Running head: COUNTING BLOCKS OR KEYBOARDS?

Counting Blocks or Keyboards? A Comparative Analysis of Concrete Versus Virtual Manipulatives in Elementary School Mathematics Concepts

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Table of Contents

Abstract

This study was designed to investigate the impact of using computer-simulated (virtual) manipulatives and hands-on (concrete) manipulatives on elementary students' learning skills and concepts in equivalent fractions. The researcher's primary interest was whether or not students who used virtual manipulatives would out-perform students who used concrete manipulatives on the researcher/teacher-generated posttest. A secondary interest for the researcher was students' attitudes about using manipulatives in the mathematics classroom.

The research sample consisted of 48 sixth-grade urban public school students. There were two treatment groups. Group A consisted of students who received equivalent fraction instruction with the use of virtual manipulatives. Group B, the control group, received equivalent fraction instruction with the use of concrete manipulatives. The researcher issued a pretest to both groups, prior to manipulative use and instruction. Following manipulative use and instruction, the researcher issued a posttest. The researcher also issued a students' attitudes survey at the end of the study.

To analyze the data generated by the pre and posttests, the researcher used a two-sample, paired-data t-test with a confidence level of 0.05. After studying the results of the t-test, the researcher concluded that students who received equivalent fraction instruction with concrete manipulatives out-performed students who received equivalent fraction instruction with virtual manipulatives. The researcher also concluded that the use of manipulatives, both virtual and concrete, enhanced the learning environment in the elementary mathematics classroom.

Chapter I: Overview of the Study

Description of the Study

A clear understanding of elementary mathematics concepts is imperative if children are to grasp higher-level thinking mathematics concepts in later grades. This being the case, it is essential that researchers and educators alike continue to explore the area of effective methods for teaching mathematics to children. While concrete manipulatives are believed to improve children's understanding of mathematics concepts (Bohan & Shawaker 1994; Burns, M. 1996; Fueyo & Bushell 1998), virtual manipulatives are also emerging as powerful instructional tools. In fact, some researchers argue that virtual manipulatives are more effective at teaching elementary mathematics concepts than concrete manipulatives (Clements & McMillan 1996; Reimer & Moyer 2005; Enderson 1997; and Taylor 2001). This study will set out to compare the effectiveness of concrete manipulatives and virtual manipulatives in teaching elementary school mathematics concepts.

Concrete Manipulatives

"Manipulatives may be physical objects (e.g., base ten blocks, algebra tiles, pattern blocks, etc.) that can be touched, turned, rearranged, and collected" (Taylor, 2001, p. 6). Furthermore, Taylor (2001) states, "Various types of manipulatives used for teaching and learning mathematics are presented as follows: tangrams, cuisenaire rods, geoboards, color tiles, pattern blocks, coins, color spinners, snap cubes, base ten blocks, dice, fraction strips, dominoes, clock dials, color counters and attribute blocks" (pp. 6-7).

McClung (1998) describes concrete manipulatives as "objects that appeal to several of the senses. They are objects that students are able to see, touch, handle, and move" (p. 2). He further states, “Manipulatives assist students in bridging the gap from their own concrete sensory environment to the more abstract levels of mathematics” (McClung, 1998, p. 2).

Fueyo and Bushell (1998) argue that the number line is also a concrete manipulative, and an effective one, when used properly. In fact, as a result of their study they state, “The step-by-step number line procedures provided the students with explicit demonstrations of how to use the number line, procedures that were missing from classroom instruction and from the classroom math text” (p. 10).

Virtual Manipulatives

“Virtual manipulatives are essentially replicas of physical manipulatives placed on the World Wide Web in the form of computer applets with additional advantageous features” (Reimer & Moyer, 2005, p. 6). These applets (Reimer & Moyer, 2005) can be downloaded, free of charge, at the National Library of Virtual Manipulatives website (http://matti.usu.edu/nlvm) or the National Council of Teachers of Mathematics Electronic Resources website (http://www.nctm.org).

Taylor (2001) goes on to state, “Progression in technology has increased the boundaries of mathematics and emphasized the importance of the integration of technology in the mathematics curriculum” (p. 8).

Purpose and Objectives of the Study

The purpose of this study is to extend the knowledge about concrete and virtual manipulatives and their effectiveness in teaching elementary school mathematics concepts. The objectives of the study are as follows:

1. To compare the effectiveness of concrete manipulatives versus virtual manipulatives in teaching elementary school mathematics concepts.
2. To determine elementary school students' attitudes while using concrete and/or virtual manipulatives.

Hypotheses of the Study

1. The use of virtual manipulatives will significantly enhance mathematics achievement in elementary school students.
2. Students will reflect positive attitudes in using both manipulatives, but virtual more than concrete.

Significance of the Study

In an ever-changing technologically advanced society, elementary school students must have a thorough knowledge of both mathematics and computers. Using computer-based programs to expand basic mathematical concepts is one way to incorporate technology in the classroom. This study will provide additional information on technology-based teaching as it relates to traditional, manipulative methods.

Chapter II: Literature Review

Literature Search

This researcher will review the literature available for several studies utilizing both concrete and virtual manipulatives in elementary school mathematics instruction. The previous researchers have offered a basis for the use of both kinds of manipulatives as well as limitations of each. It is this researcher's goal to extend the research that has already been performed in this area.

Concrete Manipulatives

Fueyo and Bushell (1998) studied the use of the number line as an effective concrete manipulative and the effectiveness of peer tutoring in teaching number line procedures. They conducted their research under the premises that manipulatives are useful when (1) teachers are knowledgeable about how and when to use them and (2) there is sufficient time to adequately teach mathematics concepts. These researchers concluded that the number line is indeed an effective manipulative when it is paired with feedback of some sort (in the case of this study, trained peer tutors). Fueyo and Bushell (1998) state:

> Research on mathematics instruction recommends that instruction (a) build on prior knowledge, (b) focus on critical features of the algorithm, (c) provide explicit teaching demonstrations, (d) present skills sequentially, (e) separate similar mathematical symbols to reduce interference, and (f) provide adequate opportunities for practice. (Carnine et al., 1994, as cited in Fueyo & Bushell, 1998, p. 10)

Fueyo and Bushell (1998) argue that the number line procedures used in their study encompassed five of the recommendations stated above by emphasizing "the students' prior knowledge of the operational signs, numerical recognition, and equations" (p. 10) and that peer tutoring encompassed the sixth recommendation. These researchers' contention is clear, ". . . tutoring with systematic number line procedures and feedback provided experimental validation of the number line's effectiveness as a mathematical manipulative" (p. 10).

Bohan and Shawaker (1994) suggest concrete manipulatives are indeed effective, but that "transfer of learning" must take place if students are to reap the full benefits of concrete manipulative use. "Transfer of learning is a situation in which studying topic A will help in understanding topic B" (Bohan & Shawaker, 1994, p. 1). They continue to state that this transfer should occur in several stages. These stages include concrete, bridging, and symbolic. "At the concrete stage, mathematical situations are attacked strictly using manipulatives. No symbols are used. . . . At the bridging stage, objects and symbols are manipulated simultaneously. . . . At the symbolic stage we begin working with symbols alone" (Bohan & Shawaker, 1994, pp. 1-2).

Taylor (2001), on the other hand, questions the use concrete manipulatives as an effective tool in teaching all mathematics concepts, specifically, probability. In fact, Taylor's (2001) study validates her null hypothesis: "There will be no significant difference between students who use concrete manipulatives and students who do not use concrete manipulatives regarding students' learning skills and concepts in experimental probability" (p. 71). Taylor's study also suggests that concrete manipulatives are more useful in teaching certain math concepts than they are in teaching others. While Taylor's study refutes the effectiveness of utilizing concrete manipulatives in teaching probability, these manipulatives did, in fact, help students learn incidental fraction concepts. Taylor also notes that students were comfortable with using concrete manipulatives in learning probability concepts. Taylor (2001) states, "Although students observed that from large probabilities, chances appeared more equal, they were more comfortable with the results of the outcomes when they were able to touch and feel the objects" (p. 98).

Virtual Manipulatives

Enderson (1997) argues that virtual manipulatives are essential for thorough, effective teaching of mathematical concepts. In fact, she suggests that one of the main benefits of using virtual manipulatives is helping students to "eliminate obstacles in doing mathematics – particularly problems involving formulas and calculations" (p. 32). Enderson's (1997) action research study demonstrated that using virtual manipulatives for studying the volume of a box expanded her students' restricted, detached view of mathematics to a broader, more practical view. Enderson (1997) states:

> All too often, students' experiences focus only on whole or integer number solutions. By making technology available, students can shift from a narrow view of whole number solutions to a perspective that includes real solutions where precision and round-off error may become yet another topic of discussion. (p. 31)

Taylor (1997) then goes on to state, "Implementation of technology in the classroom can help shift the focus of mathematical ideas from computation and manipulation to modeling and representation of functions or other phenomena" (p. 32). In other words, virtual manipulatives can help students move from a limited procedural understanding of math, to a broader conceptual understanding of math.

Reimer and Moyer (2005) also agree that virtual manipulatives increase elementary students' mathematics achievement. Their action research study, which utilized virtual manipulative applets in teaching third graders fractions, demonstrated a statistically significant improvement in students' conceptual knowledge of fractions. Similarly, Reimer and Moyer (2005) state:

> Student interviews and attitude surveys indicated that the virtual manipulatives (1) helped students in this class learn more about fractions by providing immediate and specific feedback, (2) were easier and faster to use than paper-and-pencil methods, and (3) enhanced students' enjoyment while learning mathematics. (pp. 5-6)

Reimer and Moyer (2005) argue that virtual manipulatives are more effective than physical manipulatives in classroom teaching because physical manipulatives are dependent on the teacher's ability to "make these [concrete concepts to abstract symbols] connections explicit" (p. 6). In fact, they state, "One feature that makes virtual manipulative applets advantageous for mathematics instruction is their capability to connect dynamic images with abstract symbols – one limitation of physical manipulatives" (p. 7). These researchers also note that one of the main reasons for the demonstrated effectiveness of virtual manipulatives in their study is the high level of knowledge the teacher possessed around the use of virtual manipulatives (Reimer & Moyer, 2005).

Taylor (2001), likewise, argues that virtual manipulatives are beneficial to classroom learning as it relates to elementary math students. Taylor (2001) asserts:

> Children's traditional classroom tools – pencils, notebooks, and texts – are still vital but inadequate for children to adequately solve problems, completely modify ideas, and thorough extend their learning experience" and "computer simulations can help students develop insight and confront misconceptions about probabilistic concepts (pp. 8-9).

Taylor’s (2005) study led to the rejection of her own null hypothesis, “There will be no significant difference between students who use computer-simulated manipulatives and students who do not use computer-simulated manipulatives regarding students’ experimental probability learning skills and concepts” (p. 94). Taylor (2001) also points out that “computer simulation use in the classes required less time to manipulate “ (p. 95). Less manipulation times allows for more time to perform other classroom activities. Finally, this researcher stresses that virtual manipulatives, alone, are not enough to improve elementary academic performance. Taylor (2001) states:

> Having appropriate software available, like the Probability Explorer, is important. In addition, teacher training on the use of the software and being able to provide students with a constructivist learning environment, which emphasizes understanding and builds on students’ thinking, is necessary to help students develop to their full potential in mathematics education. (p. 97)

Chapter III: Methodology

Research Design

This researcher will utilize a quantitative method in this study. The researcher will administer a pretest to selected sixth grade students, to assess their current knowledge around equivalent fractions. Upon completion of the pretest, the students will be divided into two treatment groups: Group A will receive mathematics instruction with virtual manipulatives and Group B will receive mathematics instruction with concrete manipulatives.

After a specified period of instruction, approximately two to three days, the two groups will then take a mathematics achievement posttest. The students will also complete an attitudes survey to capture their views on the use of manipulatives.

Sampling

The participants used for this study will be selected from students enrolled in sixth grade mathematics classes in the city of Detroit. These students will attend a public school. This study will be conducted during the academic school year. Therefore, students will already be assigned to their classrooms, which will eliminate the goal of attaining true random sampling. However, the variation in the students' gender, ethnic backgrounds, and socioeconomic status will reflect the composite to the greater population in that geographical area.

Variables

The pre and posttest instruments used in this study will be identical and will test students' conceptual and procedural knowledge of equivalent fractions. These instruments will be designed by the researcher. The researcher will base the content of the test instruments on the curriculum standards outlined by the National Council of Teachers in Mathematics (NCTM).

The independent variables in this study include (1) mathematics instruction with the use of virtual manipulatives and (2) mathematics instruction with the use of concrete manipulatives. The dependent variables in this study are (1) students' conceptual knowledge as is relates to the given mathematics area and (2) students' procedural knowledge as it relates to the given mathematics area. Students' attitudes around the use of these manipulatives are primarily for the researcher's personal use in future classroom instruction.

Methods of Data Collection

This researcher will generate data via the pre and posttest instruments as well as the students' attitude survey. The researcher anticipates instruction of some, if not all, of the participants in this study, which will allow her to observe students' behavior during the study. These observations will be noted for future classroom instruction.

Data Analysis Procedures

This researcher will analyze the generated data using a two-sample, paired-data t-test with a 0.05 confidence level. The data analysis will demonstrate how: (1) the use of virtual manipulatives effect students' conceptual and procedural knowledge of equivalent fractions and (2) the use of concrete manipulatives effect students' conceptual and procedural knowledge of equivalent fractions. The researcher will also determine the percentage of students that liked and disliked the use of manipulatives during mathematics instruction.

Ethics and Human Relations

All participants in this study will be assured that the risk associated with participating in this study are minimal. This researcher will do the following to protect the privacy of the participants: (1) keep participants' names confidential, (2) discuss individual responses with discretion, being certain not to disclose participants' identities, and (3) assure all participants (and their parents or guardians) that participation in this study is completely voluntary and may be withdrawn, without penalty, at any time. Permission will be obtained from the appropriate persons at Marygrove College prior to the start of the study (Appendix A). The researcher will take all foreseeable necessary precautions to ensure that the basic human rights of all participants are protected during this study. Parental consent will be required from all participants (Appendix B).

Timeline

This proposed study will be conducted in an approximate one week period. It will take place during the instruction of equivalent fractions in a sixth grade mathematics class.

Summary

As stated previously, this researcher will compare the effectiveness of concrete versus virtual manipulatives in teaching elementary school mathematics concepts, as well as students' attitudes around using these manipulatives. These findings will either confirm or refute the researcher's hypotheses that (a) use of both manipulatives will increase students' math achievement, but virtual more than concrete and (b) that students will enjoy using both manipulatives, but virtual more than concrete. The results of this study may help drive home the message that mathematical and technological knowledge of our children are basic necessities in the global society in which we live.

Chapter IV: Results

This chapter contains the descriptive statistics and results of the analysis pertinent to the8hypothesis of this study. Participants for the study consisted of 49 sixth-grade students from two mathematics classes at one public middle school in Detroit, Michigan. The instructional phase consisted of two lessons that tested the students' understanding of equivalent fractions.

Descriptive statistics for the pretest and posttest results for the equivalent fractions instrument are presented in Table 1, which includes the number (n) in each group, mean (m) and standard deviation (SD).

Table 1: Pretest and Posttest Means and Standard Deviation for Equivalent Fractions Instrument

Group	n	Pretest Mean %	Pretest SD	Posttest Mean %	Posttest SD
Virtual Manipulatives	20	22.9	21.1	38.3	24.2
Concrete Manipulatives (Control)	28	33.8	21.4	53.6	19.7

The researcher utilized a two-sample, paired-data, t-test with a confidence level of 0.05 to analyze the data. According to the Pearson correlation value (r) for each treatment group, the use of concrete manipulatives increases mathematics achievement more than the use of virtual manipulatives (0.76 versus 0.57) (see Table 2). Based on these findings, the researcher must reject her first hypothesis:

> The use of virtual manipulatives will significantly enhance mathematics achievement in elementary school students.

The students who used concrete manipulatives showed greater increase in mathematics achievement than those who used virtual manipulatives.

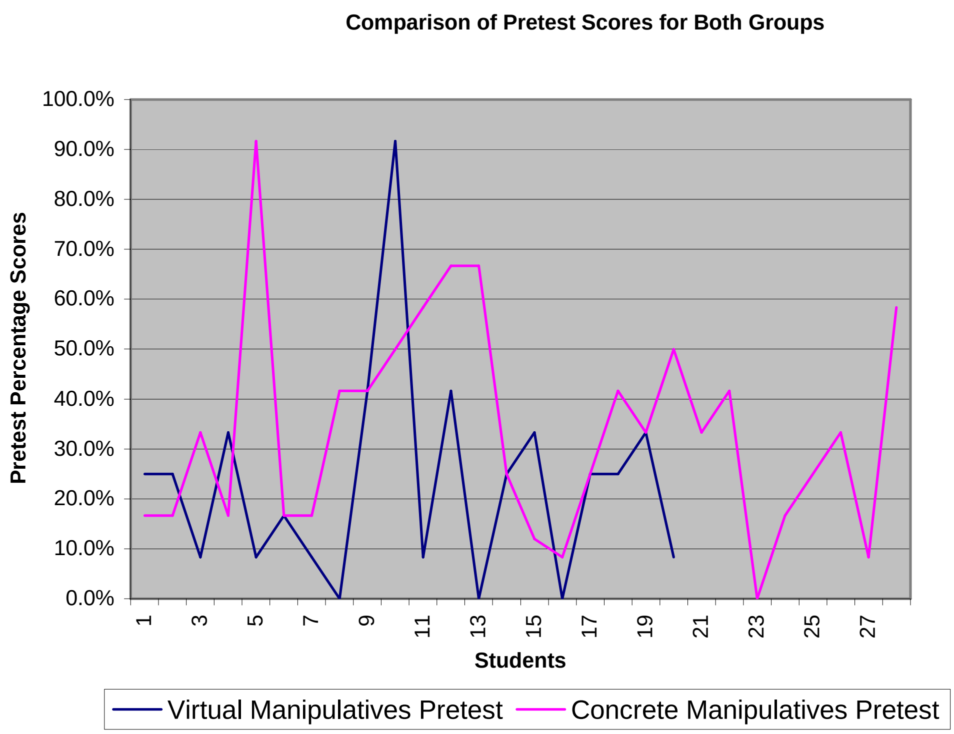
Table 2 shows the results of the T-test in greater detail.

Table 2: T-test for Pretest and Posttest Scores for Concrete and Virtual Manipulative Use

Virtual Manipulative Use			Concrete Manipulative Use	
	Pretest	Posttest	Pretest	Posttest
Mean	0.23	0.39	0.34	0.54
Variance	0.05	0.06	0.05	0.04
Observations (n)	19	19	27	27
Pearson Correlation (r)	0.57		0.76	
Hypothesized Mean Difference	0		0	
df	18		26	
t Stat	-3.25		-7.26	
P(T<=t) one-tail	1.73		5.21 x 10^-8	
t Critical one-tail	0.004		1.71	
P(T<=t) two-tail	2.10		1.04 x 10^-7	
t Critical two-tail			2.06	

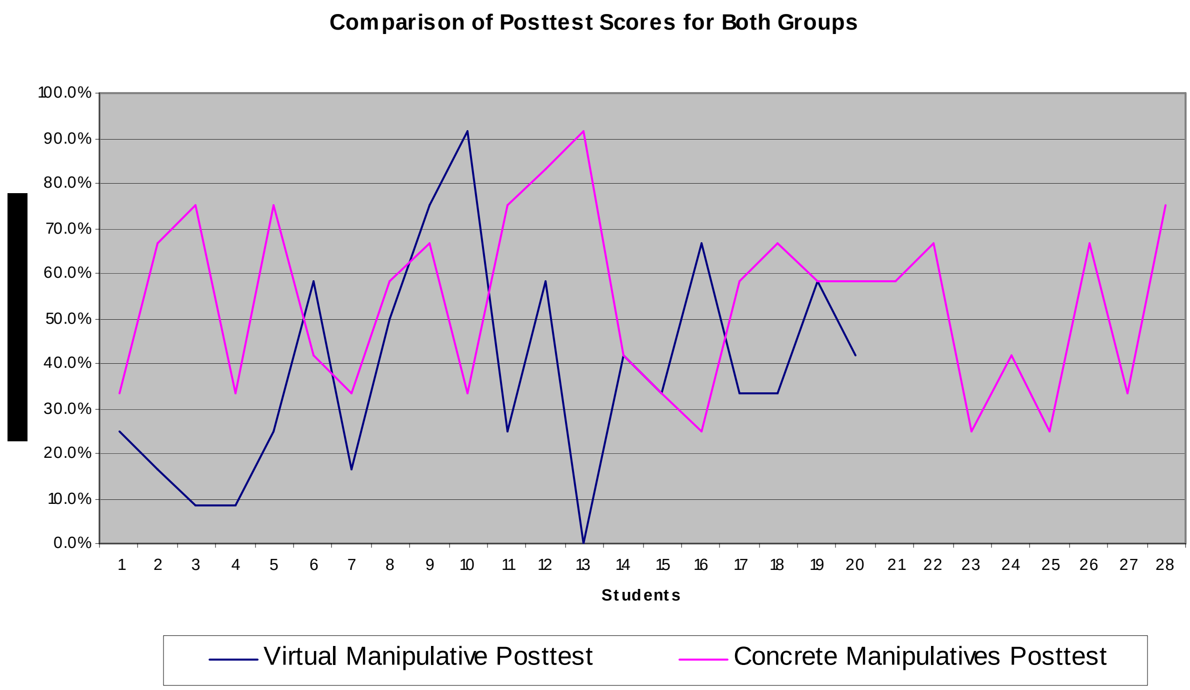
Figure 1 shows a comparison of pretest scores for both groups. Notice, that the pretest scores for the Control Group (Concrete Manipulative Use) were generally higher than for the Virtual Manipulative Use Group.

Figure 1: Comparison of Pretest Scores for Both Groups



When comparing the posttest scores of both groups, a similar trend is observed (see Figure 2). Overall, the posttest scores of the Concrete Manipulative Use Group are higher than those of the Virtual Manipulative Use Group. Possible reasons for the scoring differences are: (1) the students in the Concrete Manipulative Use group began with higher scores and therefore had a better understanding of equivalent fractions at the onset of the study and/or (2) the instruction with the use of concrete manipulatives was more effective than that with the use of virtual manipulatives.

Figure 2. Comparison of Posttest Scores for Both Groups



Another piece of information that may help explain the pre and posttest score differences between the two groups is students' mathematics grades at the beginning of the research project. Table 3 displays Group A's mathematics grades while Table 4 displays Group B's mathematics grades.

Table 3: Students' Mathematics Grades for Virtual Manipulative Use Group

Students #	**Mathematics Grade**
1	C
2	D
3	F
4	F
5	F
6	B
7	F
8	D
9	D
10	F
11	D
12	C
13	F
14	F
15	C
16	F
17	D
18	F
19	F
20	F
Average Class Grade:	**F**

Table 4: Students' Mathematics Grades for Concrete Manipulative Use Group

Student #	**Grade**
1	D
2	A
3	D
4	C
5	B
6	A
7	D
8	B
9	C
10	B
11	A
12	C
13	A
14	F
15	C
16	F
17	A
18	B
19	B
20	C
21	C
22	B
23	D
24	F
25	F
26	B
27	D
28	B
Average Class Grade:	**C**

Other Findings

In an effort to assess students' attitudes about mathematics and manipulative use, the researcher asked students to complete an attitudes survey. Figures 3 – 12 display the results of this survey for both groups of students.

Figure 3: Students' Attitudes Toward Using Virtual Manipulatives – Group A

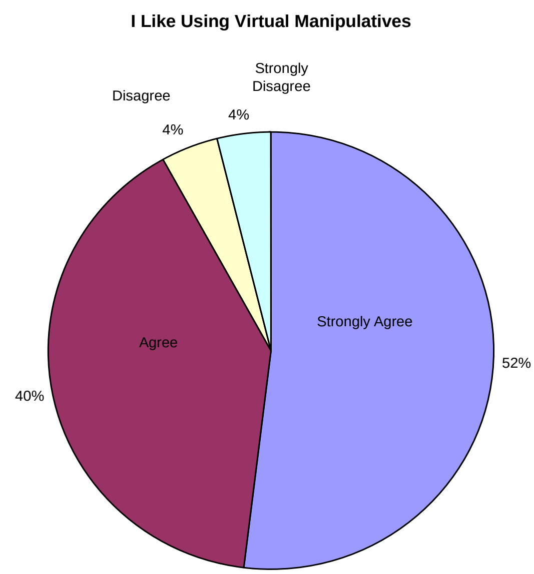


Figure 4: Students' Attitudes Toward Using Concrete Manipulatives – Group B

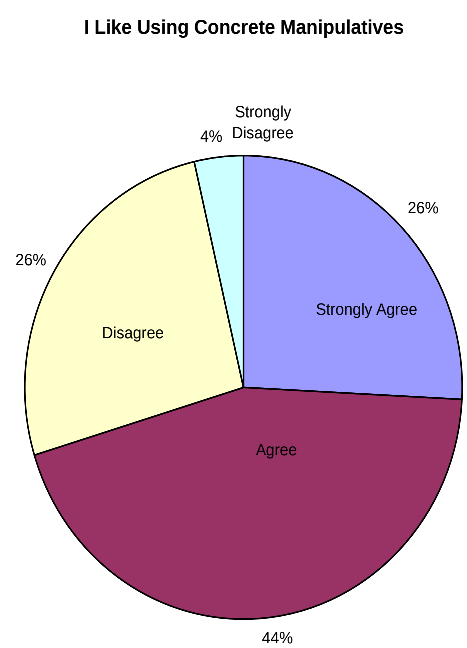


Figure 5: Students' Preference for Using Concrete vs. Virtual Manipulatives – Group A

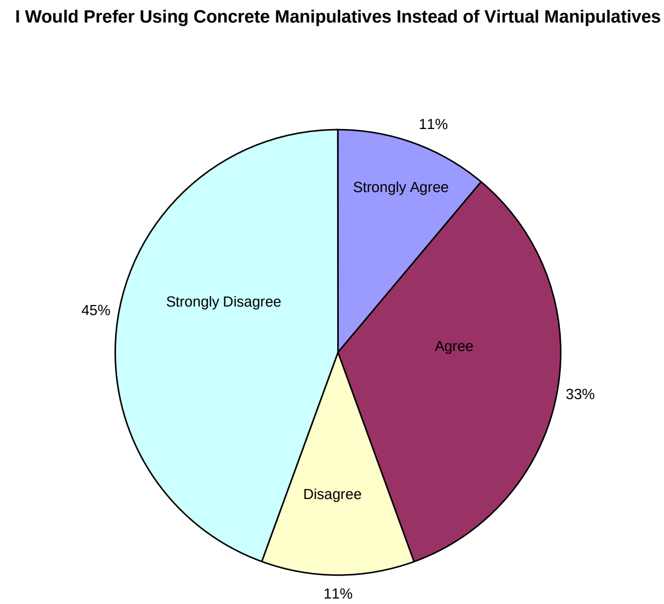


Figure 6: Students' Preference for Using Concrete vs. Virtual Manipulatives – Group B

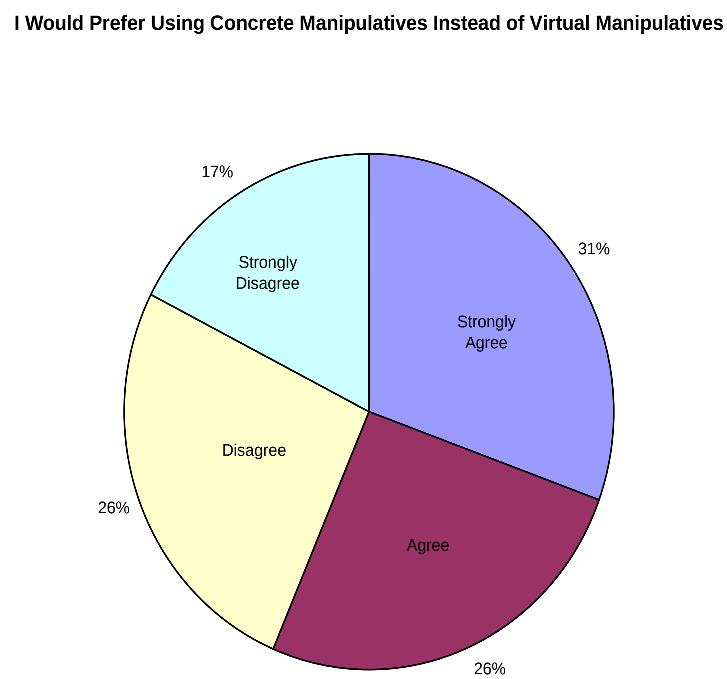


Figure 7: Students' Preference for Using Virtual vs. Concrete Manipulatives – Group A

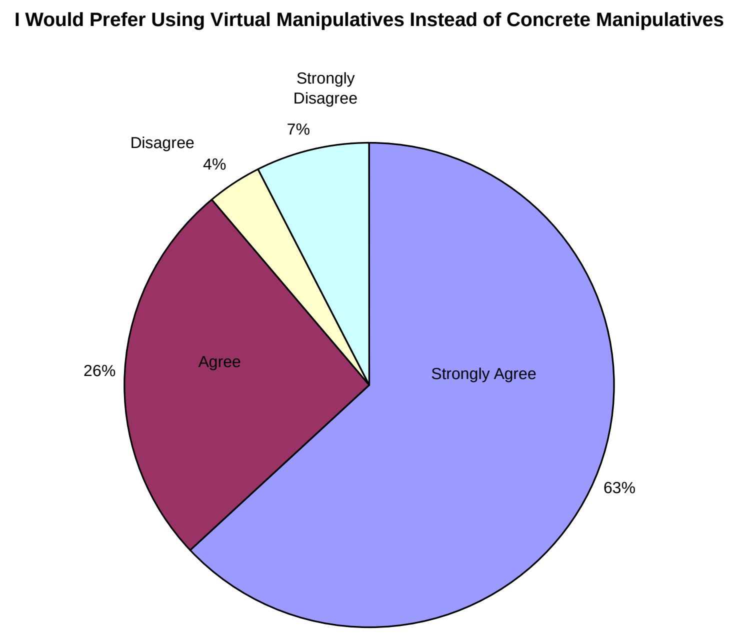


Figure 8: Students' Preference for Using Virtual vs. Concrete Manipulatives – Group B

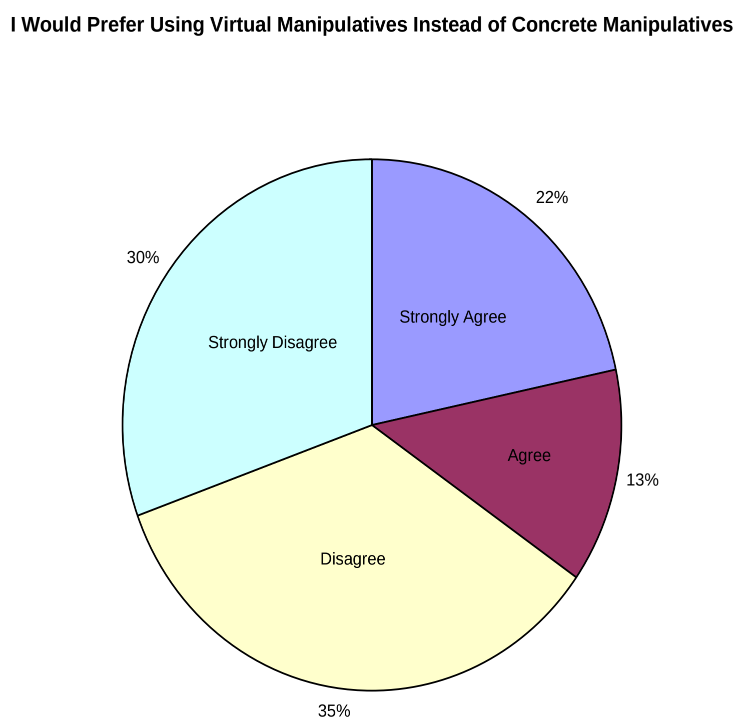


Figure 9: Students' Attitudes Toward Mathematics – Group A

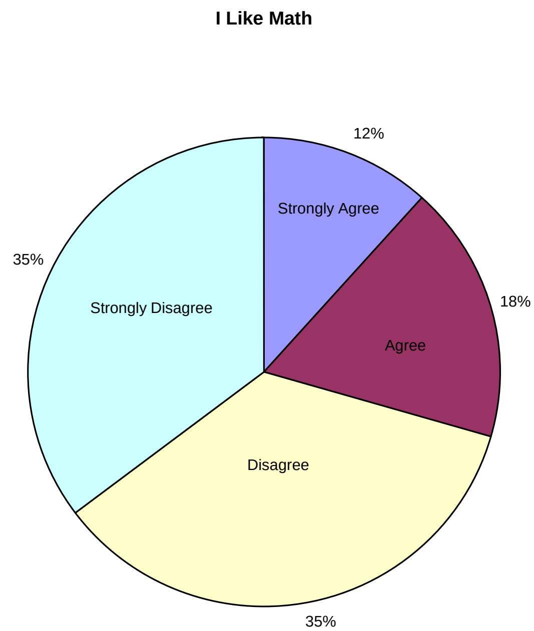


Figure 10: Students' Attitudes Toward Mathematics – Group B

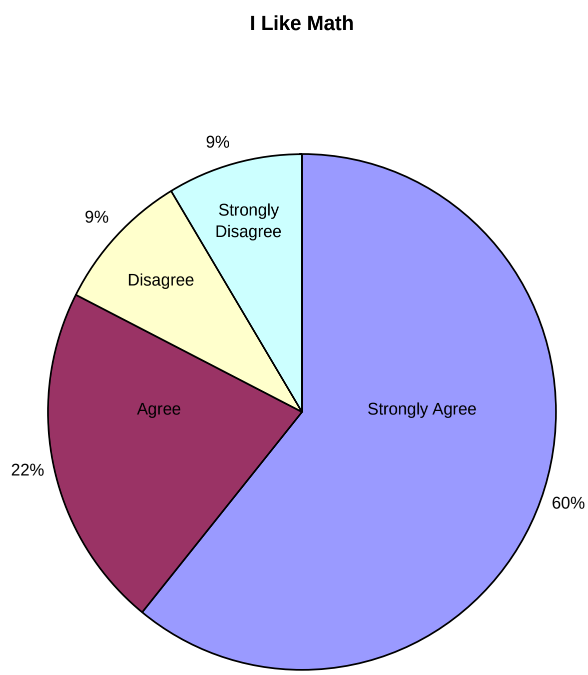


Figure 11: Students' Attitudes Toward Manipulative Use in Math Class – Group A

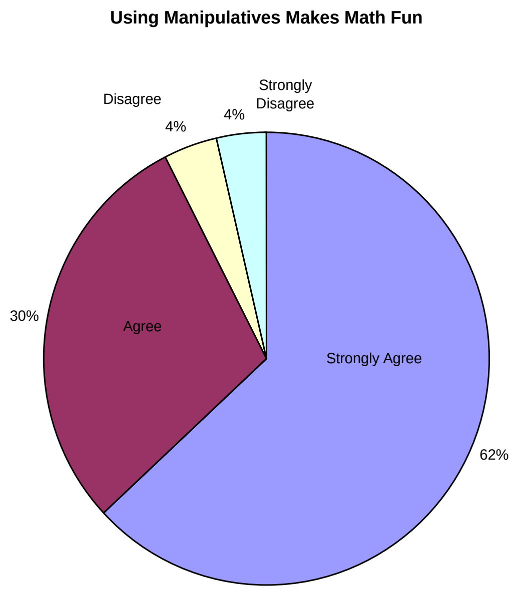
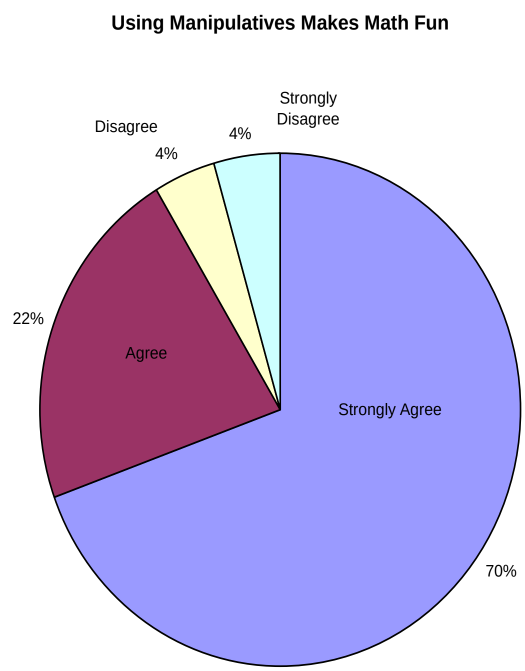


Figure 12: Students' Attitudes Toward Manipulative Use in Math Class – Group B



According to Figures 3 and 4, both groups demonstrated positive attitudes toward using their respective manipulatives in mathematics class (Group A – Virtual Manipulative Use Group; Group B – Concrete Manipulative Use Group). 92% of the students in Group A enjoyed working with virtual manipulatives while 66% of the students in Group B enjoyed working with concrete manipulatives. This data supports the researcher's second hypothesis:

> Students will reflect positive attitudes in using both manipulatives, but virtual more than concrete.

According to Figures 5 and 6, only 44% of the students in Group A said that they would prefer using concrete manipulatives instead of virtual, while 57% of the students in Group B said the same.

Figures 7 and 8 reflect the responses to the opposite statement. 89% of the students in Group A stated that they would prefer using virtual manipulatives to concrete, while only 35% of the students in Group B stated the same. The data reflected in Figure 8 opposes the researcher's second hypothesis.

Figures 9 and 10 demonstrate the most significant difference in opinion for both groups. Only 30% of the students in Group A expressed an affection for mathematics, while 82% of the students in Group B did the same. Group A's relative dislike for mathematics class may have contributed to the failing class grade average.

Finally, for both groups, 92% of the students agreed that using manipulatives makes mathematics class more enjoyable. The overwhelmingly positive response to the use of manipulatives merits continued use of manipulatives on the part of the researcher.

Limitations of the Study

Several limitations should be considered when interpreting the results of this study. Because this study occurred during the second quarter of the school year, the classes were already intact and non-randomly assigned to the treatment and control groups. This is common among studies conducted in school settings. There were preexisting differences in the intact classes to begin with (as was demonstrated by the pretest scores for both groups).

Second, the duration of the study was only two days; one day for manipulative use and one day for lecture-based instruction on equivalent fractions. The question might be raised whether two days is sufficient time to develop the concepts completely and effectively with virtual and concrete manipulatives. Because this exposure to manipulative use was the first of the school year, this researcher believes that students probably needed more time to familiarize themselves with the manipulatives and become engaged in meaningful activities. However, because of the school's curriculum, the researcher limited her outside activities to two days.

Next, the two groups in the study used two different types of manipulatives. In addition to Group A using computer-simulated and Group B using concrete manipulatives, the virtual manipulatives were fraction bars while the concrete manipulatives were pattern blocks. It is possible that the varied shapes of these manipulatives impacted students' learning.

Finally, the researcher is a pre-service mathematics teacher who has never taught a lesson using manipulatives before (concrete or virtual). Therefore, the researcher is aware that she may have not made a clear enough connection between the manipulative use and equivalent fractions. When the students (in both groups) took the posttest, many students seemed to remember the main points of the researcher's lecture as opposed to the concepts learned through the manipulative use.

Chapter V: Conclusion

Summary

The purpose of this study was to examine the effects of both virtual and concrete manipulative use on sixth-grade students' equivalent fractions learning skills and concepts. There were two heterogeneous groups with one class of students in both. Group A was allowed to use virtual manipulatives (fraction bars) with the equivalent fractions lesson. Group B, the control group, was allowed to use concrete manipulatives (pattern blocks) with the lesson. The objective of this study was to determine the effect of virtual and concrete manipulatives on elementary students' equivalent fractions learning skills and concepts on the dependent variable of posttest scores.

The study consisted of 48 sixth-grade students. The classes remained intact; therefore, random assignment to treatment groups was not possible. The researcher taught both classes. The students in both groups were administered a pretest (generated by the researcher), spent one day using their respective manipulatives, spent one day in lecture-based instruction on equivalent fractions, then took their posttest (generated by the researcher). Two days elapsed between the first and second testing sessions.

A two-sample, paired t-test was used to examine the posttest scores. Based on the t-test, it was concluded that students who experienced concrete manipulative instruction significantly outperformed students who experienced virtual manipulative instruction. Thus, the t-test results led to the rejection of the following hypothesis:

> The use of virtual manipulatives will significantly enhance mathematics achievement in elementary school students.

The researcher also issued a students' attitudes survey for manipulative use. Based on the findings from this survey, the researcher could neither reject nor accept the following hypothesis:

> Students will reflect positive attitudes in using both manipulatives, but virtual more than concrete.

Conclusion

According to the literature review, researchers have long since established the effectiveness of concrete manipulative use in the mathematics classroom. This study was designed to compare the effectiveness of virtual manipulative use to concrete manipulative use, on the skills and conceptual understanding of equivalent fractions in a sixth-grade classroom. The data in this study shows that concrete manipulative use has a greater impact on equivalent fractions posttest success than virtual manipulative use does. This study also set out to gauge students' attitudes about manipulative use in the mathematics classroom. Students responded favorably to the use of manipulatives in the classroom. In fact, students that expressed a dislike for math class also expressed that manipulative use makes math fun.

Recommendations

While the information shared in this study is indeed helpful, the researcher recommends that further testing take place in this area of concrete and virtual manipulative use in the mathematics classroom. In future studies, the following aspects should be explored:

- More than one kind of manipulative (both concrete and virtual)
- Longer time allotment to conduct the study
- More exploratory exercises while students are using manipulatives

If classroom instructors are to present meaningful lessons that promote inquiry and technical competence, then instructors must be proficient in creating lessons that support these two objectives within the framework of their school's curriculum. Studies like the one presented in this paper will help teachers reach this goal.

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Appendix A

Marygrove College
Department of Education
8425 W. McNichols Road
Detroit, MI 48221

CONCRETE VERSUS VIRTUAL MANIPULATIVES INFORMED CONSENT FORM

Dear Parent/Guardian,

My name is Sonya Brown and I am a graduate student in the TASC (Teaching As A Second Career) Program at Marygrove College. Your child's class has been selected to participate in my master's thesis research project and I am requesting your consent for participation. Before I can accept your consent, I will explain the purpose of my study.

The name of my study is "Counting Blocks or Keyboards? A Comparative Analysis of Concrete Versus Virtual Manipulatives in Elementary School Mathematics Concepts". The purpose of my study is to compare the effectiveness of concrete and virtual manipulatives in sixth grade mathematics instructions. Manipulatives are tools (like toys) that students use in various mathematics classes to help them conceptualize abstract ideas. This research is significant because its findings can help teachers instruct your child more effectively in the areas of mathematics and technology.

During this study, your child will take a pretest and be placed into one of two treatment groups (Group A: mathematics instruction with concrete manipulatives; Group B: mathematics instruction with virtual manipulatives). Upon completion of mathematics instruction within the treatment groups, each child will then take a posttest, to determine the effectiveness of each treatment. Each participant will also complete a students' attitudes survey, to assess if students enjoy using these manipulatives.

All test and survey results will remain confidential. Your child's name will also remain confidential. Participation in this study involves no foreseeable risks or harm to you or your family. You are welcome to call me at XXX-XXX-XXXX if you have any questions about your rights as a volunteer in this research study.

Your participation in this study is voluntary. You are under no obligation to participate in this study. You may withdraw from the study at any time, with no penalty. The researcher, also, has the right to withdraw you from this study at any time, if you don't meet the specified criteria.

The researcher will maintain the confidentiality of all records unless disclosure is required by law. The researcher will store all records in a secured location that will not be shared with any other person, unless your permission is granted.

If any new significant findings are discovered during this study that may affect your willingness to participate, such findings will be reported to you.

Appendix B

ACKNOWLEDGEMENT AND CONSENT

I have read the procedure described above. I voluntarily give consent for my child, _____________________________, to participate in Sonya Brown's study of concrete and virtual manipulatives in elementary school mathematics concepts. I have received a copy of this description and have an opportunity to ask any questions I might have regarding this study. I understand that the data collected from this study will be archived with this researcher for future reference/use.

Parent/Guardian Signature Date

Witness Signature Date

As the investigator in this study entitled, "Counting Blocks or Keyboards? A Comparative Analysis of Concrete Versus Virtual Manipulatives in Elementary School Mathematics Concepts", I hereby state to the best of my knowledge and belief all of the statements made in the above consent form are true and that in consenting the parent/guardian of the prospective participant exercised free power of choice without undue inducement or any element of fraud, deceit, duress, or any other form of constraint or coercion. I may discontinue participation at any time without penalty or loss of benefits to which the participant may be entitled.

Signature of the Investigator Date

Appendix C

MATHEMATICS PRE-TEST

Find two equivalent fractions for each fraction.

1. 1/2
2. 1/3
3. 3/4
4. 2/5

Find the missing numbers that make the fractions equivalent.

5. 1/8 = ?/16
6. 3/4 = 9/?
7. 1/? = 4/16
8. ?/5 = 5/25

Write each fraction in simplest form.

9. 50/100
10. 6/24
11. 15/25
12. 3/18

Appendix D

MATHEMATICS POSTTEST

Find two equivalent fractions for each fraction.

1. 2/3
2. 1/8
3. 3/5
4. 2/7

Find the missing numbers that make the fractions equivalent.

5. 1/2 = ?/10
6. 1/4 = 4/?
7. 1/? = 5/25
8. ?/3 = 8/24

Write each fraction in simplest form.

9. 50/75
10. 4/24
11. 10/35
12. 6/36

Appendix E

STUDENTS' ATTITUDES SURVEY

Please respond in terms of how you feel at the present time. Circle the number that best describes your experience on a scale from 1 to 4, with 1 = strongly disagree and 4 = strongly agree.

1	2	3	4
Strongly Agree	Agree	Disagree	Strongly Disagree

1. I like using concrete manipulatives when doing math problems.	1	2	3	4	N/A
2. I like using virtual manipulatives when doing math problems.	1	2	3	4	N/A
3. I would prefer using concrete manipulatives instead of virtual manipulatives.	1	2	3	4	
4. I would prefer using virtual manipulatives instead of concrete manipulatives.	1	2	3	4	
5. I like math.	1	2	3	4	
6. Using manipulatives makes math fun.	1	2	3	4	

Appendix E

LIST OF MANIPULATIVES USED

Concrete Manipulatives:

Pattern Blocks

Virtual Manipulatives:

Fraction Bars on the Holt Online Learning website:

http://my.hrw.com/math06_07/nsmedia/tools/Func_Bars/Func_Bars.html