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The Effect of Manipulatives on Students' Understanding of Chemistry Concepts

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THE EFFECT OF MANIPULATIVES ON STUDENTS' UNDERSTANDING OF CHEMISTRY CONCEPTS

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ABSTRACT

The purpose of this study was to assess the effectiveness of manipulatives on chemistry concepts. Manipulative activities were designed for four chemistry topics: Dimensional Analysis, Ionic Formulas, Molecular Shapes, and Stoichiometry. Seventy-five high school students were divided into a control or experimental group. The control group solved problems in small groups, while the experimental group used manipulatives to complete a guided activity. Students in the control group scored significantly higher on the posttest for the Dimensional Analysis and Ionic Formulas activities. There was no significant difference in the posttest scores for the Molecular Shapes and Stoichiometry posttest. While manipulatives can be an effective learning strategy to increase student achievement, it does not have the same effectiveness of peer collaboration in small groups.

INTRODUCTION

In 2012, half a million students in 65 countries took the Programme for International Assessment (PISA). The PISA is given to 15-year olds every three years to assess their reading, math, and science proficiency. Students in the United States ranked 20th (a below average ranking) in science, three spots down from their 17th spot ranking in 2009 (Organisation for Economic Co-operation Development, 2013). This was considered an average score among the nations tested. As a consequence of test results like these, increasing student achievement has become a common goal that dedicated educators are working diligently to obtain.

Billions of dollars are being poured into research that develops new reforms, strategies, standards, and curriculums in the hope of raising student performance. According to Dardick (2014), Bill Gates has spent 3.4 billion dollars on "improving" public education. PISA reports that America spends more money per student compared to higher achieving countries. For example, the Slovak Republic, which spends around USD 53,000 per student, performs at the same level as the United States, which spends over USD 115,000 per student (Organisation for Economic Co-operation Development, 2013). The United States recognizes that there is a problem with public education; unfortunately money may not be solution to the problem.

In effort to understand the learning strategies that were improving student achievement, Schroeder et al. (2007) performed a meta-analysis to analyze the science education studies that have been conducted since the last meta-analysis on science education had been done by KC Wise in 1996. The *Meta-Analysis of National Research: Effects of teaching strategies on student achievement in science in the United States* was pioneered by the Texas

Science Initiative to have research-based information to produce highly effective teachers and teaching, which was a parameter set forth by The No Child Left Behind Act of 2001.

A meta-analysis investigates and summarizes the findings of numerous primary studies. In this meta-analysis, twelve teaching strategies were evaluated. The twelve learning strategies investigated by Schroeder et al. (2007) were: Questioning, Focusing, Manipulation, Enhanced Material, Assessment, Inquiry, Enhanced Context, Instructional Technology, Direction Instruction, and Collaborative Learning. Of the twelve learning strategies, the Enhanced Context Strategy was found to be the most effective. This learning strategy relates learning to students' previous experiences or knowledge or engages students' interest by relating learning to the students'/school's environment or setting (e.g., using problem-based learning, taking field trips, using the schoolyard for lessons, encouraging reflection)(Schroeder et al.,2007). In an attempt to connect students' prior knowledge to new knowledge and to solidify students understanding of abstract ideas, I designed my thesis to utilize manipulatives using items familiar to students to teach chemistry in a high school setting.

Manipulatives are usually physical objects that students can investigate with their hands. They provide opportunities for students to grasp abstract ideas and translate them into concrete knowledge. For example, manipulatives can be as simple as marshmallows and toothpicks representing how atoms are bonded to one another, or they can be as elaborate as computer simulations that not only show how atoms are bonded, but describe their bond angles and geometries. Manipulatives have been found to increase student learning significantly (Sowell, 1989; Wise and Okey, 1983). This thesis investigates if activities designed around these manipulatives can strengthen students' conceptual understanding of chemistry.

LITERATURE REVIEW

The question of the effect of manipulatives on student achievement is not a new one. Math educators have been studying the use of manipulatives in education for years. According to Sowell (1989), “mathematics achievement is increased through the long term use of concrete instructional materials.” Researchers found that in a math class, manipulatives could be a powerful tool in the knowledgeable teacher’s tool belt of learning strategies. Although not as extensive as the math community, there has been some positive research on how manipulatives can affect the science classroom.

In a research article by Copolo and Houshell (1995), the researchers compared the effect of using two- and three-dimensional model representations of molecular structures on student learning of organic chemical structures. Organics structures were taught to high school students using one of four methods of molecular representation: (1) two-dimensional textbook representations, (2) three-dimensional computer models, (3) three-dimensional ball and stick models, and (4) combination of the computer molecular model/ball and stick model. Six teacher-made tests were given. The researchers investigated whether there would be a significant difference in the means of students’ scores on tests based on the method of instruction (Posttest I- paper or computer), how students were tested (Posttest II - paper only), and whether students could construct molecules in the two-dimensional form (Posttest III). Each test also had a long term retention component.

The students in Group 4 (computer and ball stick) had a significantly higher mean on the retention test I. No significant effect was evident on posttest I between the groups. On test II, Group 1 (two-dimensional representation only, 2D) had a significantly higher mean on the

posttest.   No significant effect was evident on retention test II between the groups. On test III, drawing molecules, there was no significant difference in the means on either the posttest or the retention test. In this study, the use of manipulatives proved to be beneficial to the understating of isomeric identification. The Group 4 had a significantly higher mean on retention I. The use of two manipulatives, computer and ball-stick, all students to retain new information because reasoning was based on real observations and experiences (Copolo and Hounshell, 1995). It is also important to note that Group 1 (2D) had the significantly higher mean on Posttest II. The fact that Group 1 (2D) performed better on the two-dimensional test indicates the importance of making the connection between the manipulative and how students will normally interact with the new information.

In this next study, manipulatives have again been proven to be beneficial. The study by Saitta, Gittings and Geiger (2011), saw statistically significant differences between the control and experimental groups. During the fall semester of 2008, 309 first-semester general chemistry students were exposed to one of two treatments. In addition to lecture, the control group learned dimensional analysis through a traditional procedure in a discussion section. The experimental group had lecture, then used a manipulative activity that required them to use conversion cards to practice dimensional analysis. The testing instrument was an instructor made seven-question test. It was given as a pretest and posttest where the details of the questions varied between the two tests. Saitta et al. (2011) assessed each question with five criteria, including whether the student: (1) attempted the problem, (2) attempted dimensional analysis, (3) performed correct dimensional analysis, (4) performed correct mathematics, (5) produced the correct answer. The test was a total of 35 points.

T-tests were conducted and p-values were calculated on the pretest and posttest scores for each criterion. The test indicated there was a statistical difference in 12 of the 35 areas. It also indicated there was an increase in scores in favor of the experimental group in attempting dimensional analysis and using the correct dimensional analysis. According to Saitta et al. (2011), Confidence in dimensional analysis as a problem solving tool improved, as seen by the increase in attempted use of dimensional analysis by the experimental group for five of the seven questions.

Finally, in an activity conducted by Ruddick and Parrill (2012), researchers again found manipulatives beneficial to a lesson on ionic formulas. The study took place in an inner-city high school chemistry class. The treatment groups were a traditional lecture group where the crisscross method was learned. This involved finding the charges of the ions for each element, and then crossing them and using them as the subscript for the opposite element. The second treatment group was a virtual group where students used the Rainbow Matrix game. This game randomly selects a positive and negative ion. The students then matched virtual puzzle pieces to form a rectangle. A third group used LEGO blocks to physically build rectangles from pieces that represented the ions. All three groups were administered a 10-question, multiple choice, teacher made test. A significant difference was detected between the posttest scores of the three treatment groups ($p < 0.05$). The LEGO block group scored significantly higher than the lecture group and virtual group. There was no significant difference detected between the lecture group and virtual group. From the literature, manipulatives seem to be a promising addition to the science classroom. When compared to traditional lectures and virtual applications, the addition of manipulatives has been seen to increase student achievement.

METHODS

This experiment was conducted at a public high school in Port Allen, Louisiana. The study population consisted of 75 high school juniors. The junior class was composed of 37 females and 38 males. The school is 71% African-American, 28% Caucasian, and 1% Hispanic. The participants were enrolled in one of four 11^{th} grade Chemistry classes that ranged in size from 18 to 24 students. The 1^{st} hour and 4^{th} hour classes were combined to form Group A. The 5^{th} hour and 6^{th} hour classes were combined to form Group B. Each group was flipped during the experiment, so that each treatment group was the control group twice and the experimental group twice. Students who did not complete both the pretest and posttest for the activity were removed from the study for that activity only. Classes were held five days a week for 50 minutes each day. Groups were given the same amount of time to complete the activities. Each class was taught by the same teacher.

Four manipulative activities were done over the course of school year. The four topics covered were Dimensional Analysis, Ionic Formulas, Molecular Structures, and Stoichiometry. There were two activity structures used to conduct the experiments. The control group structure consisted of a 15 minute lecture, 10 minute demonstration of how to work problems, 5 minute collaboration where teacher and students work problems together, and a 20 minute exploration where students completed problems in small groups. The experimental group structure consisted of the same 15 minute lecture, a 30 minute completion of the guided activity, and a 5 minute completion of practice problems. The experimental group used the same practice problems as the control group. However, to keep the time per topic equal in the two groups, the experimental group had less time to work the practice problems. The lecture

explains what the topic is, how it is used in science, and makes real-life connections. It is important to understand that the design of the control group activities was greatly limited by a school imposed mandate that stipulated that active learning must be used in all classroom activities.

Activities

This section contains a detailed description of the four different manipulative activities conducted in this research. In each case the activities were modeled after a study published in the literature. However, it is important to note that specific student instructions and activities were modified from their original content.

Dimensional Analysis*.* The dimensional analysis activity was modeled after the experiment conducted by Saitta et. al (2011). The experimental group was given the lecture. After the lecture the teacher explained the directions for the activity. The experimental group of students was given a manipulative that consisted of cards divided in half with a horizontal line. Above and below the lines were pictures of animals. In pairs, students worked through a guided worksheet. The students were asked to convert from one animal to another using the picture cards. After completing three questions with the animal cards (see Figure 1), the activity transitioned into problems that contained units like grams/moles, and milliliters/liter. When students completed the activity the groups were given the same practice problems to complete as the control group. The control group was given the same lecture as the experimental group. After the lecture the control group participated in an active learning strategy called *I Do, We Do, You Do*. In this lesson structure the teacher demonstrates the problem (I do), then students and teacher work together (We Do), and finally the students practice without the teacher (You

Do). During the “You Do” students worked together in small groups of peers to answer practice problems from a worksheet. The practice worksheet had basic one step problems like liters to milliliters and multi-step problems like years to seconds.

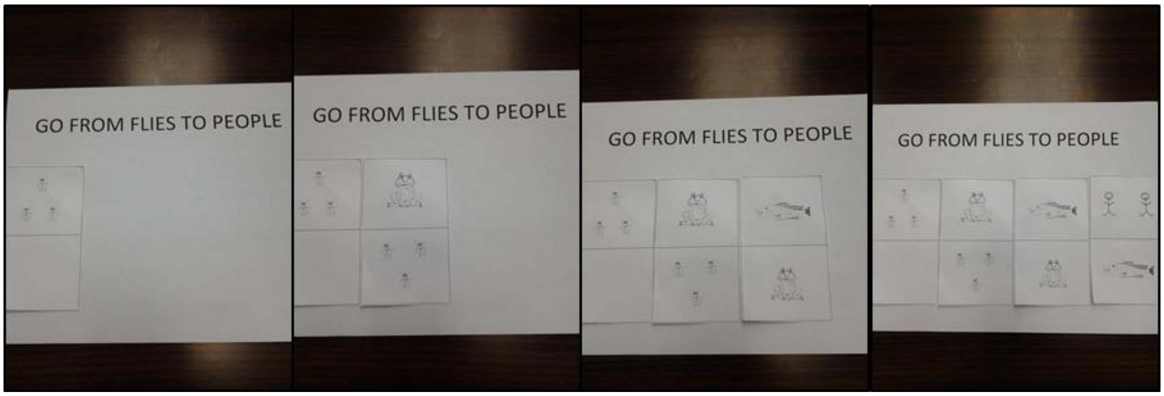

Figure 1. Dimensional Analysis Activity

Ionic Formulas*.* The ionic formula activity was modeled after an experiment completed by Ruddick and Parrill (2012). In this activity students use interlocking building blocks to create ionic compounds. Applying the experimental group activity structure, students were lectured and then given directions for the activity. Pairs of students were given two different colored building blocks in a baggie. Students decided which block color would represent positive and negative charges. Students were told that the humps on the blocks indicated the charge of the ion. For instance one hump represented +/- 1 charge. The guided worksheet gave students the name of a compound. Students were instructed to connect the blocks, balancing out their charges, until a rectangle was created. The rectangle was a neutral compound representing the ions in their lowest possible ratio (see Figure 2). When students completed the experiment they worked on the same practice problems as the control group. The control group followed the control group activity structure. The same lecture given to the experimental group was again

given to the control group followed by the I Do, We Do, You Do lesson structure. The practice problems were completed in small peer groups. The practice problems allowed students to both write formulas from names and names from formulas.

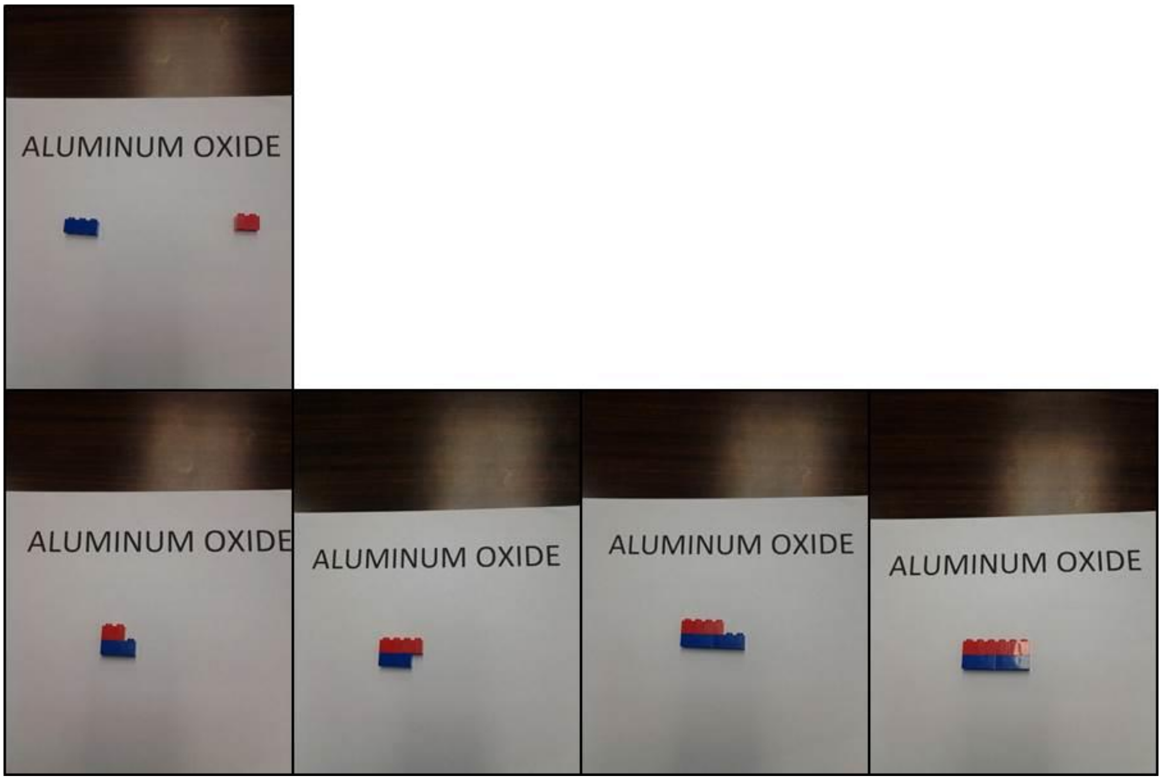

Figure 2. Ionic Formula Activity

Molecular Shapes. The molecular shape activity was modeled from the Louisiana Comprehensive Curriculum (LCC) for Chemistry. The LCC is a series of curriculums produced by the Louisiana Department of Education. They curriculums are used to guide instruction for subjects taught in Louisiana. As before, the experimental group was lectured and the directions for the activity were reviewed. The students were instructed to blow up the balloons and then tie all the balloons in the bag together. Instructions were given on how to tie the balloons together. Students were given one of two kinds of bags. Either they had a bag with solid color

balloons or a bag with solid color balloons and white balloons. Bags had between 2 and 6 balloons. For example, a bag representing a molecule like water (with two bonding domains and two lone pairs) would have had two red balloons and two white balloons. The red balloons represented the atoms bonded to the central atom. The knot represented the central atom. The white balloons represented lone pair electrons (see Figure 3). Once all models were assembled, students predict their models molecular geometry and the electron geometry based on examples given. Students then filled in a worksheet with the molecular geometry and the electron geometry of all the models as they were discussed. Lastly, they practice naming geometries from Lewis Structures they had to draw on a worksheet. The same control group activity structure was used as in previous experiments. The control group used the same worksheet of drawn Lewis Structures. In the control group students predicted the molecular and electron geometries without the use of the balloon manipulatives. But again, the control group worked more problems and used peer collaboration.

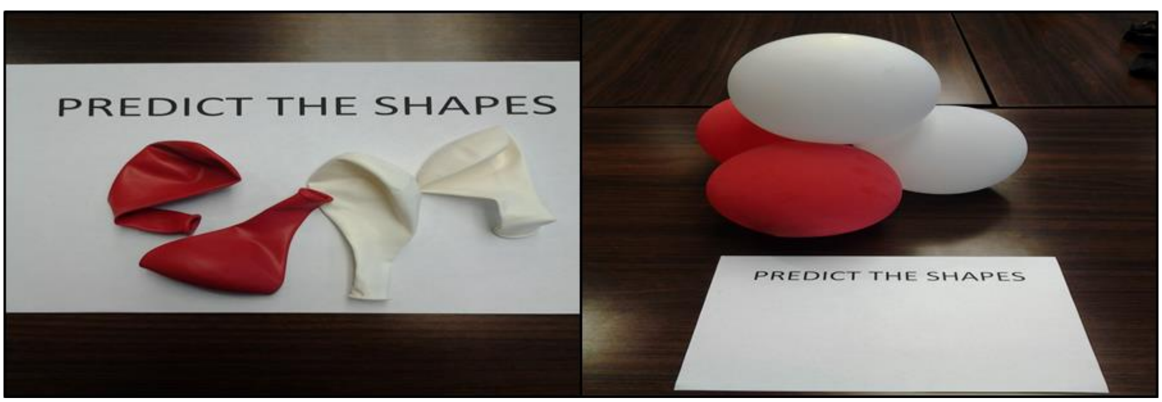

Figure 3. Molecular Shapes Activity

Stoichiometry*.* The stoichiometry experiment was based on information from a professional development workshop describing how a manipulative could be used for

stoichiometry (Fernandes and Miller, 2012). The presentation showed how their students used manipulatives to solve stoichiometry problems on white boards. In my classroom, the experimental group received a short lecture and an explanation on how to use the manipulative. Trapezoid shape pieces of paper had been labeled with units such as grams, moles, and molar mass and placed in a baggie. Working from a stoichiometry worksheet, students identified the given and wanted information in the word problems. Once these pieces of information were identified, groups built “road maps”, using the trapezoid pieces. The manipulative is designed to help the student understand how to get from the given information about the reactant/product to the wanted result of reactant/product. The pieces were arranged on the desk by the students so that the units would cancel out (see Figure 4). The students then wrote the problems on the worksheet including the numbers and solved the problems. The control group was given a short introductory lecture, then using the identical worksheet; the control group was shown how to complete the problems using the *I Do, We Do, You Do* lesson structure. The control group was also instructed to find the given and wanted variables. The worksheet consisted of three types of problems: converting from moles to moles, converting from moles to mass or vice versa, and converting from mass to mass.

Assessments

All assessments were teacher made tests. For each activity the pretest and posttest were the same test. The pretest was given on the same day of the activity. The posttest was given on the day after the activity. The activities took one 50 minute class period to complete. Scores from the pretest and posttest were used to calculate mean scores and p-Values.

Dimensional Analysis. The dimensional Analysis assessment consisted of 7 short answer questions. The questions ranged from basic one-step conversions (milliliters to liters) to multi-step conversion (years to seconds). One question had made-up units used to determine if students had a conceptual understanding of dimensional analysis. Each question was graded by giving 1 point for attempting dimensional analysis and one point for the correct dimensional analysis for a total of 14 points.

Ionic Formulas. The ionic formula assessment was a multiple choice test. It consisted of 10 questions. The questions asked students to identify the correct ionic formula from the chemical name. Each correct answer was given 1-point for a total of 10 points.

Molecular Shapes. The molecular shapes assessment was a multiple choice test. The test consisted of 9 questions for a total of 9 points. The questions asked students to identify the proper molecular shape for a given molecule.

Stoichiometry. The Stoichiometry assessment was an 8 question multiple choice test. Each question was worth one point. There were three types of questions on the test. It contained mole to mole, mole to mass, and mass to mass conversion problems.

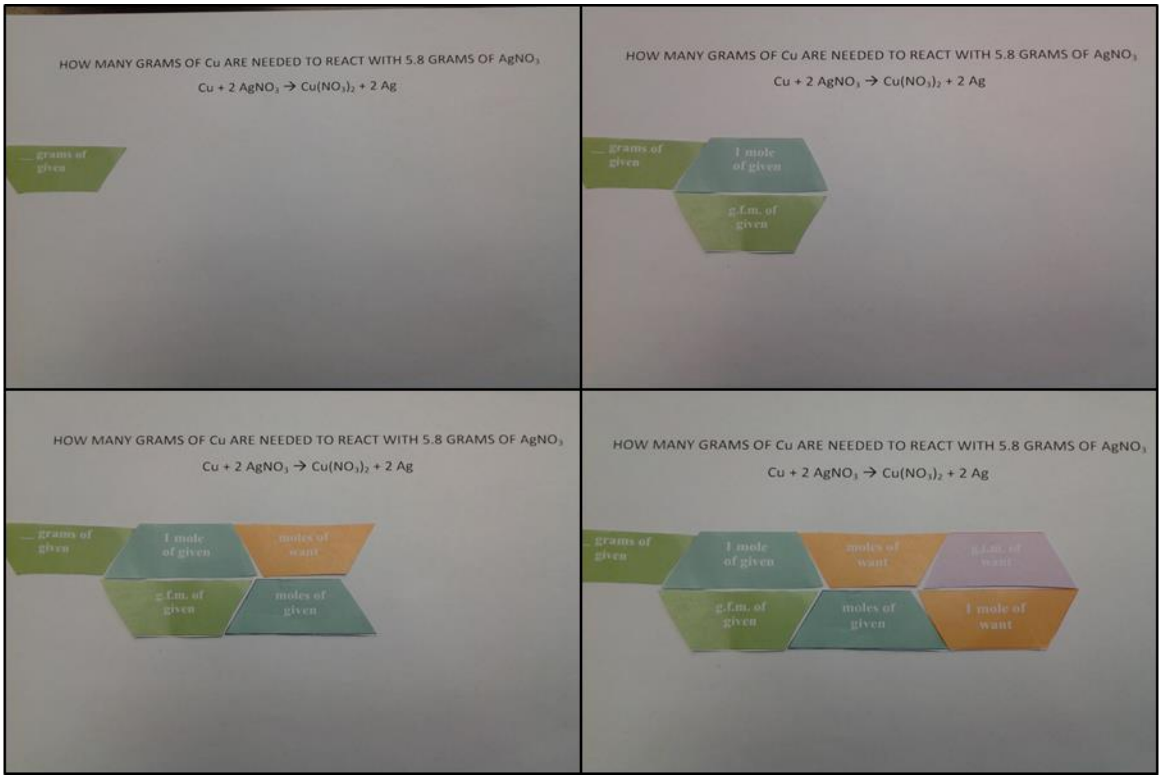

Figure 4. Stoichiometry Activity

RESULTS

The data gathered was used to calculate the mean scores, the uncertainty of the means and the standard deviations. A two tailed *t*-test was used to analyze the differences in the means of the pretest and posttest for each activity. Using the *t*-test, p-values were calculated. A p-value less than 0.05 ($P < 0.05$) indicated a statistically significant difference in the mean scores. The following results describe the data that was collected in the order in which they were covered during the course of a school year.

Dimensional Analysis. Table 1 summarizes the statistics for the Dimensional Analysis pretest and posttest. A total of 14 points were possible on this test. A *t*-test indicated there was no statistically significance between the means of the pretest ($p > 0.05$). Therefore it can be assumed the two groups are not statistically different in their understanding of dimensional analysis before the lesson. However, a statistically significant difference is seen in the posttest means ($p < 0.05$). A *t*-test determined that the Control group had a significantly higher mean on the posttest. The results indicated the two groups are not equal in understanding of dimensional analysis after the lesson.

Table 1. Summary Table Dimensional Analysis Scores*

	Pretest				Posttest			
Group	Mean	SD	UOM	p-value	Mean	SD	UOM	p-value
Control (Group A)	0.50	1.31	0.24	0.08	7.75	3.35	0.59	0.02
Experimental (Group B)	1.12	1.43	0.25		5.61	3.90	0.68	

*Total possible points on test = 14 SD = Standard Deviation UOM = Uncertainty of the Mean

Ionic Formulas. Table 2 summarizes the statistics for the Ionic Formulas pretest and posttest. A total of 10 points were possible on this test. A *t*-test determined that there was no significant difference in the mean scores on the pretest ($p > 0.05$). The two groups were not statistically different in their understanding of Ionic Formulas before the lesson. However, a statistically significant difference is seen in the posttest mean scores ($p < 0.05$). A *t*-test showed the Control group had a statistically higher mean on the posttest. This indicated that the two groups were not equal in their understanding of Ionic Formulas after the lesson.

Table 2. Summary Table Ionic Formula Scores*

	Pretest				Posttest			
Group	Mean	SD	UOM	p-value	Mean	SD	UOM	p-value
Control (Group B)	2.96	1.62	0.31	0.18	7.50	2.03	0.38	0.02
Experimental (Group A)	3.56	1.56	0.31		5.80	2.90	0.58	

*Total possible points on test = 10

Molecular Shapes*.* Table 3 summarizes the statistics for the Molecular Shapes pretest and posttest. A total of 9 points were possible for this test. A *t*-test determined that there was no significant difference in the mean scores on the pretest ($p > 0.05$). The two groups were not statistically different in their understanding of Molecular Shapes before the lesson. Likewise, a statistically significant difference was not seen in the posttest ($p > 0.05$). Neither group had a statistically higher mean score. This indicated that the two groups had no statistical difference in the amount of understanding of Molecular Shapes after the lesson.

Table 3. Summary Table Molecular Shapes Scores*

	Pretest				Posttest			
Group	Mean	SD	UOM	p-value	Mean	SD	UOM	p-value
Control (Group A)	3.14	1.24	0.23	0.37	3.43	1.50	0.28	0.60
Experimental (Group B)	2.86	1.24	0.24		3.21	1.55	0.29	

*Total possible points on test = 9

Stoichiometry. Table 4 summarizes the statistics for the Stoichiometry pretest and posttest. A total of 8 points were possible for this test. A *t*-test determined that there was no significant difference in the mean scores on the pretest ($p > 0.05$). The two groups were not statistically different in their understanding of Stoichiometry before the lesson. Likewise, a statistically significant difference was not seen in the posttest ($p > 0.05$). Neither group had a statistically higher mean score. This indicated that the two groups had no difference in the amount of understanding of Stoichiometry after the lesson.

Table 4. Summary Table Stoichiometry Scores*

	Pretest				Posttest			
Group	Mean	SD	UOM	p-value	Mean	SD	UOM	p-value
Control (Group B)	2.32	1.09	0.21	0.13	3.25	1.78	0.34	0.73
Experimental (Group A)	1.83	1.31	0.24		3.41	1.80	0.33	

*Total possible points on test = 8

Learning Outcomes. Table 5 summarizes the p-values compiled on the mean scores of the pretest and posttest on the treatment groups separately. A *t*-test was conducted and p-values were calculated to determine if there were statistically significant differences in the mean scores of the control group from pretest to posttest. The same statistics were conducted

again for the experimental group. In three of the four activities both groups had statistically significant differences in their mean scores from pretest to posttest ($p < 0.05$). Although the mean scores are not as promising as one would like, the p-values do indicate some learning did occur.

Table 5. P-values from *t*-test on learning outcomes of pretest to posttest mean scores.

Activities	Control	Experimental
Dimensional Analysis	9.52 E-17	4.47 E-08
Ionic Formulas	1.02 E-12	1.36 E-03
Molecular Shapes	0.44	0.33
Stoichiometry	0.02	3.24 E-04

DISCUSSION

The purpose of this study was to examine the effects of manipulatives on Chemistry conceptual understanding. Four activities were conducted over the course of the school year. This study rejected the hypothesis that there would be no difference between manipulatives and peer group work in the Dimensional Analysis and Ionic Formula activities, and the study failed to reject the hypothesis in the Molecular Shapes and Stoichiometry activities. The following sections will discuss the effect of the manipulatives on each topic.

Dimensional Analysis. In the dimensional analysis activity, there was a significant difference in the mean scores according to p-values. The control group had a higher mean score when compared to the experimental group. The control group was more successful at using the correct dimensional analysis. However, it is worth noting, both groups increased in their attempts to try dimensional analysis to answer questions. These two outcomes are similar to the ones found in the study by Saitta et al. (2011). Compared to the pretest, students in this study left fewer questions blank on the posttest. The posttest showed that the experimental group had trouble transferring the information learned using the conversion cards back to completing actual problems. Because the experimental group students did not have as much time completing practice problems without the cards, they had problems completing the posttest without the manipulative.

Ionic Formulas. In the ionic formulas activity, there was a significant difference in the mean scores according to p-values ($p < 0.05$). The control group had a statistically significant higher mean score than the experimental group. The control group was more proficient at correctly determining the correct ionic formula from the compound name. The use of the

interlocking building block manipulative did not solidify the abstract concept of ions bonding to form molecules, into a concrete understanding that would allow students to write ionic formulas. In the future, more effort must be made to help students make the connection between the manipulative and the abstract concept of ionic compounds. For example, some students may not have realized the building blocks represented ions. Furthermore, relatively simplistic concepts may not warrant the use of a manipulative. The crisscross method used with the control group was a quicker and simpler way to work with the concept when compared to the building block manipulative.

Molecular Shapes. In the molecular shapes activity, there was no significant difference detected in the mean scores by the *t*-test ($p > 0.05$). Although the control group had a higher mean, it was not statistically significant. In fact, there were no statistically significant differences observed between the pretest and posttest measurements in both the control and experimental groups. According to Small and Morton (1983), without guided instruction or practice in transferring mental three-dimensional representation of molecules to two-dimensional form, students have difficulty with two-dimensional representations of molecules. The creation of balloon models by students in the experimental group did not efficiently convey the ideas of the structures molecules form, thus presenting challenges when students were required to take a two-dimensional test.

Stoichiometry. In the stoichiometry activity, there was no significant difference measured by *t*-test ($p > 0.05$). Although there was no statistical difference detected, the experimental group had a higher mean score than the control group. Because the groups were flipped in the study, the experimental group for this activity was the control group for the

dimensional analysis activity. This could account for the higher mean scores calculated for the experimental group. Stoichiometry is a difficult topic for students to grasp. The activity was designed to use a “road map” manipulative that would allow students to easily visualize subsequent steps in solving stoichiometry problems. Unfortunately, students expressed a great deal of frustration with understanding the order of the conversions. For example, because of students’ familiarity with time, students could quickly convert from seconds to years. However, students did not have the same familiarity with particles like moles, thus creating confusion when completing stoichiometry problems.

It is interesting to note, that the control group performed better on three of the four activities. In two of these cases the differences were statistically significant. Because of the district mandate to use active learning strategies in all lessons, the control group used problem solving in peer groups as opposed to traditional lecture. Therefore, when compared to another active learning strategy, manipulatives may not see the increased learning outcomes of other studies where manipulatives were compared to traditional lecture. In addition, Group A had higher means on three of the four activities. Group A was the experimental group in the activity where the experimental group obtained the higher mean. At the beginning of the year a Chemistry Benchmark was given to create Student Learning Targets (SLTs), a state requirement for all teachers. A t-test showed that there was no statistical significant difference ($p > 0.05$) between the groups from the benchmark scores. However, Group A appeared to have a better classroom environment, general student performance and motivated attitudes throughout the school year.

In reference to the activities, the dimensional analysis and ionic formula lessons were modeled after studies that had already been designed and tested. The molecular shapes and stoichiometry lessons were derived from a curriculum and a professional development workshop respectively. These activities were not previously tested. Although the null hypothesis failed to be rejected in two of the activities in favor of the control group, the experimental group did experience statistically significant learning gains in 3 out of 4 activities. This indicates that manipulatives are effective teaching tools, but must be strategically designed to produce student achievement.

CONCLUSION

Wise (1996) concluded that innovative science instruction is a mixture of teaching strategies and no one strategy is as powerful as utilizing a combined strategies approach. It can be concluded from this study, that even though manipulatives are better than traditional lecture, they do not produce the same benefits as collaborative practice. Teachers must be equipped with the knowledge of various learning strategies and prepared to use them based on the topic being covered.

In 3 out of 4 activities the experimental group did see increased learning outcomes based on test scores. In future research it would be interesting to test if the effectiveness of manipulatives could be enhanced by redesigning the activities to help the student bridge the gap between physical manipulative and abstract chemistry concepts. It would also be interesting to test if a redesigned manipulative activity, including more time for problem solving in the peer groups, would be more effective than the control group in the current research.

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APPENDIX

IRB APPROVAL

Application for Exemption from Institutional Oversight

LSU

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/irb

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

-- Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-F, listed below, when submitting to the IRB. Once the application is completed, please the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard%28IRB%29/item24737.html

-- A Complete Application Includes All of the Following:

(A) A copy of this completed form and a copy of parts B thru F.
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
(C) Copies of all instruments to be used.
*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
(D) The consent form that you will use in the study (see part 3 for more information.)
(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtraining.com/users/login.php)
(F) IRB Security of Data Agreement: (http://research.lsu.edu/files/item26774.pdf)

1) Principal Investigator: ✓ Jasmine W. Banks **Rank:** Graduate Student

Dept: Natural Science **Ph:** 225-636-2420 **E-mail:** jwbanks9@yahoo.com

2) Co Investigator(s): please include department, rank, phone and e-mail for each
*If student, please identify and name supervising professor in this space
✓ Dr. John B. Hopkins, Professor, Dept. of Chemistry, 225-578-3478, chhopk@lsu.edu

IRB# E8353 LSU Proposal #
✓ Complete Application
✓ Human Subjects Training
✓ IRB Security of Data Agreement

3) Project Title: The effect of Manipulatives on students understanding of Chemistry Concepts.

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 8/1/2016

4) Proposal? (yes or no) NO **If Yes, LSU Proposal Number**

Also, if YES, either
◯ **This application completely matches the scope of work in the grant**
OR
◯ **More IRB Applications will be filed later**

5) Subject pool (e.g. Psychology students) High School Students
*Circle any **"vulnerable populations" to be used**: (children <18; the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature Jasmine W Banks **Date** 1-10-2013 (no per signatures)

**** I certify my responses are accurate and complete.** If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted ✓ Not Exempted ____ Category/Paragraph 1
Signed Consent Waived?: Yes (No)
Reviewer Mathews **Signature** [signature] **Date** 8/2/13

VITA

Jasmine Banks, a native of Baton Rouge, Louisiana, received her bachelor’s degree at Louisiana State University in 2008. She has been teaching science in Baton Rouge and the surrounding area for six years. The desire to be the best science teacher in Baton Rouge propelled her to seek additional education from the Department of Natural Science. She will receive her master’s degree in August 2014 and plans to use her new found knowledge to inspire students to embrace science.