amount
of time used for a topic ends up being approximately the same.
When students have a concrete experience upon which to
base their learning, that experience helps them to internalize
the concept. It is important to note that not all students need to
use manipulatives for the same amount of time. Extended use
may keep some students using procedures which are too
simple and inefficient for them. Teachers must keep each
individual student's development in mind at all times (Suydam,
1984).

Teachers must take great care when choosing manipulative
materials. They must know which materials are most
appropriate for each particular concept; this is difficult. The
task of the manipulative is to help make the lesson easier for
the students to understand. Because of this, teachers must
take into consideration the academic and maturity level of the
students. It is important for teachers to determine the amount
and type of manipulatives used by the students in earlier
grades. If a manipulative has been used before, it would be
advantageous to use a different aid so as to approach the lesson's objective from a new perspective. Keep in mind that what is important is the child's thinking rather than the actual manipulation of objects. Whatever manipulative aids you choose, they must accurately represent the concept. Teachers must use a great deal of guidance and appropriate questioning in order for the students to connect the manipulation with the operation (Hillger, 1988).

Implementation of Manipulatives

The National Council of Teachers of Mathematics (1973) listed the following recommendations for manipulatives. They recommended that manipulatives be

1. relevant to the mathematical content with a desired outcome in mind,

2. multi-sensory,

3. durable,

4. constructed so that the details are accurate,
5. made with high standards of workmanship,
6. attractive in appearance,
7. easily maintained,
8. simple to assemble,
9. flexible and have a variety of uses,
10. simple to operate,
11. large enough to be seen by students,
12. something that has moving parts or can be moved. (p. 303)

The NCTM (1973) also listed some guidelines for the use of manipulatives,

1. Choose a device that best suits the purpose of the lesson.
2. Become familiar with the device before using it.
3. Correlate the operations depicted by the manipulative and those done with paper and pencil.
4. Provide each student with manipulatives, if possible.

5. Encourage rather than force use.

6. Create opportunities for each child to become less dependent on symbolism and abstraction.

7. Allow a child to stop using a manipulative when they are ready for higher, more abstract level of thinking, so the manipulative does not become a crutch. (p. 304)

It is important that teachers encourage their students to think while manipulating concrete objects. Williams and Kamii (1986) stated that there are three ways to encourage thinking while manipulating. First, try to use or create situations which have personal meaning to the children. Children think harder about things that matter to them. Secondly, provide them with opportunities to make decisions. It is not necessary for the teacher to decide everything. A third way to encourage children to think is to provide them with opportunities to
exchange ideas and personal views with their peers. This exchange can evolve into a "brain-storming" situation where all can benefit.

Summary

Research by developmental psychologists, such as Piaget, and by other educators have found that proper use of manipulatives can improve understanding of mathematics. Meaningful teaching is more likely to succeed than rote memorization. Middle level children, and those beyond, experience less frustration, internalize more mathematical knowledge, experience less failure, are more motivated, and have more positive attitudes toward mathematics when manipulatives are involved. For students to develop abstract mathematical concepts, they need to have experience with physical objects, to discuss that experience, to use and recognize pictures that represent that experience, and finally to use symbols to record that experience (Harrison & Harrison, 1986). Evidence shows that the majority of middle level students are either in the concrete operations stage or in transition between concrete and formal operations stages.
Because of this, the majority are not ready for the abstract process of using symbols. Even though the most common teaching method in middle schools is the lecture method, research shows that lessons using appropriate manipulatives have a greater opportunity for increasing mathematical achievement. Middle school students have not "outgrown" the use of manipulatives. Research has shown that when middle level students were given an opportunity to use manipulatives, their mathematical knowledge increased significantly, particularly for the average and above average students.

Teachers need to orchestrate the use of manipulatives very carefully. It may possibly necessitate learning new management techniques since students will be active rather than passive participants in the learning process. Careful planning and sequencing of activities which are developmentally appropriate is a must. Manipulative materials need to be available for students who still need them and want to use them.

The use of calculators and computers as a link between concrete and abstract levels of thought is becoming more vital.
The increased use of calculators by middle level students makes it less important to memorize algorithms and more important to have internalized the thought processes.

Manipulative activities have been shown to be motivational when used appropriately to stimulate students' mathematical thinking ability. The effectiveness of manipulative materials is most noticeable when they have long-term use. Sowell (1989) found that "treatments of a school year or more gave positive effects of moderate to large size in elementary grade studies" (p. 504).

The teaching methods used in middle level math classrooms should reflect the developmental stages of their students. Textbooks and workbooks need to be replaced with a broader multi-sensory approach to learning which caters to the intellectual needs of all students in the middle and junior high schools. It is vital that we do all that is possible to help every student reach his or her full mathematical potential.
REFERENCE LIST


American Educational Research Association, New Orleans, LA.


