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The Effect of Manipulative Materials on Mathematics Achievement of First Grade Students

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Abstract: This study investigated the effect of manipulative materials on the achievement of first grade students in mathematics. The data of scores obtained from students in the pretest and posttest were crunched and analyzed with the aid of Statistical Packages for the Social Sciences (SPSS) program. Using a pre-test post-test single group design and the t-test for dependent samples for analysis, it was found that students (n=18) achieved significantly higher scores on the end- of- unit test administered by the researchers, with $t(17) = 4.310$, $p < .001$. It was concluded that the instruction that incorporates manipulative materials in the form of money (magnetic coins) aided the achievement of students. Implications for teaching were discussed.

Key words: Mathematics education; Achievement in mathematics; Manipulative materials; Mathematics teaching

Introduction

Mathematics has historically been a subject that many students struggle with and increasingly dislike as they progress through the grades. In her book, *The Subject Matters*, Stodolsky (1988) reported that "on average, students like mathematics and science in the elementary grades, but they dislike both subjects more in junior high and high school." She also stated that of all subjects mathematics is the least liked subject. The focus then should be on how teachers can change this perception and bring some acceptance to the subject of mathematics. Teachers should always try to find ways to actively engage their students not only for understanding concepts but also to create elements of fun and excitement so that students interest can be kindled. Using manipulative materials has become one way of involving students in fun learning that encourages motivation of students. Manipulatives have also been useful in making abstract ideas concrete for learners and thereby making for conceptual understanding.

Problem Statement

There is a general phobia associated with learning mathematics (Ojose, 2009). It will be an understatement to say that even adults dread mathematics too. To put it in perspective, much of the problem of loathing mathematics will not be too pronounced if students, from the onset are provided with the necessary tools that make the concepts in mathematics less abstract. That is the inherent issue here: if students are exposed to manipulative materials to help them better connect to mathematics, chances are we will have a less-phobic mathematics consumers. Adults and children alike would then profess how much they enjoy mathematics and that attitude will have chain positive effect from one generation to another.

Another issue is that of performance of students in mathematics, especially as it relate to high stakes tests. It should be highlighted that the students may not perform well in the tests for various reasons. One of such reason is the likelihood that they never learn the material to the level of conceptual understanding. Thus the lack of understanding manifests in low performance. For example, studies by the National Assessment of educational Progress (NAEP) and the Third International Mathematics and Science Study (TIMSS) have documented poor student performances. The premise of this study is that if teachers can make instruction meaningful for students by exposing them to hands-on manipulative materials, students will learn the material well enough and have conceptual understanding. This will then result in better performance and achievement in mathematics. According to Ojose (2008), exposing students to hands-on materials will lead to conceptual understanding and therefore enhance cognitive development of children.

Review of Related Literature

The use of manupulatives in teaching mathematics has become almost commonplace as the use of textbooks. And with good reasons, as both Sowell (1989) and Ruzic & O'Connell (2001) found that the long –term use of manipulatives has a positive effect on student achievement by allowing students to use concrete objects to observe, model, and internalize abstract concepts. Manupulatives not only allow student to construct their own cognitive models for abstract mathematical ideas and processes, it also provides a common language with which to communicate these models to the teacher and other students. In addition to the ability of manipulatives to aid directly in the cognitive process, manipulatives have additional advantage of engaging students and increasing both interest in and enjoyment of mathematics. And, long-term interest in mathematics translates to increased mathematical ability. (Sutton & Krueger, 2002)

Moyer & Jones (2004) stated that "manipulatives are designed to represent explicitly and concretely abstract mathematical ideas," that are often hard for students to understand. As a result they can become valid resources to use in the classroom when teaching complex ideas to a class. Research studies have also shown that in lessons whereby manipulatives were used, "students appeared to be interested, active, and involved" in their learning, seeing math as a fun activity (e.g., Moyer, 2002). It is interesting now to see the changes in perspective regarding the subject with students who are given the opportunity to use manipulatives in their classrooms. The lessons become interactive, engaging, and student driven. Some researchers had even reported students becoming more independent when they were given the opportunity, or choice, to use manipulatives provided for them by their teacher (e.g., Moyer & Jones, 2004). They also pointed out that "Overall, having the tools available for them to use brought about a greater understanding of the concepts and allowed the students to devise their own solution strategies, promote autonomous thinking, and create confidence in learning math."

As a result of empirical and anecdotal evidence that shows higher student achievement when manipulatives are used, districts throughout the country encourages their teachers to attend workshops that acquaints them with how to properly use manipulatives as instructional tools. Also, the production of manipualtives with technological interaction has started. These kinds of manipulatives allow students to directly interact with a computer that reinforces the same concepts being taught in class, allowing for accommodations and differentiations for students at various levels of learning. Overall each individual is able to "work at their own pace" making it possible for students to correctly complete more tasks at their specific levels (Reimer & Moyer, 2005). As Drickey (2006) reported when doing a similar project on the effectiveness of manipulatives (both physical and technological), she found many students who said they enjoyed working with manipulatives and they made them "want to learn more."

Theoretical Framework

The study was guided by the learning theory based on the constructivist model. This learning theory indicates that mathematical understanding in young children is closely associated with sensory perception and concrete experience. Children begin to understand symbols and abstract concepts only after experiencing the ideas on a concrete level (Piaget, 1952). Manipulatives are effective tools in mathematics education by helping children move from a concrete to an abstract level of understanding. Students who see, touch, take part, and manipulate physical objects begin to develop clearer mental images and can represent abstract ideas more completely than those whose concrete experiences are limited (Heddens, 1986).

Children whose mathematical learning is firmly grounded in manipulative experiences will be more likely to bridge the gap between the world in which they live and the abstract world of mathematics (Dienes, 1960).

Also, constructivism advances the idea that the individual begins to develop understanding through personal experiences and personal connections. "The interlacing of content, context and understanding, the individual negotiation of meaning, and the construction of knowledge" are promoted in a learning environment that promote constructivism (Land & Hannafin, 2006). Furthermore, collaboration, real or virtual, which brings about new ways of conceiving concepts that might not be visualized by individual alone are considered integral (Abrami, 2001).

Hypothesis

Not every research finding on the use of manipulative materials has shown improvement in student performance. However, most of the findings have indicated that its use improved students' performance. Therefore, it is hypothesized that there will be a significantly higher students' achievement from the pretest to the posttest due to the usage of manipulative materials in teaching grade one standards of number sense. Put simply, the study was guided by the alternative hypothesis modeled by H_1: $M_{PO} > M_{PR}$, where M_{PO} is the mean of the posttest and the M_{PR} is the mean of the pretest.

Research Methods

Subjects/Participants

The participants for this study were 18 students enrolled in a first grade class at Victoria Elementary in the Redlands Unified School District. The students were selected based on the convenient sampling method because of their immediate availability. The age of the children ranges from 6 to 7. There were 6 boys and 12 girls. The students are diversified in abilities as well as cultural background, with most, however, coming from low-socioeconomic homes that receive aid from the community and school including free or reduced lunch. Six different languages are spoken within the classroom, with 9 students being categorized as English Language Learners.

Instrumentation

The data collection instrument for the study was the tests administered before and after instruction. The pretest and posttest were based on the number sense unit found in the Houghton Mifflin book adopted by the Redlands Unified School District. Content validity and reliability is good; items in the tests were selected from a large item bank provided by other teachers of mathematics and curriculum experts. On each of the pretest and posttest, there were 20 possible points based on skills as simple as counting coins to answering word problems. Some of the questions especially the ones involving problem solving required students to show their working. Scoring of both tests was done independently by the two researchers and an average of both scores per student was reported. This was done to ensure raters reliability of scores.

Experimental Design

The design used in this study was the single group pretest-posttest design. The 18 participants in the study made up the single group whose knowledge of number sense was determined over a 4 week time period. The pretest was given at the beginning of the unit to measure students' knowledge prior to instruction and the posttest was administered at the end of instruction.

Procedure

The study was carried out during the second half of the 2008-2009 school year. The lessons were based on the California Content Standards on number sense. The number sense standards included *1.4* (count and group object in ones and tens); *1.5* (identify and know the value of coins and show different combinations of coins that equal the same); and *5.1* (model and solve problems by representing, adding, and subtracting amounts of money). The students were given the pretest before beginning the unit that incorporates the above-mentioned standards. One of the researchers then taught the lessons using magnetic coins as the manipulative materials. In the teaching episodes, instructor/researcher generally modeled how the magnetic coins are used in solving math problems with examples. After the modeling phase, the students were given one practice problem and are provided with manipulatives to aid them in working the problem. If they show understanding of the concepts, they are then given independent work to do using the manipulatives. Students are given a standing instruction to only use manipulatives even if they are able solve problems analytically or with other methods. At some point in most of the lessons, the instructor/researcher would require class participation that involves various students going to the white board to solve problems using the magnet coins. On other occasions, table groups would be given a task to buy an imagined article and the student would figure out different combinations of coins that correspond with the cost of the article. For example, if the cost an article is 35 cents, student would be expected to list the different combinations of pennies, nickels, dimes, and quarter with which one can buy the article. In this example, students can form different combinations using the magnetic coins like: 3 dimes and 5 pennies; 1 dime and 1 quarter; 7 nickels, etc. As the unit progressed, students were asked to use the money manipulatives (magnetic coins) during their independent and group tasks to problem- solve like this one: *Lisa has 37 pennies. Fillipe has 2 dimes and 16 pennies. Who has more money?* In this example, students would use the magnetic coins to solve the problem and explain their solution the rest of the class. Each activity or lesson presentation done in the class was later reflected on by the instructor/researcher to determine if more review was necessary before moving forward. In all, 12 different lessons were taught in the 4-week period using the Houghton Mifflin book adopted by the school district. At the end of the 4^{th} week, the students were then given the posttest which had question similar to the ones below:

1. Add: $0.28C + $0.14C =
2. Subtract: $0.35C - $0.09C =
3. List all possible coin- combinations for 38 cents.
4. Tom has 2 dimes and 5 pennies. Emma has 1 dime and 18 pennies. Who has more money? Show your work.
5. There are 6 quarters, 4 dimes, 5 nickels, and 9 pennies. They are supposed to be put in piles of ten (coins). How many such piles can be formed by all these coins, and how many are left over?

The pretest and posttest were each graded on a scale of 20 points maximum. After administering the posttest, the researchers then compared achievement based on the teaching using manipulative materials.

Data Analysis

To measure the effectiveness of manipulative materials (independent variable) on student achievement, a t-test for dependent samples was used with the (Statistical Packages for the Social Sciences) SPSS program. The analysis showed significance difference in means of the pretest and the posttest. With the comparison of the pretest and posttest, the researchers were able to determine differences in achievement as a result of the independent variable.

Results

Table 1

Paired Samples Statistics

		N	M	SD	Std. Error Mean
Pair 1	Posttest	18	6.39	3.398	.801
	Pretest	18	3.61	3.202	.755

Table 2
Paired Samples Statistics

Pair 1 Posttest - Pretest	Paired Differences							
	M	SD	Std. Error Mean	95% confidence interval of the difference: lower	95% confidence interval of the difference: upper	t	df	Sig. (2-tailed)
	2.778	2.734	.645	1.418	4.138	4.310	17	.000

Following the administration of the end of the unit test (posttest), significant differences were found between the students' scores of the pretest and students' scores on the posttest. As indicated on Table 1, the mean score of the pretest was 3.61 with a standard deviation of 3.202, while the mean score of the posttest was 6.39 with a standard deviation of 3.398. There is difference in performance as exhibited by the mean of the pretest which was 3.61 and SD of 3.202 and the mean of the posttest which was 6.39 and SD of 3.398 statistically significant at $t(17) = 4.310$, $p < .001$. Therefore, the original hypothesis that "there will be a significantly higher achievement from pretest to posttest due to the use of manipulative materials in teaching grade one standards of number sense" was supported.

Effect Size

Using the Cohen's d formula for calculation, the effect size of the data was determined to be 0.84. It thus can be argued that the use of the manipulative materials (magnetic coins) for the first grade students produced a moderate effect on the achievement of the students in the end-of –unit test given by the researchers. This conclusion based on the effect size is quite conservative. Being a large number compared to the maximum of 1.00, it could also have been safe to infer that the effect is strong. Point here is that the effect size can be interpreted to be moderate or strong depending on the reader. This against the backdrop of issues associated with establishing cut-off points for effect sizes. According to Muijs (2006), one needs to be careful not to mechanically follow an established cut-off because they are arbitrary and adhering strictly to them could easily lead to erroneous conclusions.

Certainly, two factors that needed control could have affected the effect size. One is pretesting. The internal validity of the study may have been affected by the effect of pretesting. Students learned from the pretest given to them and that has the potential to affect the scores of the posttest. The other important factor that could have affected the effect size is the number of subjects in the study. The effect size could have been different if the number of participants in the study was large. These are issues that future researchers would want to address when replicating this study.

Major Findings

The following are the major findings associated with the study:

1. It was evident that students' knowledge of composing and decomposing numbers was greatly enhanced as a result of using the magnetic coins manipulatives.
2. Using the manipulative materials positively affected the achievement of students in the number sense standards.
3. Manipulative materials have effect on all students regardless of sexual orientation, socioeconomic status, academic level, and disability.

Discussion and Suggestions

The results of this study support the original hypothesis that using manipulatives as a tool in teaching mathematics will positively affect student achievement. The results of this study are consistent with previous work done in the area. For example, Fennema (1972) summarized research on the use of Cuisenaire rods to teach arithmetic compared to more traditional approaches. She found that research generally supported the use of manipulatives for first-graders, but that the value of the rods for second-and third-graders was less conclusive. Fennema concluded, "There is some indication that children learn better when learning environment includes a predominance of experiences with model suited to the children's level of cognitive development." Her recommendations were that teachers use manipulative to teach early grades and then gradually decrease their use as students are able to grasp concepts more symbolically.

Suydam and Higgins (1977) performed a meta-analysis of 40 research studies into the use and effectiveness of manipulatives on students' achievement in mathematics. 60% of the studies indicated that manipulative had positive effect on student learning; 30% showed no effect on achievement; and 10% showed significant differences favoring the use of more traditional (non-manipulative) instructional approaches. In similar work, Sowell (1989) performed meta-analysis of 60 additional research studies into the effectiveness of various types of manipulatives with kindergarten through post-secondary students. On the basis of this research, she concluded that achievement in mathematics could be increased through the long-term use of manipulatives.

Marsh and Cooke (1996) analyzed the effect of using manipulative (Cuisenaire rods) in teaching third-grade LD students to identify the correct operations to use when solving math word problems. After using the manipulatives, students showed statistically significant improvements in their ability to identify and use the correct operations to solve the problems. Also, in a study of 1,600 fourth-and fifth graders, Cramer, Post, & delMas (2002) compared the achievement of students using a commercial curriculum for learning fractions with the achievement of students exposed to specialized curriculum that placed great emphasis on the use of manipulatives. Students using the manipulative-based curriculum had statistically higher mean scores on posttests and retention tests.

Although the results of this study indicated that the use of manipulatives lead to higher student achievement, these results may not be generalized to a larger population for couple of reasons. First, participants used in the study were chosen for convenience rather than random selection from a large population. Secondly, and as indicated with the effect size, the number of participants was limited to 18, class size of one of the researchers. These are issues that future researchers attempting to embark on this study should endeavor to control.

Further studies are needed in at least four areas within the paradigm of manipulative material usage. One is that there is need to expand the research to other grades especially the upper elementary grades and the middle school grades. Second, there is the need to focus on the *how* of manipulative usage to gain insights into methods and practices that are replicable and can inform instruction. Third, it will be interesting to have control group(s) in the study so as to ensure stronger internal validity and compare such results to the finding of this study. And four, it is strongly suggested that future studies selects the subjects by means other than convenient sampling. Specifically, randomized samples should be used.

Implications to Teaching

The finding of this study, as with others, point to the need for teachers to recognize the importance and impact of hands-on activities and manipulatives for students in all grades. Overall, findings from this study have implications for teaching. First, the findings of the study suggest that instruction can have fun and enjoyment elements to it while students learn the material that is intended for them. Teachers can capitalize on the findings and embark on more hands-on experiences and activities that enhance conceptual understanding for their students. The study also underscores the importance of kinesthetic learning for those categories of students that cannot learn by visualization or analytically.

Also, the study suggests that all students can learn mathematics using manipulatives: general learners, special learner, gifted and talented, and English Language Learners. With the *Least Restrictive Environment* law in place, special education students are constantly being mainstreamed into general education classrooms. The use of manipulative materials enables the mathematics teacher to reach *all* students. Given the increasing number of students with disabilities currently being served in general education classrooms (Cawley et al., 2001), providing them with effective strategies to access the general education curriculum as mandated by the amendment to the Individuals with Disabilities Education Act (IDEA, 1997) is critical. Teaching with manipulatives, with its emphasis on conceptual understanding, facilitates higher order thinking and may be an effective and feasible option for teachers. It provides students with high academic content standards. This is particularly important given current legislation's emphasis on "scientifically-based instruction instructional programs and materials" (No Child Left Behind, 2002).

Conclusion

The importance of providing student with direct experiences with concrete material is supported by evidence from the classroom and an understanding of how learning takes place. While children can remember information taught through books and lectures, studies show that deep understanding and the ability to transfer and apply knowledge to new situations requires learning that is founded on direct, concrete experience. An important justification for hands-on learning, then, is that it allows students to build functional understanding and an ability to inquire themselves, in other words, to become independent learners and thinkers. It is also important to note that children cannot learn mathematics simply by manipulating physical objects. When using manipulatives, teachers should closely monitor students to help them discover and focus on the mathematical concepts involved and help them build bridges from concrete work to corresponding work with symbols. There is no single best way to teach math. However, research shows that using manipulatives in conjunction with other methods can deepen students' understanding of abstract concepts. Appropriate use of manipulatives should be one component of a comprehensive mathematics instruction.

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