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## Using manipulatives in the Chemistry classroom as a tool to increase the understanding and knowledge of the law of conservation of matter

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# Using manipulatives in the Chemistry classroom as a tool to increase the understanding and knowledge of the law of conservation of matter

## **Abstract**

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In this small-scale study the use of simple manipulatives are used to model the law of conservation of matter when balancing equations. The students use manipulatives to build representations of balanced equations in order to understand the concept. Since atoms cannot be seen, they must be represented by models to facilitate student understanding.

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Using Manipulatives in the Chemistry Classroom as a Tool to Increase the Understanding and  
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By

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**Abstract**

Students at the secondary level have a difficult time balancing equations and comprehending the law of conservation of matter. The law of conservation of matter is a fundamental concept in the chemistry curriculum and is necessary for students to understand more advanced topics. The purpose of this study is to justify the use of manipulatives in the science classroom and to show the increased ability, knowledge, engagement level, and impact of students it has.

In this small-scale study the use of simple manipulatives are used to model the law of conservation of matter when balancing equations. The students use manipulatives to build representations of balanced equations in order to understand the concept. Since atoms cannot be seen, they must be represented by models to facilitate student understanding.

### **Introduction**

The law of conservation of matter is a foundation in the development of chemistry and its understanding is essential for the subsequent understanding of the course. The law of conservation of matter is found within the New York State Education (NYSED) Physical Setting/Chemistry Core Curriculum. Balancing equations correlates and bridges to other concepts within the curriculum. If students struggle with the law of conservation then they will have a higher probability of struggling with other concepts relating to it.

The ability to balance equations is used as an indication of student understanding of the law of conservation of matter. The law of conservation of matter states that under the conditions of a normal chemical reaction, matter can neither be created nor destroyed. Students demonstrate their understanding of the concept by using coefficients to show that a balanced chemical equation has the same number of atoms of each element on both sides of the equation. At the secondary level, students are taught the skill of balancing equations by visual inspection and through the use of atom inventories. Students unable to learn this skill are left further behind when the balanced equations are used for stoichiometric calculations.

During the past six years I have worked as a chemistry teacher at a local Rochester high school. I work with students each day on difficult and abstract material. Many students need additional help to fill in gaps of their understanding of the concepts they learn throughout the year. A high percentage of these struggling students do not have a grasp on the law of conservation of matter and balancing equations. Students struggle with this concept every year. After trying to work with my students on several occasions using the tried and true methods, my students were still unable to complete the skill. I decided that I needed to try something else that would help them grasp the concept.

Instead of only using paper and pens, I pulled out colored paperclips from my desk. The students and I assigned each color paperclip to represent a particular element. Disregarding any structural references, we strung appropriately colored paperclips together to represent chemical compounds. By looking at the number of each color on both sides of the equation, the students could now pick out which equations were balanced and which were not. From there they were able to work toward determining what was needed on each side to balance the equation.

As a result of this experience, I became interested on how to assist my students in understanding balancing equations. My focus in this research was the use of manipulatives in helping students learn the law of conservation of matter, how to balance equations, and to develop their ability to apply the relationship between the two. Specifically, I used manipulatives in the chemistry classroom as a tool to increase the understanding and knowledge of the law of conservation of matter.

I focused and worked with five of my struggling students during homeroom and after school in study sessions during a two week period. The students gave me feedback during the process and after. They completed a survey after the two week period on their thoughts and opinion about the lessons. The data that I collected will help me teach the law of conservation better in order to accommodate all of my students and their learning needs.

## Literature Review

### Introduction

The use of physical manipulatives increases the capacity for students to learn the law of conservation of mass and matter in chemistry. In the New York State Education (NYSED) Physical Setting/Chemistry Core Curriculum, students are expected to “create and use models of particles to demonstrate balanced equations” (NYSED, p.14). Manipulatives are considered models used to teach an abstract topic or difficult content, which can be beneficial to students because the hands-on materials are an active way to learn the subject matter and to increase student engagement for science-related topics. Ueckert and Gess-Newsome (2008) defines science as “the process of making observations, testing ideas, generating evidence, and using that evidence to justify explanations. In short, the scientific process is active” (p. 48). This definition makes science an applicable field for multiple content areas. The authors encourage an active learning process and state that “passive learning can lead to student boredom and apathy. Active learning recognizes that individuals have to engage with the content and with others, unveil prior ideas, make connections between ideas, and construct new knowledge from their experiences” (Ueckert & Gess-Newsome, 2008, p.48). Since science is an active discipline, the manipulatives help facilitate the learning process by allowing the students to visualize atoms that are invisible to the naked eye, which makes the comprehension of the topic easier.

A way to achieve active learning is through the use of physical manipulatives. Many studies have demonstrated that learners are more successful at understanding concepts when manipulatives are used (Gire et al., 2010; Klahr, Triona, & Williams, 2007; Marshall & Young, 2006; McCarthy, 2005; Olympiou, & Zacharia, 2012; Zacharia, Olympiou, & Papaevridou, 2008). According to the National Council of Supervisors of Mathematics (2013) “manipulatives

used in classroom instruction are physical objects handled by individual students and small groups” (p.1). This means physical manipulatives should be used in the classroom because research indicates it’s a beneficial educational tool as it aids learning about abstract ideas. Manipulatives can be used to develop a greater understanding about a concept or idea in chemistry and allow for the use in experimental data and research. Martin, Shaw, and Daughenbaugh (2014) found that “manipulatives give students ‘hands-on’ activities and allows teachers to enforce concepts with their students” (p. 93). There is a wide array of ways to use and implement manipulatives in the classroom.

This paper is organized in four sections. First, I will provide an overview of manipulatives. Second, I will explain how and why they are used in the classroom. Third, I will discuss the use, benefits, and differences between physical and virtual manipulatives. Lastly, I will conclude the paper with how manipulatives can be applied to specific content in the chemistry curriculum, such as teaching about the law of conservation of mass and matter while learning how to balance equations. The overall premise of the paper is to justify the use of manipulatives to increase the ability, knowledge, and engagement level of students in the science classroom.

### **Overview of Manipulatives in Science Classrooms**

The NRC (2011) states that with an inquiry-based approach in science teaching, the expectation is that all students are engaged in the practices and not merely learn about them secondhand. Further, they state that “Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves” (NRC, 2011, p. 30). Research implies that inquiry and hands on activities especially manipulatives are best practices when it comes to teaching science. The use of manipulatives in science teaching helps to achieve two major goals: promotion of students’

understanding about main science concepts and enhancement of students' problem solving skills (Duschl, Schweingruber, & Shouse, 2007). The use of manipulatives and the two main goals that Duschl, Schweingruber, and Shouse (2007) mentioned support the goals of NYSED and the New York State Core Curriculum. Teachers use the core curriculum and prepare students to explain both accurately and with appropriate depth of concepts and models relating to chemistry. Both knowledge of the concepts and practice are essential. The assimilation of science concepts and enhancement of students' problem solving skills will benefit students in the science classroom. Relevant to the field of chemistry, Ozmen and Ayas (2003) define chemistry as:

A branch of science that should be taught with student centered activities, because it contains many abstract concepts which are difficult to be grasped by students. Therefore, hands on activities, audio-visual aids and demonstrations should often be used in teaching. The key to success is ensuring that students are constructing or reconstructing a correct framework for their new scientific knowledge during the instruction. (p.288)

In the above definition, Ozmen and Ayas (2003) are justifying the need for manipulatives in the classroom. This coincides with current trends in the educational practice of teaching science.

The national education reform movement places inquiry at the core of science education (NRC, 1996, p. 105). Bell, Smetana, and Binns (2005) concur and state that "inquiry instruction is a hallmark of the current science education reform efforts" (p.30). There has been a trend in the past 20 years to improve students' knowledge, engagement, and understanding of scientific phenomena. This change has increased the pressure to identify and implement evidence-based and engaging instructional methods. The National Science Education Standards characterize inquiry instruction as involving students in a form of active learning, which includes the use of manipulatives, questioning, data analysis, and critical thinking.

Inquiry is an important path in a student's education and is a meaningful tool to use in daily classwork and activities. It should be a main focus for instruction and can be achieved in the science classroom. According to Doucerain and Schwartz (2010) "instead of students relying on the traditional superimposition of the 'scientific truth,' delivered by the teacher and layered over existing preconceptions, students should start with their own preconceptions and work together to develop a coherent framework to think about topics in science" (p. 121). Doucerain and Schwartz (2010) believe inquiry is a positive learning tool that should be encompassed into the classroom. Classes should not be completely teacher led while students passively take notes and listen. Teacher led classrooms and environments lead to lower engagement, participation, and understanding of content. Traditional classrooms are not as common in the current reform for education and are not as beneficial to students. Manipulatives are a more novel way to incorporate students into an active learning process.

Research from Schwartz and Sadler (2007) says "the issue in traditional classrooms is that the assignments, lessons, and lectures often represent solutions to curricular goals students do not understand or recognize as problems" (p.989). They find that students in traditional classroom settings often resort to memorizing procedures that they cannot apply in new contexts. Ueckert and Gess-Newsome (2008) affirm that learning science concepts involves more than just knowing facts and vocabulary. When students understand content, they not only recognize the main concepts but understand the relationships between these ideas. In their study, students who lack sound understandings of science concepts are not able to use these concepts in everyday situations (BouJaoude, Salloum, & Abd-El-Khalick, 2004). Students need to know more about a concept or idea than just reciting the definition. This research has found that inquiry can lead to a higher development, understanding, and correlation between ideas and concepts.

The NRC (1996) standards document claims that “engaging students in inquiry helps students develop ... an appreciation for ‘how we know’ what we know in science, understanding of the nature of science [and] skills necessary to become independent inquirers about the natural world” (NRC, 1996, p. 105). The research of Ueckert and Gess-Newsome (2008) view inquiry as “a way to engage students in science through the process of making observations, testing ideas, generating evidence, and using that evidence to justify explanations. In short, the scientific process is active” (p. 48). Ueckert and Gess-Newsome (2008) believe that when students are not actively participating they often become bored and apathetic. Manipulatives are a great example of a foundational strategy that can be incorporated with discussion to enhance student learning.

### **Manipulatives in Science Classrooms**

There has been much research about the strength and use of manipulatives in the science classroom and the perceptions teachers have about manipulatives as a teaching tool (Klahr, Triona, & Williams 2007; Marshall & Young 2006; McGinnis 2013; Plass et al. 2009; Swarat, Ortony & Revelle 2012). According to the National Council of Supervisors of Mathematics (2013) manipulatives used in classroom instruction are physical objects handled by individual students and small groups. Klahr, Triona, and Williams 2007 define *physical* to mean real materials such as chemicals, test tubes, laboratory equipment, mechanical devices, and instruments found in the science classroom. The use of manipulatives in the science classroom increases student’s interest. In a study conducted by Swarat, Ortony and Revelle (2012) about students’ interest in science learning teachers and students stated that “activities that were ‘hands-on’ in nature and allowed for engagement with technology elicited higher interest” (p. 515). This can be achieved through the use of manipulatives.

Burns (2007) indicates that manipulative materials help students make sense of abstract concepts, provide students ways to test and verify ideas, are useful tools for solving problems,

and make learning more engaging and interesting by lifting the material off textbook and workbook pages. Using manipulatives is imperative in order for students to grasp more difficult content and ideas that they cannot normally visualize or touch. This is the case in the science of chemistry. Chiu and Linn (2014) state that “visualizations enable students to interact with chemical reactions on a molecular level and allow them to see atoms which are invisible to the naked eye” (p. 37). Without the use of visualizations or manipulatives, students would have a hard time grasping the difficult concepts that they learn in chemistry class.

Teachers are consistently incorporating strategies that will be beneficial to their student’s education. According to McGinnis (2013):

A significant concern of science teachers at all grade levels and contexts is deciding what instructional practices empirical research suggests as effective and/or promising in supporting the learning needs and expected achievement for students across a diverse spectrum of capabilities and challenges. (p. 43)

The research specifies that manipulatives can be used successfully in general and special education classrooms and work for an array of students and learning abilities.

Listening to classroom teachers allows you to gain practical insight into the theoretical benefits of manipulatives. Educators have been using manipulatives in the classroom and understand that they are an imperative tool in the science classroom. Martin, Shaw, and Daughenbaugh (2014) found in a survey that teachers indicated their frequent use of manipulatives included a shown interest by the students, the belief that hands-on activities are beneficial for students, and acknowledgement of differing learning styles among students. One of the teachers responded that “manipulatives and hands on activities are some of the ways science teachers enforce concepts with their students” (p. 93). Teachers use hands on manipulatives in order for every student to become fully engaged in the lesson. Another educator shared that “It is

very motivational to know they will have an opportunity to 'play' with the science" (Martin, Shaw, & Daughenbaugh, 2014, p. 94).

The National Council of Supervisors of Mathematics (NCSM) (2013) states that in order to develop student's proficiency leaders and teachers must integrate the use of concrete and virtual (computer based) manipulatives into the classroom instruction at all ages. NCSM position papers are designed to provide support regarding critical actions that lead to improved student achievement in mathematics. This position of the NCSM (2103) can be accomplished when leaders and teachers understand that "manipulatives are not toys but are powerful learning tools that build conceptual understanding of mathematics" (p. 1). Teachers can implement the use of manipulatives in the general education and special education population with a positive outcome and gain of knowledge for their students.

The use of manipulatives helps the general education population and the special education population as well. The research of McGinnis (2013) found that students with disabilities successfully learned more when taught with adapted activities and materials in a science course. Additionally, McGinnis (2013) reported that students with disabilities overwhelmingly enjoyed the peer based instructional activities more than the textbook instruction. Teachers noted that during the peer based instructional activities, "students appeared more motivated to learn and to participate in class, and demonstrated more on-task behaviors when using hands on activities and manipulatives" (McGinnis, 2013, p. 46). Based on his findings, McGinnis (2013) recommends that science teachers include an activity oriented, inquiry approach rather than a content-oriented approach and make instructional accommodations a regular feature of teaching practices. This supports the usage of manipulatives in the classroom.

### **Using Physical and Virtual Manipulatives**

One of the goals of science education at the secondary level is that students will “actually use the cognitive and manipulative skills associated with the formulation of scientific explanations” (NRC, 1996, p. 173). This advocates the use of manipulatives in the classroom either through virtual use or physical, hands on use. Manipulatives are objects used to help better understand abstract concepts or properties, and are found in two varieties: physical or concrete, and virtual or computer generated manipulatives (Bouck & Flanagan, 2010).

There has been several research studies in the past ten years that have investigated the value of using physical manipulatives (real-world physical/concrete materials) and virtual manipulatives (virtual materials, such as computer-based simulations) in science laboratory experimentation (Zacharia, 2007; Zacharia & Olympiou, 2011; Zacharia, Olympiou, & Papaevripidou, 2008). Research shows that the use of physical manipulatives and/or virtual manipulatives as learning tools has the potential to benefit students and teachers (Bouck & Flanagan, 2010).

Manipulatives enrich the learning process students receive in school. There are benefits to both physical and virtual manipulatives. In a study, Olympiou and Zacharia (2012) concluded that “physical manipulatives can offer students experiences that involve the manipulation of the actual items of a lab experiment” (p. 22). Virtual manipulatives provide students with the ability to manipulate conceptual objects involved in a lab experiment or problem (Olympiou and Zacharia, 2012). As explained in their study, both physical and virtual manipulatives offer guidance, help, and opportunities for students’ conceptual understanding across subjects and age groups. Manipulatives can be used with any grade level with a high success rate. Physical manipulatives and virtual manipulatives offer students “the possibility to inquire into the event

presented, to alter the values of parameters, to initiate processes, to probe conditions, and to observe the results of these actions” (Olympiou and Zacharia, 2012, p. 26).

Manipulatives give students experience with firsthand activities that help them understand mathematical and science concepts they would otherwise struggle with. According to Gire et al. (2010), physical, hands-on science investigations allow students to experience science concepts and ideas directly through experimentation with physical materials and by designing and engineering physical objects. They further argue that through these processes, students can gain experience in planning investigations, collecting, recording, and analyzing real-world data. Science courses allow students to ask questions, discover ideas, and become curious about the world. It gives students the chance to find new interests that they are passionate about and the opportunity to learn more.

Gire et al. (2010) discovered occasions where physical manipulatives were a greater advantage for student learning than virtual manipulatives. They found that physical manipulatives appeared to enhance students’ conceptual understanding more than virtual manipulatives. A recent study suggests that physical manipulative experimentation was found to have an advantage over the virtual manipulative experimentation because physical manipulatives carried the affordance of physical touching and analyzing, which was necessary to understand the science concepts introduced through experiments (Gire et al. 2010). The physical manipulation of data and material engages students at a higher level and provides a wider array of benefits.

The research of Marshall and Young (2006) implies that “scaffolding of the exploration process, whether in simulated or physical environments, should be a part of the pre-service training as well as a classroom practice” (p. 934). They imply that best practices would include the use of physical manipulatives. This corresponds with the research by Ueckert and Gess-

Newsome (2008). Science means more than just knowing the facts and vocabulary (Ueckert & Gess-Newsome, 2008). Students need to be actively participating in the learning and application of science. They state that “science is the process of making observations, testing ideas, generating evidence, and using that evidence to justify explanations” (p. 48). The scientific process is active so students need to be involved with their own education using manipulatives. This is another reason why physical manipulatives are becoming an increasingly popular instructional strategy for teaching abstract concepts in science classes, especially in Chemistry.

### **Using Manipulatives to Support the Law of Conservation of Matter and the Law of Conservation of Mass**

High school students need to be sufficient and knowledgeable in problem solving skills to answer questions in chemistry about the law of conservation of matter and the law of conservation of mass. Conservation of mass and chemical reactions are central to chemistry and serve as the foundation for many topics such as stoichiometry, limiting reactants, chemical equilibrium, and acid/base reactions (National Research Council 2011). The definition of the law of conservation of matter is “the same number and kind of atoms that are present at the beginning of a reaction must be present at the end of it” and the definition of the law of conservation of mass is “when two or more elements or compounds react, the total mass of the products is equal to the total mass of the reactants” (Salta and Tzougraki, 2011, p. 591). An understanding of these laws is necessary because it is a foundation of chemistry curriculum.

Conservation of mass and matter are two areas that illustrate the problems students have with the fundamental law in science. To further this point, “because scientific knowledge in chemistry is based on the understanding of these principles, the shortcomings of education in dealing with these notions unquestionably hinder student ability to progress in the sciences” (Agung and Schwartz, 2007, p. 1680). This concept is an integral part of the chemistry

curriculum but chemistry teachers spend only a few lessons introducing the key concepts, such as chemical reactions and the conservation of matter to beginning learners of chemistry.

Therefore, many students are not constructing appropriate understanding of such fundamental chemical concepts from the very beginning of their studies. As a result of this, not only do they hold many misconceptions about the key concepts, but also they cannot fully understand the more advanced concepts (Ozmen & Ayas, 2003).

Salta and Tzougraki (2011) states that “there are three primary impediments to successful problem- solving; insufficient understanding of concepts involved, the use of memorized algorithms or rules, and the inability to transfer understanding from the atomic level conservation of atoms to the macroscopic level conservation of mass” (p. 605). Since the law of conservation of matter is a basic fundamental part of the chemistry curriculum students need to be able to use this background knowledge as a foundation for new learning. If students cannot transfer the information from one topic to another area in the chemistry field then they will have a difficult time with the course. Problem solving is a substantial part of the chemistry curriculum and is an invaluable assessment tool and gauge for educators. (Salta & Tzougraki, 2011). There are many problems in chemistry where students will need to rely on the law of conservation of matter and mass in order to answer the question. Students will continuously use this information as a guide through the year, again, quite clear, making strong argument for why this part of science is so difficult.

The use of manipulatives increases the ability and knowledge level in learning about the law of conservation of mass and matter in chemistry. Adding to this conversation, Chiu and Linn (2014) explain that “visualizations enable students to interact with chemical reactions on a molecular level” (p. 37) since atoms cannot be visibly seen. They also stated that “Students observe chemical reactions in labs, see molecular pictures of chemical reactions in textbooks,

and use symbols in chemistry to solve math like problems” (p.38). The use of manipulatives supports student learning in Chemistry. Students can more easily conceptualize that atoms are conserved during chemical equations and reactions by examining the visualization of the atoms through the use of manipulatives (Salta & Tzougraki, 2011). Agung and Schwartz (2007) point out that the most important point emerging from their study is:

The fragile and incomplete understanding that students achieve with the principle of conservation of matter. The difficulty that students’ have in applying the principle of conservation to conceptual problems points to a general weakness in the national curriculum’s ability to help students overcome their misconceptions. (p. 1698)

Furthermore, students appear to be ineffective in producing a general understanding of the conservation of matter in questions about balancing equations and solving problems in stoichiometry. There needs to be an additional resource for students to use to assist them with these types of questions. The research of Ozmen and Ayas (2003) further suggests that there needs to be more effective strategies for improving classroom instruction in Chemistry. Their research affirms that “the traditional teaching methods are ineffective and therefore more effective teaching methods need to be developed to help students’ stop rote learning in favor of meaningful learning” (p. 288). It is recommended that a combination of visualizations and instructional support can help students link molecular interactions to relevant chemistry concepts. Research supports the need to incorporate hands on approach when teaching about balancing and the law of conservation of mass and matter. A combination of effective guidance with the inclusion of visualization-based instruction can have a large impact on how students interact with the material and how much students learn (Plass, Homer, & Hayward, 2009).

### **Conclusion**

The use of physical manipulatives when learning how to balance equations increases the ability for students to learn the law of conservation of mass and matter in chemistry. Science teaching emphasizes the learning about main science concepts and the improvement of students' problem solving skills. Students need to be sufficient and knowledgeable in problem solving skills to answer questions in chemistry about the law of conservation of matter and the law of conservation of mass. There has been much research about the strength and use of manipulatives in the science classroom and the benefits it provides. This paper attempts to look at the effects of using manipulatives when teaching about the law of conservation of mass and matter. It is expected that as the above authors found, there will be an increased understanding of the law of conservation of mass and matter through the use of hands-on manipulation of models.

### Methodology

This study is taking place in a large suburban high school located outside the city of Rochester, New York. Enrollment at the high school is approximately 1,282 students in grades ten through twelve. Regent's chemistry is taken mainly by tenth graders but there are eleventh and twelfth grade students in the class. This year, about 225 students are enrolled at the regent's level, with 20-24 students per class. I currently teach three regents chemistry courses and a science elective. I am working towards earning a Master's of Science in Special Education.

This research involved working with five high school students who were unsuccessful at learning to balance equations and the meaning of the law of conservation of matter during the first seven units in chemistry. The students had already completed this topic in class but have not passed the unit exams which cover this concept. The students were invited to participate based on the exam scores for this section of content area and my observations of the students' ability and interest. The students and I met for four sessions as a small group after school and during homeroom. They also met individually with me during this process.

During each session, students worked together in groups of two to three students using colored paperclips as manipulatives to balance chemical equations. (See Appendix A). After finding the ratio of substances in the equation, they wrote the balanced equation and diagrammed it, with colored pencils, on a worksheet. I moved between the groups answering questions and helping out as needed.

The steps of this process was the recognition of what makes a balanced equation, balancing equations with manipulatives, balancing equations with drawings on paper, and transitioning to mental manipulation of the equations and an increased knowledge and understanding of the law of conservation of matter.

On the first day students were given the worksheet, Recognizing Balanced Equations (Appendix A). Each student built the first equation on the worksheet, and then the group discussed what was required for a balanced equation. The students developed several rules that could be used to evaluate equations.

They were then asked to work in small groups to build with paperclips and evaluate the equations listed on the worksheet as to whether they were balanced. At our subsequent meetings, students worked at their own pace to complete worksheets, using the manipulatives (paperclips) as needed. As they completed worksheets they were permitted to advance to the next.

The research includes data and notes taken from sessions, student worksheets, and individual surveys (interviews). The worksheets used in this study focused on the law of conservation of matter and a short session on building molecular models was added on the first day (Appendix A). Notes were taken during the sessions and an evaluation was given to students at the end (Appendix B).

Misconceptions and trends in the way students recognize the law of conservation of matter and their ability to balance equations were identified during and at the conclusion of the sessions.

### **Data Collection**

The data collected was to see if using manipulatives in the chemistry classroom increase students' understanding and knowledge of the law of conservation of matter in regards to balancing equations. The following is a description of each student feelings, reactions, and their ongoing process, while learning how to balance equations using manipulatives. Each student's growth and improvement was observed and evaluated during each study session with the use of worksheets and the final survey (interview).

#### **Chris**

Chris is a reserved and quiet with incomplete abilities. He wants to be successful in the course and is disappointed when he earns a failing grade on an exam or quiz. Chris is shy and does not advocate for himself during class so I thought it would be beneficial and easier for him to work in a smaller group atmosphere.

Chris was silent during the first session while working parallel with another student in his group. He took a longer time to complete the first worksheet and did not use the manipulatives on his own. I had to persuade him and work through the next question with him making sure he used the paperclips. After we completed the question using the manipulatives, he continued to use them to finish the worksheet. He did not correctly balance all of the equations so I went over them with him to see why they were not balanced and to show him how to balance them using the paperclips. Chris seemed thankful and optimistic about the future sessions.

During the second session Chris raised his hand to ask questions when he was having a difficult time balancing equations on the worksheet. He seemed eager to use the manipulatives in order to help him balance the equations.

By the end of the third and fourth session Chris was conscientiously using the paperclips to help him balance the equations. He was able to complete the worksheet more accurately and in less time than the previous sessions. Chris chose to work with the manipulatives during all four sessions.

In the follow-up survey, Chris indicated that he felt the “hands-on” approach to balancing equations helped him and that he thought that I should use this technique when I introduced and taught the topic to class. Chris enjoyed the one-on-one time he received during the sessions, stated that he was more comfortable asking questions during the sessions, and that it was easier to get my attention and help in the small group. He felt confident that he would be able to continue to use this process in future classes and be more successful. Chris was able to define the law of conservation of matter and explain how a balanced equation shows the law of conservation of matter.

### **Moose**

Moose struggles in chemistry but is always willing to put in extra effort in order to do better. He is a hard worker but feels like he “just doesn’t get it.” I felt that giving Moose more time to work on this topic that he finds difficult would help him and improve his knowledge.

During the sessions Moose asked questions to me and the other students at his table. He talked his way through the problems and wanted clarifications and reinforcement that he was balancing the equations correctly. Throughout our time together Moose worked through the worksheets the fastest and did not need to come to the final session.

In the first session, Moose was able to visually determine whether an equation was balanced or not. He was already able to define the law of conservation of matter. Moose was hesitant to use the paperclips to help him balance the equations because he thought that they were baby like. I asked him to work through at least one equation using them and then he could

decide whether to use them or not. After he completed a few questions using the manipulatives he started drawing the molecules out as circles to help him balance the equations using the same rationale as the paperclips.

Moose was successful at balancing equations and finished the worksheets during the third study session. He was very pleased and proud of himself. He told me that he didn't know why he thought balancing equations was hard because it was an easy task.

In the follow-up interview, Moose responded that using the paperclips made him feel "like a baby." However, he thought that his class would have benefited from using this process at the start of the unit. Moose liked the fact that he was given more attention during the sessions and that he felt confident that he could balance any equation that he was given.

### **Chelsea**

Chelsea is a role model to her peers in chemistry. Even though she struggles and is failing the course, you wouldn't be able to tell this because of her positive attitude and work effort. She never gives up and is always trying to improve. Chelsea consistently comes in for extra help so she took this opportunity with enthusiasm.

Throughout the first session Chelsea worked diligently on the first worksheet. She used the manipulatives and drew the substances as different colored circles on her paper. She did not ask any questions during this session but did want me to check her work at the end. Chelsea did not get any of the questions wrong. When she found this out, she gave the biggest smile and was proud of herself. Chelsea told me that she looked forward to our next session.

During the second session Chelsea continued using the paperclips to assist her in balancing equations. She told me that she was worried that she would become dependent on the paperclips and would have a hard time balancing without the manipulatives. I told her that she could stop using the paper clips once she felt comfortable and confident that she could balance

the equations without them. By the end of the second session Chelsea was working without the manipulatives.

Chelsea was eager to continue working on balancing equations during the next few sessions. Her confidence grew in the four study sessions and she began to help out her group and answer their questions if I was not available.

Chelsea attributed her increased understanding of the topics to a combination of the use of manipulatives and the increased time she had to work on the topic. She felt that she might have understood more of the initial classroom presentation of the topic if manipulatives had been modeled and used as an introduction to the law of conservation of matter. Chelsea liked the fact that she was able to see me model how to use the paperclips and then be allowed to have her own hands on experience.

When asked to state the law of conservation of matter in her own words, Chelsea indicated that she had a general idea of the definition saying “matter stays the same, it’s never lost, no matter what the product it.” She was able to further explain that in a balanced equation, the same numbers of each type of atom are on both sides of the equation.

### **Averianna**

Averianna was the most reluctant student in the study sessions. She sees herself as being smart, and not needing any additional help. When I approached her about the sessions, she was unsure as to why I had recommended her for the program because she already understood the law of conservation of matter and how to balance equations. She agreed that she would come to the first session to see how she felt and that after she could decide whether to return for the other sessions.

Averianna showed her impatience with the modeling process of using the manipulatives on the first day. She asked whether she “had” to build the models using paperclips. When she

was told the process was essential to my research, she was willing to participate and use the paperclips but was the first to stop using the manipulatives.

By the end of the first session, Averianna had completed the first two worksheets and was ahead of the group. She confirmed that the coefficient determined how many molecules there were for each substance and she defined the law of conservation of matter as “all atoms stay the same and that none are created or destroyed.” This supported her argument that she already knew what a balanced equation represented.

Even though Averianna only needed to go to the first session, she came back for the second session and completed all of the worksheets. She said it was to help with my research but she was engaged in the material and seemed to feel accomplished when she correctly balanced an equation.

At the end of the sessions, Averianna did not believe that the manipulatives or hands on activity helped her learn the law of conservation of matter better. However, she did think that she gained more from the extra time and practice during the sessions.

### **David**

David has a hard time with the difficult content in chemistry class. He is averaging a 65 for the year and he has been added to an extra chemistry homeroom to help him improve. David is shy and does not advocate for himself. He does not initiate conversations or ask questions on his own but he does respond to teacher initiated discussion and questions.

During all four sessions, David worked quietly and did not ask for any help. Instead, I checked on him after each question to make sure he was completing it correctly and to review the equations he balanced wrong. He not only used the paperclips but he also drew the paperclips on his paper to help him balance the equations.

David tried to wean himself from using the manipulatives during the last session. When he didn't use the manipulatives he tended to get more of them wrong. At the end of the session, he asked me if he could have some of the paperclips so he could use them at home and at school.

In the follow up interview, David indicated that he had already "kind of" known what a balanced equation was but that he had a difficult time balancing it correctly. He stated that he learned best by doing things himself and that he thought that the paperclips helped him balance equations. David said that it was "easier to see" when using the paperclips instead of mentally balancing them like he had done before. He thought that it would have been helpful to learn this process at the beginning of the year when the class first learned about the law of conservation of matter.

### Conclusion

Using manipulatives improved the students' understanding and knowledge of the law of conservation of matter as demonstrated by their ability to balance the equations in the worksheets. Although the students used manipulatives in the work sessions, some were able to work without them by the end, showing that the paperclips helped them improve their balancing equation skills. This indicates that the hands-on experience was useful in advancing their understanding of the concept, as was also found in the studies by Gire et al., 2010; Klahr, Triona, & Williams, 2007; Marshall & Young, 2006; McCarthy, 2005; Olympiou, & Zacharia, 2012; Zacharia, and Olympiou, & Papaevridou, 2008.

The reluctance of some students to use the manipulatives in this study may be attributed to the fact that they had not been previously introduced to the students so they were unfamiliar to them and it made them feel uncomfortable. Interestingly, all students indicated in their surveys that they thought the presentation of manipulatives in their classroom, at the start of the unit, would have been beneficial to their classmates. Additionally, some of the students may have felt that they were singled out because they did not earn good grades or that they did not learn as well, or by the same means, as their peers. This was shown by Moose's response about the paperclips being "baby like."

After observing the students working with manipulatives over four sessions, it appears that the use of manipulatives did help them visualize a balanced equation. The overwhelming response to the interview question about whether this strategy should be used in the classroom was positive. In the future, the law of conservation of matter and balancing equations should be introduced with the use of manipulatives in order to benefit the classroom.

The use of manipulatives during this study can only be considered part of the strategies to support learning. It must be acknowledged that the small group of students involved had teacher

assistance much more readily available to them than they would in a regular classroom setting. In the interview, all students agreed that this was essential to their increased learning.

In addition to the benefits of small group sessions, the students in this study also had additional time to work on and complete the task. The interviews also indicated that students thought this was an important influence on their achievement during the study.

Following the completing of the study, the students involved were exhibiting a better understanding of the meaning of a balanced equation and the law of conservation of matter. I believe that the use of manipulatives made a difference in helping the students learn the topic. In future years I will start teaching how to balance equations using this method.

In conclusion, there is a strong indication that the use of manipulatives did help students increase their understanding of the law of conservation of mass and matter through the use of hands-on manipulation of models. This was demonstrated when they were able to recognize and use the necessary steps for balancing chemical equations and started to articulate their own definition of the law of conservation of matter. Even though the definitions were not complete, they showed an increase from the students' previous understanding.

Future studies on this topic could compare students' knowledge about the law of conservation of matter in class who were taught using manipulatives and students who were taught traditional methods. Additionally, studies could include more students and include a pre and post assessment to evaluate the effectiveness of the study.

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**Appendix A- student worksheets**

Name \_\_\_\_\_

Introduction to the use of Paperclips

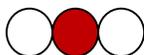
Directions: Use a different colored paperclip for each element.

Build the compounds with the exact number of paperclips for each element shown in the formula.

Do not change the number of atoms in the compound.

Draw colored circles to represent your paper clips.

Ex.



Name \_\_\_\_\_

Recognizing Balanced Equations

Directions: Build the following equations with your colored paper clips as shown below.

Determine whether the following equations are balanced or not.

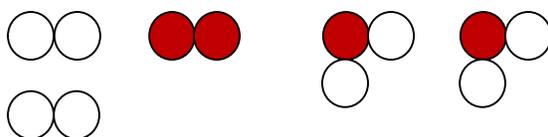
Explain why it is or is not balanced.

Balance the equation if it is not balanced.

**Example**

<u>Equation</u>	<u>Balanced?</u> <i>Yes or No</i>	<u>Reason/Explanation</u>
$\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$	No	There are 2 Oxygen atoms on the reactant side and only 1 Oxygen atoms on the product side.

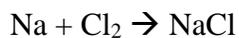
Balanced Equation:  $2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}$



1) Equation

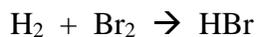
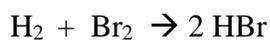
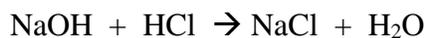
Balanced?

Reason/Explanation



*Yes or No*

Balanced Equation:

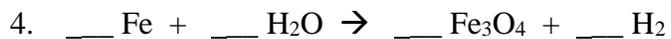
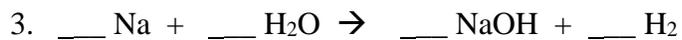
2) EquationBalanced?Reason/Explanation*Yes or No*Balanced Equation:3) EquationBalanced?Reason/Explanation*Yes or No*Balanced Equation:4) EquationBalanced?Reason/Explanation*Yes or No*Balanced Equation:5) EquationBalanced?Reason/Explanation*Yes or No*Balanced Equation:

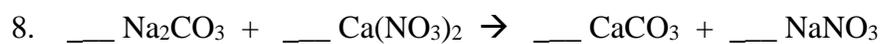
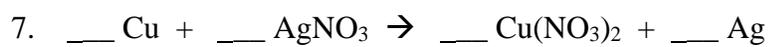
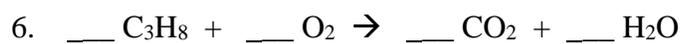
Name \_\_\_\_\_

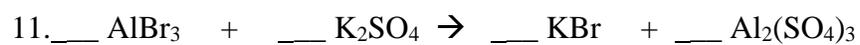
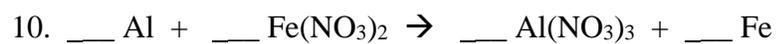
## Balancing Equations

Directions: Balance the following equations.

Use the colored paperclips and draw circles to help you.







**Appendix B- session notes/observations**

Name \_\_\_\_\_

Session Notes/Observations

*Checklist:*

\_\_\_\_\_ Does student use manipulatives to form the reactants and products?

\_\_\_\_\_ Does the student move the manipulatives to try to balance the equation?

\_\_\_\_\_ Does the student ask questions while completing the worksheets?

\_\_\_\_\_ Is the student able to balance the equations?

*Comments:*

**Appendix C- survey/interview questions**

Name \_\_\_\_\_

Survey/Interview Questions

1. Did you feel working with the paperclips helped you to understand the law of conservation of matter and balancing equations? Why or why not?
2. What do you think of the process we used during these sessions? What helped you?
3. Do you think this method would help during your regular class time? Why or why not?
4. Do you consider yourself a person who learns best by seeing, hearing, or doing? Explain.
5. Define the Law of Conservation of Matter in your own words.
6. How does a balanced equation show the Law of Conservation of Matter?