The Effects of Mathematics Manipulatives on Middle Childhood Students

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Introduction

Using manipulatives is often beneficial for students at any age, grade level, or learning level. However, if not planned for and created with purpose, lessons with manipulatives often have little or no meaning to the intent of the lesson. Manipulatives cannot serve as the lesson, but, rather, as part of a lesson to help students gain a deeper understanding of the topic at hand. Manipulatives can be used as a tool to enhance learning, but not be the sole form of learning. This study looks at the use of manipulatives in a 5th grade classroom with two separate classes. Two different non-traditional manipulatives were used: M&M’s and playing cards.

Literature Review

Mathematics classrooms often use hands-on learning, or manipulatives, to enhance student learning. Especially in elementary school, students are accustomed to learning with these hands-on materials. “As [they] go up in grade, fewer and fewer manipulatives are used in math education,” (Stewart 2002, para. 5) although they are beneficial at all grade levels. As students progress in school into middle and high school, less and less hands-on learning seems to be utilized and students are often expected to gain understanding solely on abstract principles.

Using manipulatives in mathematics classrooms sometimes has been viewed as the only way to teach mathematics for a deep understanding (Stein 2001, pg. 359). Manipulatives are an important and necessary piece of the mathematics puzzle. It is important to define what is meant by manipulatives. One definition is “an object that can be handled by an individual in a sensory manner during which conscious and unconscious mathematical thinking will be fostered” (Swan & Marshall, 2010, pg. 14). Students need concrete examples at any age or grade level to explore and gain a deeper understanding of mathematics knowledge.
According to Piaget’s Stages of Cognitive Development, children need concrete examples. Piaget discussed four stages of development which he termed Sensorimotor, Preoperational, Concrete Operational, and Formal Operational. The Concrete Operational stage is from 7 to 11 years and “abstract thinking is not possible” (Slavin 2006, pg. 34). In the Formal Operational stage which is from 11 years old to adulthood, “abstract and purely symbolic thinking [is] possible” (Slavin 2006, pg. 34). Piaget believed that children cannot learn abstractly until at least age 11. For some students, he believed this process would take more time. Manipulatives can provide the concrete learning that many students need; however, manipulatives often are not used long enough in a student’s schooling to gain the full advantage from the concrete examples.

The use of manipulatives presents some challenges. One challenge can be that educators attempt to use manipulatives as a lesson in and of themselves. Manipulatives, rather, should be used as part of a lesson because, “simply using manipulatives, does not guarantee a good mathematics lesson” (Stein, Bovalino, & Smith, 2001). It is beneficial for teachers to create a lesson that includes manipulatives rather than using the manipulatives as the entire lesson in order for the manipulatives to help student understanding the concepts rather than hinder it. Another challenge is the teacher’s content knowledge of mathematics. The teacher must understand the concepts in order to help build student understanding. A focus must be placed on teacher understanding of mathematical knowledge, the manipulatives, and the use of manipulatives in relation to content in the classroom. Teachers need to have formal instruction on the use of manipulatives through their pre-service programs or through professional development. “A deep understanding of mathematics is essential for enabling teachers to provide
quality educational experiences for their students” (Puchner, Taylor, O’Donnell, & Fick, 2008, pg 314) which can be gained through professional development, programs, or other courses.

Another challenge is preparing for lessons that use manipulatives; organization is crucial for manipulative use. One suggestion for organization of manipulatives is “classroom kits, rotated or shared materials, and materials to be kept in a storeroom” (Swan et. al, 2010, pg. 16). This means having some manipulatives in each classroom at all times, some that are able to rotate every few weeks that are not used as often, and some materials that are rarely used can be kept in a storage closet or another storage area. This is a challenge because there are so many different manipulatives and it is important to keep them organized and ready at a moment’s notice. Classroom kits consisting of frequently used manipulatives should be well organized and have enough manipulatives for each student or groups of students. Manipulatives can be costly to purchase and timely to create, although many teachers become creative in their ways to adapt from the costly store-bought manipulatives. Preparation and understanding of the lesson are essential to successful mathematics lessons. This means trying the lesson with the manipulatives before using it and anticipating problems or issues that the students may run into with the lesson.

Using manipulatives can be beneficial if properly prepared ahead of time. Often, it makes sense to use manipulatives before formal instruction of processes so students have time to explore and gain understanding. This allows students to grasp a concept before learning algorithms or steps in a more traditional manner. “Manipulatives are a much more useful tool for testing out ideas that are slowly emerging within the student rather than understanding a concept after a procedure has been taught,” (Puchner et. al, 2008, pg. 321) because if the student already knows what he or she is doing, the usefulness of concrete examples becomes obsolete. Using manipulatives calls for teacher preparation, including creating lessons based on the needs of the
classroom and students. This is not to say that other lessons cannot be borrowed or used, but teachers should understand the lesson and how it is to be used, and then make adaptations for his or her students. Manipulatives may not always be traditional mathematics manipulatives, such as Pattern Blocks, Unifix Cubes, Base Ten Blocks, etc. (See Appendix A). Creating, developing, or using other materials as manipulatives are often a creative alternative that can be just as beneficial to student learning (See Appendix B). In Stewart’s (2003) article, one teacher used tangerines to teach fractions and straws to build polygons. Teachers must be creative because there are not always manipulatives currently available for a topic for which the teacher feels students need a concrete example.

Manipulatives do not always have to be traditional necessarily. A multiplication chart can be used as a manipulative. In an education course at Clemson University in South Carolina, a professor used a multiplication chart as a manipulative. Pre-service teachers put together the multiplication chart out of pre-cut strips and viewed patterns and other uses for the multiplication chart. This chart also served as a “perfect visual … to see square numbers of the form n^2” (Matteson, 2011, pg. 563). A multiplication chart could be created at the beginning of the year and used throughout the year in a middle childhood classroom; many different concepts can be visualized from this one simple chart. This is also a manipulative that can be made by a teacher or student, rather than ordered from a catalog or other outlet.

The use of manipulatives also can be beneficial for students with special needs, especially learning disabilities in the area of mathematics. It is vital that students understand “math is an integral part of everyday life” (Cass, Cates, Smith, & Jackson, 2003, pg. 112) and not only problems in a textbook. Using manipulatives can be beneficial especially for students with individualized education plans (IEP’s) because it can allow students to make connections
between hands-on learning and paper and pencil computations. It is especially important for students with learning disabilities to make connections to real-life problems in order to understand how it will affect their lives. Mathematics is a pivotal part of everyday life; some examples include managing money by balancing a checkbook, comparing costs, and paying for necessities. To connect “mean” to real life, a teacher could talk about averages, such as gas mileage with older students or batting averages in baseball. The instruction used with manipulatives in these cases must be structured as well, following a plan, and sometimes more individual attention is necessary.

Using manipulatives is often beneficial for students at any age, grade level, or learning level. However, if not planned for and created with purpose, lessons with manipulatives often have little or no meaning to the intent of the lesson. Manipulatives cannot serve as the lesson, but, rather, as part of a lesson to help students gain a deeper understanding of the topic at hand. Manipulatives can be used as a tool to enhance learning, but not be the sole form of learning.

**Materials & Methods**

This study was performed on two mathematics classes of fifth grade students in a suburban middle school in Central Ohio. This middle school ranges from 5th to 6th grade, with a total of about 400 students. The first class observed had 21 students and the second class had 24 students. The students were mostly from middle-class socioeconomic households. Six students in the two observed classes had IEP’s for learning disabilities in mathematics. Besides myself (the researcher), others in the classroom included the 5th grade general education mathematics teacher and the intervention specialist. The class times were observed in October of 2011 from 9am – 1pm. Each class was roughly two hours, for a total of four hours spent in the classroom.
To study the effects of manipulative use with mathematics in a middle school classroom, a lesson based on mean, median, and mode was observed. Each student received one-fourth of a cup of M&M’s after the instructions were explained. The 5th grade students were in groups of three to four and had to count the number of each color of M&M’s in one-fourth of a cup. The students had to find the mean, median, and mode based on the entire groups data for each color. The students filled in a chart to assist them (See Figure 1).

<table>
<thead>
<tr>
<th>Name of Student</th>
<th># of yellow M&amp;M’s</th>
<th># of orange M&amp;M’s</th>
<th># of red M&amp;M’s</th>
<th># of blue M&amp;M’s</th>
<th># of brown M&amp;M’s</th>
<th># of green M&amp;M’s</th>
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*Figure 1.* “This sure is a *mean* bag of M&M’s” activity chart.

As students completed the M&M’s activity, they started another activity for mean, median, and mode. In partners, this activity used decks of playing card in which the face cards had been removed. Each player received seven cards. The players both put their cards in order from least to greatest (See figure 2). For the mean game, each player added up their cards and divided by seven (the total number of cards). The player with the highest number for mean got that number of points. For example, if player one’s mean was 8 and player two’s mean was 10, player two would get 10 points. The first player to 21 points was the winner. This value could be changed based on the needs of the grade level.
Figure 2. On the left, a group of four students plays the mean card game. On the right, students set up their cards for the median game.

For the median game, using the same deck of cards, each player got seven cards and put them in order from least to greatest. The middle card is the median and the player with the highest value median got that value of points. To find the median, students flipped over three cards on the left and three cards on the right, leaving one card flipped upright which represented the median. The mode game used the same deck of cards and each player received seven cards. The players put the cards in order from least to greatest. The player figured out the mode or modes in his or her set of cards. The player with the highest value mode got that number of points. If the player had two modes, for example two 7’s and two 4’s, the player got 11 points.

After the activities were completed, the following day, students took mean, median, and mode notes (See figure 3) and did some practice problems while taking notes. After the student took notes, students did practice problems on mean, median and mode, putting the use of the manipulatives to practice by applying them to more traditional problems on paper (See figure 4).
NOTES ON MEAN, MEDIAN, MODE, AND RANGE

The mean is the sum of all the numbers from a given set of numbers divided by the number of data entries used. A synonym for mean is average.

<table>
<thead>
<tr>
<th>Shoe Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>Harry</td>
</tr>
<tr>
<td>Clay</td>
</tr>
<tr>
<td>Melanie</td>
</tr>
<tr>
<td>Rich</td>
</tr>
</tbody>
</table>

The average shoe size is 9.

The median is the middle number of a given set of numbers when the numbers are arranged in order.

**YOU MUST ALWAYS PUT THE #S FROM LEAST TO GREATEST BEFORE DETERMINING THE MEDIAN (MIDDLE NUMBER)**

Example: 6, 15, 3, 7, 15, 2, 1

1, 2, 3, 6, 7, 15, 15

6 (15) is the median, because it is the number directly in the middle. There are the same amount of numbers on each side of 15, and there are three numbers to the left.

What is the first thing that you must do before determining the median?

Figure 3. The notes that students took on mean, median, and mode.
Figure 4. Sample traditional practice problems from worksheets that students completed.

At the end of class on the second day, students filled out a survey answering which way they liked learning about mean, median and mode the best, why, and were asked to explain if they understood mean, median, and mode (See Figure 5). The students filled out this survey at the end of the second day so they could explain if they learned more about mean, median, and mode from traditional learning or hands-on learning.
Figure 5. The first survey students filled out at the end of the second day.

A month later, students filled out another survey where they explained what mean, median, and mode were and how to find each one. A question at the bottom asked the students to state how they remembered these terms and what each one meant (See Figure 6). The students filled this survey out a month after learning about mean, median, and mode to allow enough time to see what students remembered after learning about different mathematics topics as well. In doing this, I gained a true representation of what the students remembered.

Figure 6. The second survey students filled out after a month had passed.
The use of two different manipulatives, playing cards and M&M’s, were used in the observed lesson for two different groups of fifth grade students. Both of the manipulatives used allowed students the opportunity to discover and understand mean, median, and mode.

**Results**

During the observation of two different classes of 5th grade students working with manipulatives, M&Ms and playing cards, the students appeared to be engaged and actively working to find mean, median, and mode. While observing, students were making comments such as, “This is a fun way to learn,” and “This is better than doing a worksheet.” It was interesting to see how students used the M&M’s to find mean, median, and mode. The use of manipulatives seemed to give students the freedom to explore and make sense of a topic in their own ways. Students grouped the M&M’s differently and used different methods to get their personal answers for how many of each color M&Ms they received (See figure 7). Three different representations are shown as to how students grouped their M&Ms. Most students put them into rows, made a design, or just made little piles of each color.

**Figure 7.** These pictures show three different representations of grouping the M&Ms to count the different colors.
After the M&Ms activity was complete, students transitioned to the playing card activities. This gave students a different way to think about mean, median, and mode. Some students used calculators to figure out their answer for mean, others calculated in their heads if the numbers on the cards were low. The card activities gave students a different use of manipulatives that was more methodical, but still allowed for hands-on learning and competition between classmates.

The day after I observed the students, the 5th grade teacher went over notes on mean, median, and mode with the students (See figure 3 above). Then, the students practiced finding mean, median, and mode more traditionally before filling out the first survey. By traditional, I am referring to the teacher being in the center of the classroom, providing information to the students through lecture and example. To teach mean traditionally, for example, a teacher might be at the front of the classroom and have a set of numbers on the board and teach students how to add the numbers together and divide by the number in the data set to find the mean, or average, of the data.

Out of 21 surveys returned from the day after the activities, the surveys received from one class were used to calculate in the manner which students felt they best learned about mean, median, and mode. Eight students said they learned best by the M&M’s activity, two said they learned best by the card activities, and seven said they learned best from both of the activities. The remaining four students did not answer how they learned best or said they learned best from notes and practice problems (See figure 8). The total number of students who preferred learning by use of manipulatives was 17 students, or a total of 81%. The other 19% (4 students) preferred using notes or did not specifically say how they preferred learning about mean, median, and mode.
After roughly a month had passed, another survey was handed out and answered by the students. This survey was similar to the first survey. Students were asked to state how they remembered what mean, median, and mode are, after being asked to define and explain how to find each of the previously stated terms. A total of 45 surveys were obtained from all of the students that were present on the days that mean, median, and mode had been taught and discussed. Out of the second set of surveys, 16 students said they remembered mean, median, and mode from the M&M’s activity, 5 remembered from the card activities, and 7 remembered from both of the activities. Out of the other 17 surveys, four said they remembered mean, median, and mode in a different way (notes, previous years, other activities, etc.) and 13 did not answer how they remembered or just restated how to find mean, median, and mode (See figure 9). A total of 28 students, out of 45, remembered mean, median, and mode from the use of the two manipulatives, M&M’s and playing cards, used in their 5th grade class. The remaining 17 students remembered mean, median, and mode from previous years, a different method, or did not remember mean, median, and mode. This calculates to 63% of students remembering mean, median, and mode from manipulative use and 37% of students remembered mean, median, and mode from a source other than manipulatives.
Immediately after using manipulatives, a majority, 81%, of the students said they best learned mean, median, and mode by using the manipulatives. Encouragingly, a month later, over half of the students, 63%, remembered mean, median, and mode from working with manipulatives (See figure 10).

<table>
<thead>
<tr>
<th></th>
<th>Manipulatives</th>
<th>No Manipulatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey #1</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Survey #2</td>
<td>63%</td>
<td>37%</td>
</tr>
</tbody>
</table>

**Figure 10.** This table shows the breakdown of student surveys where students said they found manipulatives helpful in learning mean, median, and mode or if they did not find manipulatives helpful.

From the first set of surveys, students had various reasons for the way they felt they learned best. A student who said she learned best from the M&M’s activity said, “I usually learn better by doing hands-on projects/lessons.” Another student said he liked the M&M’s activity because, “I like to work in groups to figure things out.” One student did specifically state, “I liked the activities, but I learned more from the notes and practice [problems].” By giving students a survey to fill out, they were able to answer honestly and this showed me how they felt about the use of manipulatives.

From the second set of surveys, when asked how they remembered what the terms mean, median, and mode meant, one student said, “I remember by using the M&M’s by putting them into groups.” Another student stated that she remembered from “doing fun activities with M&M’s and playing cards.” One student said he remembered because he had been learning about mean, median, and mode for “a long time, this year and last year.” Students had various ways of remembering mean, median, and mode, but many students referenced the activities I had observed since it was fresh in their minds from this school year, rather than previous years.
Discussion

Many studies have been done researching the effectiveness of manipulatives in classrooms, with an emphasis in early childhood classrooms. This study added to that research by looking at the effectiveness of the use of manipulatives in middle childhood classrooms.

During this study, I observed that in two classes of 5th grade students, over time a majority (63%) of the students recalled learning mean, median, and mode from the use of manipulatives. Immediately after the lesson was completed over the course of two days, 81% of students felt they learned best from using the manipulatives. One month after the lesson was completed, 63% of students remembered learning about mean, median, and mode from the use of manipulatives including M&M’s and playing cards.

When I originally planned this study, I asked the general education teacher if she would teach the lesson a different way for each class. One class would have been taught in a traditional way with the mean, median, and mode notes followed by practicing with sets of numbers and worksheets (see figures 3 and 4) and the other class would have been taught using the two manipulatives activities, with M&M’s and playing cards. The classroom teacher said she did not feel comfortable teaching one class without manipulatives because she felt that it would hinder student learning. This just showed me how strongly she felt about the use of manipulatives and how it benefits her students.

If I were to perform this study again, I would make sure all surveys were turned in from all of the students, rather than just one class, who participated in the study, the first set and the second set. I believe that this would have given me results closer to the actual values. As more data would have been gained, the results would have become more distinct. Another way I would
have changed my study would be to omit any surveys that did not answer the question, rather than leaving them in my data set.

Another change I would make to this study if I were to perform it again would be to have the students complete a pretest. This would allow me to see what students remembered from previous years about mean, median, and mode. This information would allow me to see the growth the students made after this specific lesson with manipulatives as well.

To get an even better idea of the effectiveness of the use of manipulatives in this classroom, I would observe these two classes using manipulatives for more than one lesson. Then, I would have done one survey at the end of all of the lessons and the questions would have asked the students how they remembered learning each topic. For example, how did you remember learning about mean, median, and mode; how did you remember learning about the value of pi; how did you remember learning about fractions and decimals; etc. This way, I would be able to assess if each student remembered most of the topics from more traditional teaching methods or the use of manipulatives.

Another way I could expand this study would be to observe the use of manipulatives in classrooms spanning the whole middle childhood licensure area, 4th through 9th grades. I assume the results would be similar to my study, and students would remember learning through the use of manipulatives more often than using only traditional methods of learning.

The use of manipulatives can be beneficial as part of a lesson. Planning and preparation are critical to lessons that use manipulatives effectively. It is beneficial for teachers to plan or create their own lessons that incorporate manipulatives that best serve the needs of their students. Nevertheless, if a teacher borrows a lesson with the use of manipulatives, the teacher can adapt
the lesson to the needs of his or her students. This means trying the lesson ahead of time to predict problems students may face. Preparation for lessons with manipulatives also assists in creating a cohesive lesson. Preparation includes having materials ready and accessible, creating directions that students can follow, and allowing enough time during the lesson for the manipulatives to be used and explored.

While using manipulatives may seem difficult or time consuming, the use of these tools is often beneficial for students. Manipulatives, at any grade level, offer valuable learning experiences, help students construct their own mathematical knowledge, and promote the use of inquiry-based teaching and learning.
Appendix A- Examples of traditional manipulatives.

Pattern blocks

Unifix cubes

Base ten blocks

Two-sided counters
Fraction circles

Geoboards

Dice

Pictures of traditional manipulatives retrieved from Google.
Appendix B - Examples of non-traditional manipulatives.

M&M’s

Playing cards

Hershey bars
Oranges

White boards and dry erase markers

Buttons
Paper clips

Pictures of non-traditional manipulatives retrieved from Google.
References


