THE EFFECTS OF INCORPORATING VISUAL REPRESENTATION DAILY INTO THE HIGH SCHOOL SCIENCE CLASSROOM

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2022

ACKNOWLEDGEMENTS

During my time in the MSSE program I have received a great deal of support and guidance through my capstone exploration and writing process. I would first like to thank my advisor, John Graves whose guidance through my many questions and vast knowledge of the capstone process was invaluable in formulating my capstone research and keeping me on track to finish in a timely manner. Your feedback and support pushed me to think deeper into my project and brought out a stronger and more focused topic to look at in my own classroom. I would also like to thank my science reader, Elinor Pulcini for agreeing to be my science reader and sparking my interest in microbiology and how it relates to infection disease. Lastly, I would like to thank the Science Department at Colorado Academy for their support and guidance as I navigated completing the majority of my Masters through a pandemic.

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ABSTRACT

The purpose of this study was to determine if student understanding and output on assessments would increase if visual representation, both teacher provided and student created, was used on a regular basis. A sub purpose of this study was to see if student attitudes and interest in the class increased when visual representation was used during the lessons. The same group of students went through a nontreatment unit and two treatment units in a conceptual chemistry course. The nontreatment unit, dimensional analysis, was taught in a more teacher centered way, using more lectures and traditional labs and little to no visual representation, while the treatment units, stoichiometry and solution: Molarity, were taught with daily visual representation, included demonstrations, manipulatives, hands on exploration labs, flow charts, and infographics. Pretest and post test scores for each unit were compared through normalized gains to see if there was an increase from the nontreatment unit to the two treatment units. Statistical testing indicated that students learned chemistry concepts better when visual representation were used during the learning process. The students had higher normalized gains on both treatment units compared to the non-treatment unit. Using visual representations on a regular basis also increased student interest and attitudes towards the content being taught. Students were more curious about the topics as well as had better attitudes about the class and what they were learning when they could see it visually and explore it though hands on explorations.

INTRODUCTION AND BACKGROUND

Context of the Study

Visual representation plays a vital role in the communication of concepts discussed in the science classroom. I have observed that students build a better understanding and retention rate when visual representations are presented in conjunction with the content. Aside from videos and drawings, students have found hands-on labs and student created visual representations helpful in building their understanding of topics that would be otherwise hard to learn from just verbal explanation. I saw much more “ah-ha” moments when they could see how gas molecules were affected in a hands-on lab or when they could see how momentum was conserved in various types of collisions. As a result of this observation, I decided to formally explore how much visual representation can foster student understanding and achievement in the science classroom.

I teach conceptual chemistry, biology and physics at Colorado Academy (CA) in Lakewood, Colorado. Colorado Academy is a pre K-12 private school that has a little over 1000 students total. The program is based on academics, arts, and athletics. Twenty six percent of our students are from racially diverse. backgrounds and that number continues to grow each year. Most students who attend CA are well off, but we do have about 19% of students on some sort of financial aid (https://www.coloradoacademy.org). The classes are small, and students receive ample amounts of teacher attention as well as hands on learning. The students are very motivated to do well in all aspects of their lives and have tremendous support from faculty and staff.

The visual representations I focused on were split into two categories. The first were teacher provided visual representation, such as demonstrations, infographics, and videos and diagrams. The second were student made visual representations, such as manipulatives, inquiry-based labs, and student made drawings/diagrams. I felt this broad range of visual aids would reach the various types of learners I have in my classes. Some visual representations provide a way for students to show creativity and their own understanding of the topics while others are there to support the verbal explanation.

Focus Question

My focus question was: How will using visual representation on a regular basis, both teacher provided and student created, affect my students' understating and achievement in the science classroom? This was based on studies showing words are not enough to build a strong student understanding of many phenomena of science (Cook, 2011).

My sub-question included the following:

1. How will using visual representations affect students' interest and attitude to the topics we are learning in class?

CONCEPTUAL FRAMEWORK

Visual Representation in the Science Classroom

The world around us is filled with scientific wonder, from the cell of a plant to the concept of gravity, we live in a highly complex and mysterious place. Science teachers aspire to teach their students the wonders of our world, exposing them to the ideas of biology, physics, chemistry, geology, and many other topics. Many of the concepts the students observe and investigate in science, whether macro or micro, are difficult to grasp, especially for students new to learning science (Eilam & Gilbert, 2014). Words often are not enough to get students to fully understand the many phenomena of science, and so teachers need to show them the macro and micro levels through visual representations. Visual representations are a vital component to fully communicating science concepts. They can help build a stronger and more conceptual understanding of the science concepts that students may not get from just verbal explanations (Cook, 2011).

Science has always been a challenging subject to teach. Getting students to understand how molecules bond together or why a ball comes back down to earth when thrown, is not easily conveyed. Science teaching, together with mathematics, were some of the first subjects to introduce visual representation into the learning environment (Eilam & Gilbert, 2014). From textbooks rich in pictures to models and demonstrations, science teachers learned early on the value that visual representation brought to the classroom. In the last several decades, visual representation has become more than just a way to help show scientific wonder, but has helped with student's cognition and learning (Cook, 2012).

Visual representation can range in function from being decorative, to acting as representation, to helping with organization or ideas, and to helping see transformations (Cook, 2011). Teachers use visual representation to draw students in and motivate them to help support authentic science inquiry. For example, when introducing properties of water starting with a visual of an insect on the surface of the surface of the water engages students' thinking (Figure 1).

Figure 1. Water strider visual used to help introduce properties of water (Miller, 2017).

Not all functions produce the same cognitive response and research shows that creating cognitive interest through visual representation is more important than creating an emotional interest. Students gain a better understanding from visual representations that have a purpose and are accompanied by text and an explanation then those that are simply decorative and entertaining (Cook, 2011). Scientists have researched the best practices to get the greatest cognitive effects from students, including adding verbal information in the visual representation, integrating verbal ques and the visual aid simultaneously, being carefully not to be redundant, and keeping the visual representation as simple as possible. This guidance can help make visual representation a more useful tool in helping students to better understand the concepts represented (Cook, 2012). An example of a simple but useful visual representation is the illustrated food web (Figure 2). It gives an idea of how the food web works, labeling each area of the habitat. It gives students a visual to look at, with simple descriptions, and allows the teacher to build from it to help student understanding.

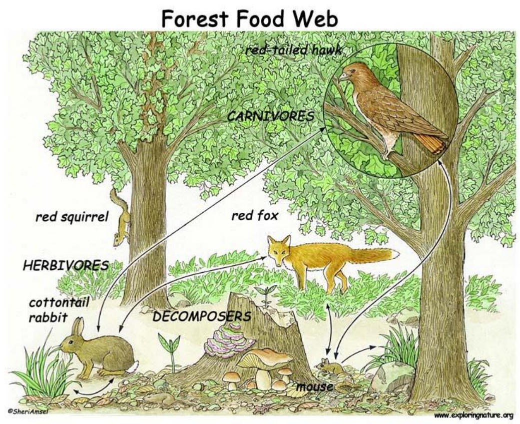

Figure 2. Example of a simple visual aid. It shows a basic forest food web, labeling each component, and giving students something to visualize as the teacher describes the concept (Staake, 2020).

Demonstrations as a Visual Representation

Demonstrations can be an effective tool to engage students and make them curious about the topics they are learning (Morgan et al., 2007). These days, textbook learning is just not enough to get students to fully comprehend concepts, especially in subjects like chemistry or physics. Simple demonstrations can help create cognitive links between what they have previously learned to the new information. They allow teachers to approach teaching concepts in ways that address multiple learning styles. Demonstrations can help build student understanding and problem-solving skills by allowing students to observe, question, and explain what is happening (Meyer et al., 2003). When adding cognitive conflict, such a lightning never strikes the same place twice, into a demonstration the conflicting ideas of what they once believed to be true can encourage students to have conceptual changes and move away from their initial misconceptions. This misconception resolution is critical for students to move their understanding forward (Baddock & Bucat, 2008).

A key component to demonstrations is student engagement, getting them involved in demonstrations purpose, hypothesizing what is going to happen, and having them explain the why of what happened. When teachers engage students in questions before and after the demonstrations, student attention stays on is the critical aspects of the demonstration. By seeing where the topic is leading, students can connect why the topic is important. They can see a whole picture of the process, and the problem being solved and connect it to the information being shared (Morgan et al., 2007). A demonstration is only as good as the follow up. Learning and conceptualizing are shown through the discussion and summarization the content learned during the demonstration (Meyer et al., 2003).

Diagrams used as Visual Representations in Science

Diagrams, such flow charts and models, can be a powerful tool to help students understand topics in science. They are often embedded into course material as a supplement to help students visualize patterns, systems, cycles, scales, structures and functions. They can serve as a way for students to build on their emerging ideas and work through processes better (Ainsworth & Tytler, 2011). Teacher use diagrams to show the how concepts connect or flow from one to the next. For example, geoscience may use diagrams to show the rock cycle to illustrate the changing earth and how the different types of rocks are connected (Figure 3).

Figure 3. Example of diagram. Our changing Earth (Polias, 2016).

Although diagrams are often helpful in providing a visual representation for students, if they are not presented in useful way, it can do more harm, then good. Biology students for example, have shown less comprehension with diagrams then with verbal knowledge of the same content. This often has to do with misinterpretation of the diagram and struggling to comprehend and reason with the visual representation, especially when it is unfamiliar content to them. What does prove useful with diagrams is when the diagrams are of higher complexity and more specific in their information rather than using arbitrary numbers or letters to signify objects (Kottmeyer et al., 2020). It was also found that having students draw their own diagrams, where they explain and justify their process, helps them develop science understanding. Diagrams are best utilized when detailed and specific about the topics being shown, but also when students create their own to show understanding and critical thinking rather than just being shown one to help teachers enhance the concept (Waldrip et al., 2010).

Manipulatives in the Science classroom

Manipulatives are models used to help teach abstract concepts. They can be beneficial to student understanding and give students an active way to learn and engage in the concept with hands-on materials. Manipulatives give students the opportunity to actively learn, which has been shown to help individuals engage better with the content as well as with their peers. This helps to building stronger connections between ideas, and make new knowledge from their experiences (Kirk, 2015).

Studies have shown that a deeper learning of scientific topics is facilitated by non-conventional tools, like model making, videos, and visual moving components (Nordstrom & Korpelainen, 2011). When manipulatives are used with topics that students cannot see or fully grasp, like the molecular process, students understanding increases. Even Watson and Crick, who helped discover the structure of DNA manipulated carboard cutouts of nucleotides to help determine the base-pair bonding which helped them to find the helical structure we know today (Couper et al., 2016). Manipulatives help make abstract or unseen concepts, make sense. They move the notions from words in a textbook or in a presentation into a visual representation that students can use to better understand and engage in (Kirk, 2015). For instance, in chemistry, students can get a better understanding of what ink is made up of and solubility rules by doing ink chromatography (Figure 4). They can better understand what parts of the ink are more soluble by seeing them move up the medium vs. just reading about it.

Figure 4. Black pen chromatography on various types of paper (Bosly, 2018).

Infographics as a Visual Representation

Infographics are a visual representation of information that is quick and easy to interpret. They are becoming more commonly used to create visuals to communicating information and data relating to science, technology, engineering, and mathematics in classrooms and to the public (Gebre & Polman, 2016). Teachers have started to introduce infographics into the classroom more as visual representations and tools for students to display projects (Weidler-Lewis, 2018).

Students have been found to be more engaged in science research and its presentation with the use of infographics (Davidson, 2014). They promote creativity and critical thinking that require students to make sense of multiple sources of data and then condense into a persuasive visual form. As students research and create the infographics, they have to make decisions about concepts, visualizations, and designs which leads to deeper comprehension of the topic (Davidson, 2014). Students have also been found to get more involved because they get to show creativity in their work (Weilder-Lewis, 2018).

METHODOLOGY

The primary purpose of my research was to determine how the addition of daily visual representation, such as demonstrations, flow charts and diagrams, manipulatives, videos and infographics, would help students gain a deeper understanding of the course material and thus giving them stronger outputs on assessments. Specifically, I measured how adding in daily visual representation to a unit impacted students' scores on a posttest compared to pretests. A secondary purpose was to examine how adding visual representation into the class affected students' attitude and interest in the course. I used my findings to determine if adding additional visual aids not only help understanding but attitude and interest towards the class.

Demographics

The nontreatment and treatment was administered to 18 students, ten that identified as female, six who identified as male, and two who identified as nonbinary. They were all in conceptual chemistry at Colorado Academy located in Lakewood Colorado. Conceptual chemistry was taken by sophomores; the students were around 14-15 years old and were students of middle- and upper-class families. Of the 18 students, three were students of color and the rest were Caucasian. The students in conceptual chemistry were often ones who had lower math skills and benefited from additional time to learn and grasp the content. Ten of the 18 students in the class had learning profiles and had accommodations, like extra time, using technology to take notes, and math accommodations. There were no English Language Learners in this class.

The research methodology for this project received an exemption by Montana State University Institutional Review Board and compliance for working with human subjects was maintained (Appendix A). This exemption was approved by my administrator and the Institutional Review Board prior to me starting my research.

Treatment

This research was conducted over three units, one nontreatment and two treatment units to allow for comparison. Due to only having had 18 students in the class, all students participated in the nontreatment and treatment groups. The nontreatment unit was dimensional analysis and the mole which lasted two and half weeks. In the unit the students studied how to use conversion factors to convert units like millimeters to kilometers as well as grams to ounces. They then used the knowledge they gained from basic conversion factors and applied that to the concept of the mole, using the mole to convert from molecules to grams and via versa. This unit was taught in a more teacher-centered manner with one exploratory lab and traditional lectures. The two-treatment units were stoichiometry and solutions: molarity. The students learned about how to convert a known amount of one substance to an unknown amount of another substance and about moles in solutions and how to find the concentration of solutions. The two treatment units lasted approximately three to three and half weeks. The treatment units were taught with daily incorporations of visual representations, like demonstrations, pictures, videos, manipulatives, concept maps and infographics. The nontreatment units were used to compare with the treatment units to determine the effects of visual representation in the science classroom.

Throughout the nontreatment unit, the students learned through lecture and basic pictures, when necessary or provided in the books, but daily visual representation was not added to the lecture notes. Students were given guided notes but no demonstrations, manipulatives, or exploration labs were used to help enhance the content. Students worked with peers to complete in-class practice problems and on traditional labs, ones where explicit directions are given but not much exploration took place. These labs were part of a typical unit, and were intended to give the students an example of what they had been learning in lecture. The lab that accompanied the non-treatment unit was called *What does a Mole Look Like*, a yearly lab all chemistry students did to help students grasp how small a molecule/atom was and how big a number the mole was (Appendix B). Aside from the traditional lab, no other experiments or hands on activities took place in the classroom during the nontreatment unit.

The two treatment units covered conversion of a known amount of one substance to an unknow amount of a different substance as well as molarity. In the treatment unit, each days lesson was accompanied with either a student manipulative activity, animated video explanation, teacher demonstration, infographic or concept map to help give a visual of the learning goals of the day. Each unit still included a traditional lab, but students were asked to include concept maps as part of the lab write ups to help them connect the material together and see how what they were doing in the lab related back to what they had learned in class. On top of the traditional labs, there were also exploration labs or lab challenges, where students were given more freedom to explore the concepts and challenged to dig deeper into the ideas using visual representation. For example, in the stoichiometry unit, students did a design your own lab, where they had to use what they learned about stoichiometry and solubility to figure out a product they wanted to make based on what chemicals were available in the lab. Before students started the wet lab, they had to map out their plan, using pictures, concept maps, and videos of the reactions to figure out what product they wanted to make, how much reactants they need to start and which reactant was limiting them from make more product.

Data Collection and Analysis Strategies

In each unit, formative assessments were given including, sticky note exit slips, flow charts/concept maps, and quizzes (Appendix C). These fell into participation grades as well as quiz grades, which accounted for 15% and 20% of their trimester grades. These are scattered throughout the units and were used to help gauge understanding as we worked through the unit. Examples were provided to help support the data, but no special test was used to analyze the data from these formative assessments.

To assess student learning during both nontreatment and treatment units, pre and posttests called; What do you know about Dimensional Analysis, What Do You Know About Stoichiometry and What Do You Know About Solutions: Molarity and Unit Test: Dimensional Analysis, Unit test: Stoichiometry and Unit Test: Solutions: Molarity, were given at the start and end of each treatment unit (Appendices D-I) All 18 students completed the, What Do You Know About Dimensional Analysis, What Do You Know About Stoichiometry and What Do You Know About Solutions: Molarity and Acid/base Chemistry, as an introduction activity, given explicit directions that this was just to see what they already knew and that it would not affect overall grades but was treated as a comparison of how they grew throughout the unit (Appendices D,E &F). Most students completed the pre-tests within 15-20 minutes. All 18 students completed each Unit test; Unit Test: Dimensional Analysis, Unit test: Stoichiometry and Unit Test: Solutions: Molarity. This test was given in the classroom in a traditional test environment, where they had the class period to complete the test (Appendices G, H &I). Each unit pre and posttest, had the same number of questions and same format of questions but the examples were changed to help ensure that students were not just memorizing answers, but showed the students understood the material. The averages of the pre and posttests of each unit were presented graphically with a whisker and box plot. The test scores were analyzed using normalized gains and common statistics like mean and median. A paired T-test was used to compare the averages between the pre and posttest. The mean and median and paired T-test helped determine the amount of knowledge students gained in both treatment and non-treatment units.

To asses students' learning and attitudes towards the units, non-concept pretreatment and non-concept post treatment interviews, called How do you learn best in chemistry? and How do you Feel you Learned in Chemistry? were given to five students, two boys two girls and one nonbinary student (Appendices J & K). The responses from students were used to support quantitative claims. All interviewees were reminded this was voluntary and did not contribute towards their grade. Interviews were conducted during students' free blocks and I transcribed the students answers during the interview. I choose my interviewees based on which blocks they had free and if they correlated with my free blocks. Students of varying academic ability and backgrounds were equally represented.

At the start and end of each unit, students were asked to fill out a survey called Student Attitude About the Class and Learning Styles Survey (Appendix L). This ten question Likert-Style survey was filled out by all 18 students prior to starting the unit and after they took their unit test. The students were asked to rate each question either, Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), and Strongly Disagree (1). The Likert-scale analyzed qualitatively four categories: overall feeling about science, learning styles, attitude and confidence. There were also two open ended questions at the end. Before the survey was administered, the students were reminded of the voluntary nature of the experiment. Students were given the survey via Google Forms, where they were told their responses were anonymous. Graphical analysis of the Likert data was done using a stacked bar chart, one for each qualitative category. The survey was analyzed using a T-test to see if there were any significant differences between pre and post treatment.

Throughout my research, I took teacher observations when the students were using visual representation. The notes were in the realm of student excitement (or lack thereof) about chemistry class, students participate (or lack thereof) in class discussion, students participate (or lack thereof) in group activities, Questions asked that go deeper into the concept vs. just understanding, Student's attitude/understanding during using visual representation vs. when just normal class. The journal allowed me to track individuals and the class success and challenges through each unit and see what worked for them or what didn't. Excerpts from my journal are shared in the appendix (Appendix M) (Table 1).

Table 1. Data Triangulation Matrix.

Focus Question	Source 1	Source 2	Source 3
Primary: How will the addition of visual representation, such as demonstrations, diagrams, manipulatives, videos and infographics, to help them gain a deeper understanding of the course material so they can produce stronger outputs on assessments?	Pretest: What Do You Know About Dimensional Analysis? Pretest: What Do You Know About Stoichiometry? Pretest: What Do You Know About Solutions: Molarity and Acid Base Chemistry? Unit Test: Dimensional Analysis Unit Test: Stoichiometry Unit Test: Solutions: Molarity and Acid Base Chemistry?	Students' Attitudes about the Class and Learning Styles Survey (Post survey)	Teacher Journals
Secondary: What are the effects of incorporating visual representations, such as demonstrations, diagrams, manipulatives, videos and infographics, on students' interest and attitude in the course?	Students' Attitudes about the Class and Learning Styles Survey (Pre and Post survey)	How do you learn Best in Chemistry? Nonconcert Pretreatment Interview Questions How do you Feel you Learned in Chemistry Nonconcert Post Treatment Questions?	Teacher Journals

DATA ANALYSIS

Results

The results of the non-treatment unit compared to the two treatment units indicated that the incorporations of daily visual representations such as demonstrations, diagrams, manipulatives and infographics impacted the students understanding and outputs on assessments. The mean of the pretest scores in the non-treatment unit was 17.03 and the mean of the posttest in the treatment unit was 30.61. Of the pretest scores in non-treatment unit: 12 students scored below the average and six were average or above (*N*=18). Of the post test scores in the non-treatment unit six students scored below the average and 12 students scored average or above (*N*=18). The non-treatment unit had a pretest median of 17 and a posttest median 32.50 (Figure 5)

Figure 5. Pretest and Post test score distribution for non-treatment unit with points and means shown, (*N*=18).

The mean of pretest scores in treatment unit one: stoichiometry was 13.26 while the mean of the post test scores were 32.01. Of the pretest scores in treatment unit one: stoichiometry 11 students scored below the average and seven were above the average (*N*=18). Of the post test scores in treatment unit one: stoichiometry, eight students scored below the average and 10 student score average or above (*N*=18). The median of the pretest for of treatment unit one: stoichiometry was 12, while the posttest median was 32.38 (Figure 6).

Figure 6. Pretest and Post test score distribution for treatment unit one: stoichiometry with points and means shown, (*N*=18).

The mean of pretest scores in the treatment unit two: solutions: molarity was 11.24 while the mean of the post test scores were 32.10. Of the pretest scores in treatment unit two: solutions: molarity nine students scored below the average and nine were average or above (*N*=18). Of the post test scores in treatment unit two: solutions: molarity seven students scored below the average and 11 student score average or above (*N*=18). The median of the pretest for of treatment unit two: two: solutions: molarity and acid/base chemistry was 12 while the posttest median was 32 (Figure 7). Of the students who were interviewed, one expressed, “The visual aids used during class help me in everything I do in the class, especially the assessments. When you add them into the start of the unit and continue to tie them in throughout, I can use them to connect back to when taking assessments or doing homework, which helps me remember and piece all the material together." As a teacher, I also noticed that during the treatment units, students were asking fewer question during the assessment and had a calmer more confident demeaner to them.

Figure 7. Pretest and Post test score distribution for treatment unit two: solutions-Molarity and Acid/Base Chemistry with points and means shown, (*N*=18).

Comparing the non-treatment mean scores to treatment one mean score, the mean of the pretest was higher in the non-treatment unit compared to both treatment units but the post test scores mean was 1.4 higher in the treatment unit one and 1.49 higher in treatment unit two.

The analysis of students understanding and assessment was done through the difference of posttest normalized gains to pretest normalized gains, 78% of the students had positive gains during treatment unit one and 67% of students had positive gains during treatment unit two. Of those students, during treatment unit one, 28% had gains between 0.5 and 0.75, 44% had gains 0.76 to 0.95 and 28% had gains above 0.95. Of those students, during treatment unit one, 28% had gains between 0.4 and 0.75, 44% had gains 0.76 to 0.95 and 28% had gains above 0.95 (*N*=18). Of those students, during treatment unit two, 17% had gains between 0.4 and 0.75, 61%

had gains 0.76 to 0.95 and 22% had gains above 0.95 (*N*=18). The non-treatments normalized gains and treatment unit one normalized gains were compared using a paired T-Test to see if there was significant difference between the means. The p-value was 0.0124 with a 95% confidence interval, so the null hypothesis was rejected when looking at the non-treatment unit and treatment unit oneThe non-treatment unit normalized gains were also compared to treatment unit two using a paired T-test to, again, see if there were significance between the means. The p-value was 0.0372 with a 95% confidence interval, so the null hypothesis was also rejected when looking at the non-treatment unit and treatment unit two.

The increase in understanding and overall increase output on assessment is further highlighted through the post treatment units Likert survey questions "I feel I do better on assessments due to visual aids being used during my learning process" and "I feel more confident in chemistry when I can see it represented visually." Of the students who took the survey, 83% strongly agreed, 11% agreed, and 6% were neutral that they felt they did better on assessments due to visual representation being used during the learning process (*N*=18). Those scores had significantly increased from the pretreatment unit survey where only 11% strongly agreed, 22% agreed, 39% were neutral and 28% disagreed (*N*=18). Of the students who took the survey, 78% strongly agreed and 22% agreed that they felt more confident in chemistry when they could see it visually (*N*=18). The response increased from the pretreatment unit survey where only 11% strongly agreed, 6% agreed, 67% were neutral and 17% disagreed that they felt more confident when seeing chemistry represented visually (*N*=18) (Figure 8).

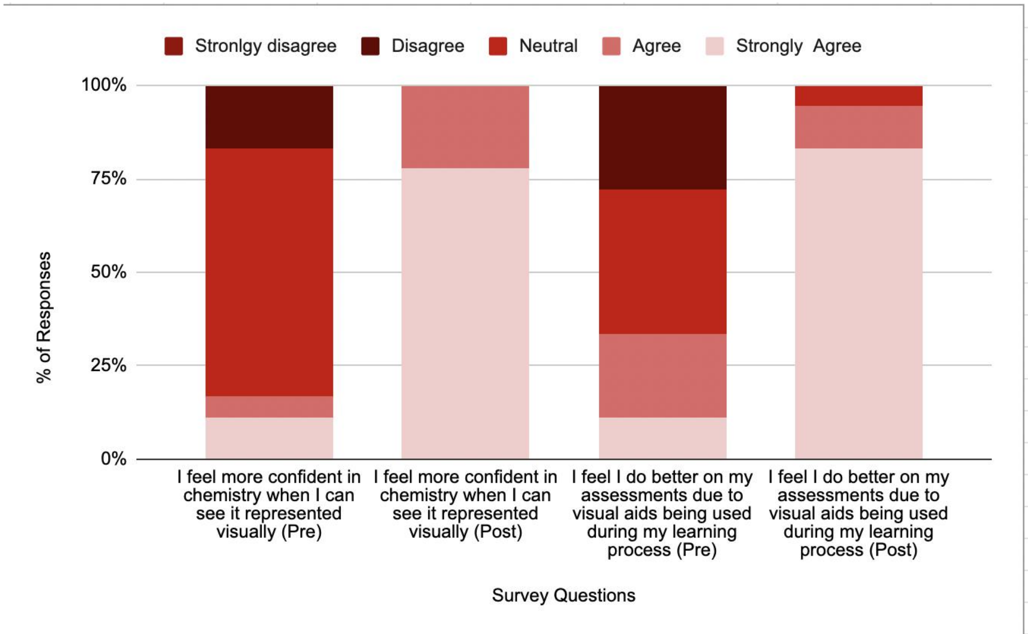

Figure 8. Pretreatment and post treatment survey results to questions relating to confidence in course material when visual representation was used or not used, (*N*=18).

Students were also asked at the end of both the pretreatment and posttreatment survey to describe the topic we were learning. One hundred percent of students in the pretreatment unit put "I don't know or "not sure" when ask to describe stoichiometry. In the posttreatment response, 39% of students use one of the visual aid tools used in the unit to describe stoichiometry. One student said "Stoichiometry is figuring how to get from one thing to another thing, for instance how to get figure out how many M&Ms I need on a snowman compared to marshmallows."

Of the five students interviewed, 80% of them expressed that demonstrations, manipulatives, and concept maps helped them better understand the concepts in the unit. One student said, "Demonstrations are the best, they helped me so much in the Stoichiometry unit and the Solution unit to grasp what you were trying to explain. I think they are a better way to see things rather than just having pictures." Another student expressed, "I think I do better when doing hands on stuff. I like doing labs or hands on explorations as they help me figure out how the grasp the concepts off the paper and get it on my own and in my own time." During the treatments units I also took notes of how students presented themselves coming into the test and preparing for the test. I wrote that during stoichiometry unit, students were much more relaxed coming into the test day, there was less complaining of not be prepared or feeling like they were going to completely bomb the test, but more of a sense of preparedness. As well they spent their review day asking deeper questions that often related back to a visual representation we did in the class or using various visual representation to help them practice for the test, such as manipulatives and concept maps.

The results of pretreatment and posttreatment surveys and interviews showed that the majority of the students were more interested and had better attitudes when visual representation was used on a daily basis. When analyzing students' interest and attitude towards the course when visual representation was incorporated, 72% of students post treatment either agreed or strongly agreed that they liked science vs. only 39% of pretreatment response were either strongly agree or agree. Students' curiosity in chemistry also increased from pretreatment response to post treatment response, where 89% of students either strongly agreed or agreed they were curious vs. only 61% of student's pretreatment. (Figure 9). The pretreatment unit response and posttreatment unit response to both questions related to the interest in science were compared using a T-Test to see if there was significant between the means. The p-value for "I like Science" was 0.016 with a 95% confidence interval, so the null hypothesis was rejected when looking at pretreatment and posttreatment response. The p-value for "I am curious about Chemistry" was 0.0571 with a 95% confidence interval, so the null hypothesis was not rejected when looking at pretreatment and posttreatment response.

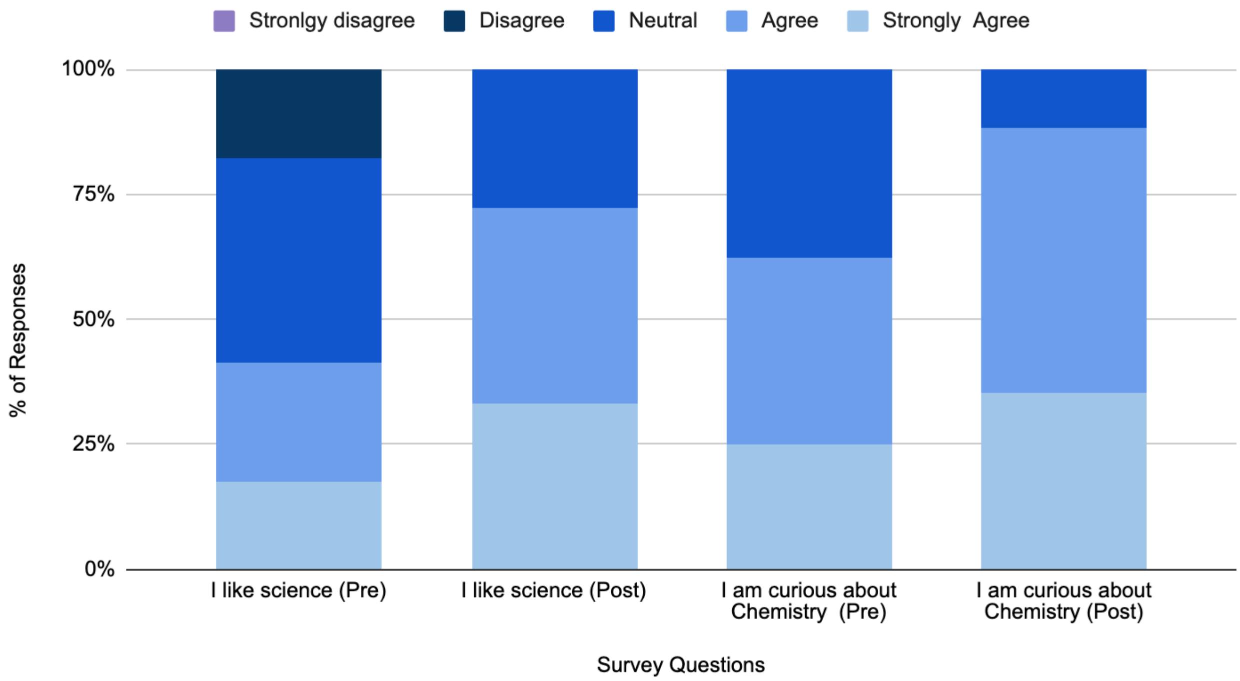

Figure 9. Pretreatment and posttreatment survey results to questions relating to interest in Science and Chemistry, (*N*=18).

Of the five students interviewed, 60% of them expressed they enjoyed chemistry and liked the class. This was a change from the pretreatment interviews where only 20% of students expressed, they enjoyed chemistry. Most of the pretreatment response showed students enjoyed me as a teacher, but the classes were ok or meh. One students' response, pretreatment, was, "It is ok, I mostly show up because you teach it. I do not know if I would give another teacher the effort, I give you and that is because you rock." Comparing that to post treatment responses, one student said, "It's one of my favorite classes. It is something that I understand and I like that. I also feel confident to speak up on class and I have a good time learning, which is largely due to you." Another student said, "It's not my favorite class, but I do enjoy it. I have learned to like it more and more as the year has progressed on, especially the last two units with all the labs and visual stuff." As well, when I look over my teacher observations, students' participation, excitement and willingness to ask questions and be more curious about the topics increased during both treatment units. For example, after the Make Your Own Mini Airbag Exploration to explore stichometry in the real world, we spent 20 min discussing other real-world applications that the students were curious about, such as shampoo, food, deodorant, and rockets and fuel. They wanted to know more about how it applied to what they use every day and were genuinely curious the topic.

The pretreatment and posttreatment survey data also indicated that student attitudes increase when visual representation was used. When analyzing students' attitude towards in the course when visual representation was incorporated, 100% of post treatment response were either strongly agreed or agreed that they had a more positive attitude when visual representations were used to help learning vs. only 33% of pretreatment response were either strongly agree or agree (*N*=18). Students' responses also improved posttreatment regarding discovering concepts through hands on activities. 100% of students either strongly agreed or agreed that they liked that they could discover concept, we were learning in class through hands on activities vs. only 28% of students either strongly agree or agree in the pretreatment survey (*N=18*) (Figure 10). The pretreatment unit response and posttreatment unit response to both questions related to the attitudes towards chemistry were compared using a T-Test to see if there was significance between the means. The p-value for "I like when I can discover the concepts we are learning in class through hands on activities" was 0.00000005 with a 95% confidence interval, so the null hypothesis was rejected when looking at pretreatment and posttreatment response. The p-value for "My attitude towards chemistry is more positive when there are visual aids, like videos, flow charts, hands on labs or pictures to help my learning" was 0.00000004 with a 95% confidence interval, so the null hypothesis was rejected when looking at pretreatment and posttreatment response.

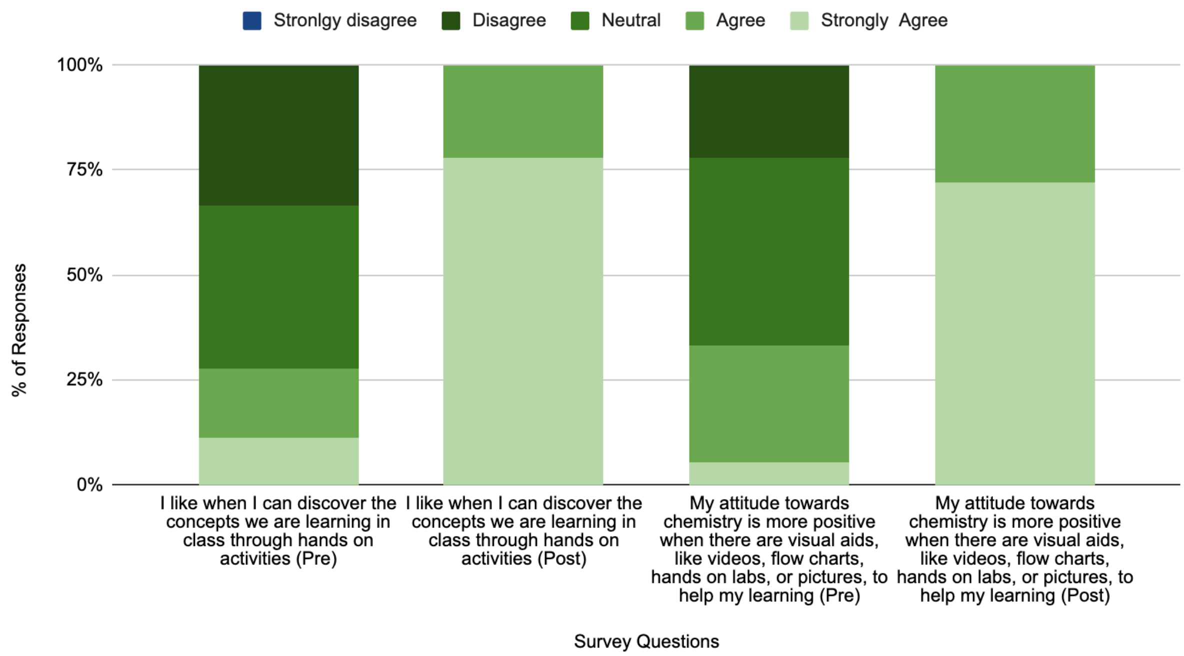

Figure 10. Pretreatment and posttreatment survey results to questions relating to attitudes towards Chemistry, (*N*=18).

Of the five students interviewed posttreatment, 80% of them expressed that their feelings towards the class increased when visual representations were used during their learning. One student expressed "I am more excited about the topics because I can see it and I get to do more than just sit and take notes, I get to explore and move around, at least most of the time." Another student shared, "Manipulatives are helpful and make me feel happy because they allow me to move around during class and play around with the ideas, we are learning rather than just taking notes." As a teacher, I also observed more laughing and enjoyment during the class when visual representation was present. Students were excited and happy to be there, especially when the visual representation was a manipulative or concept map, where they were able to be up and moving around and collaborating with their peers.

CLAIMS, EVIDENCE AND REASONING

Claims From the Study

The results of using visual representation, such as demonstrations, diagrams, manipulatives, videos, and infographics on a daily basis in the science classroom indicated that students' positivity gained a deeper understanding of the course material and gained better references to draw from when thinking of content. Thus, they produced stronger outputs on post treatment assessments compared a traditional science instruction with minimal visual representation present. The non-treatment unit was taught in a teacher centered style, where more lectures were done and less visual representation was used. This means that I used less demonstrations to help explain topics, no hands-on manipulative explorations, and minimal labs were done. The mean test scores and average of gains of post test scores were greater in both treatment units compared to the non-treatment unit. The group of students were the same in the non-treatment unit and both treatment units, helping support that there was an increase in understanding between the nontreatment unit and the treatment units.

In each unit the students were asked to take a similar pre and posttest. The style of questions and value of each assessment were the same, but questions were changes to avoid students just memorizing the answers. In treatment unit one: stoichiometry all students scored below 59% (*N*=18). After the completion of the unit, all students passed the with a mean score of 89% (*N*=18). Looking at the average of gains in treatment unit one: stoichiometry, the class had an average of gains of 0.83. In treatment unit two: solutions all students scored below 42% (*N*=18). After the completion of the unit, all students passed the with a mean score of 89% (*N*=18). Looking at the average of gains in treatment unit two: solutions, the class had an average of gains of 0.84. Comparing the non-treatment average of gains to both treatment units average of gains, there was a 0.11 increase from non-treatment average of gains to treatment unit one average of gains and 0.12 increase from non-treatment average of gains to treatment unit two average of gains. This indicated that students' knowledge and understanding of the material increased from pretest to posttest more in the two treatment units compared to the non-treatment unit. Most students expressed they were able to reference back to the visual representation when they took and prepared for assessment, which helped them better understand the material and perform better on the assessments.

The pretreatment and post treatment survey data were used to gauge students' interest and attitudes towards science and the chemistry class in general. Four questions on the survey were analyzed to see if there was a change in interest and attitudes from the pretreatment survey to the post treatment survey. All questions were done on a Likert scale. The first question was "I like science." Looking at post treatment response, a majority of students either strongly agreed or agreed, that they liked science, which was a positive increase from the pre survey results. Students who were interviewed indicated that they like science better when they could see what was happening vs. just being given notes and asked to do practice problems. This indicated that students' perception of science in general increased when visual representation was added to the unit vs. when the class was more teacher centered and lecture based. The second question was "I am curious about chemistry." A similar increase in strongly agree and agree responses in post treatment survey compared to the pretreatment response indicated that the treatment unit had a positive impact on their curiosity in the class. The third question was "I like when I can discover the concepts we are learning in class through hands on activities. The results indicated that students were more curious about chemistry and liked learning it better when they could visually see the processes and do visual exploration, such as playdoh models, teacher demonstrations, and lab challenges throughout the unit. The fourth question was "My attitude towards chemistry is more positive when there are visual aids, like videos, flow charts and hands on labs, or pictures to help my learning". Student response indicated that adding visual aids during two units drastically increased their attitudes towards chemistry and helped them want to engage and dig deeper. Having observed students during this time, I could see they were more excited and had a more positive outlook on the class on days when they got to do visual representation that got them up and moving, such as labs and stations exploration. Students who were interviewed also expressed that they enjoyed coming to class when they knew we would be doing more hands-on visual representation compared to lecture days. A follow up question was asked regarding their attitudes when visuals were used during lectures. All of students interviewed expressed they enjoyed the lectures better when they had demos or visuals used to help break up the talking or to help enhance the content being learned (n=5).

Values of the Study and Consideration for Future Research

Looking back at the data and overall journey through the action research, the results were very pleasing. Students were able to show a larger increase in understanding from pretest to posttest when visual representation was used in the unit. Students' attitude and interest in the science and chemistry also increased when visual representation was used on a daily basis. Although using visual representation on a daily basis did increase the time it took to get though a unit, students were better able to grasp the content and used the visual representation to reference back to when learning harder content or preparing for assessments. As well students enjoyed the class more when they could do more guided self-exploration of topics through visual representation and could move around and be more active during class rather than just sitting and taking notes.

I did question throughout the process if I had a large enough group of students going through the process. I only had one section of 18 students in chemistry this year so my data came from a smaller pool then I would have liked. Looking back, I would have liked to have had two sections of the class so I could have done a true treatment and nontreatment group vs. doing nontreatment unit vs. treatment units. Although I still think the data was valuable and there was an increase in understanding when visual representation was present, it is hard to truly judge if the nontreatment and treatment units were of similar difficulty thus were hard to truly compare them side by side. I would also like to incorporate more student create visual representation, such as concept maps, simple student done demonstrations and design your own labs.

I would also be curious to see if changing the unit assessments or pairing the unit assessment with visual representation project or design your own labs would have different outcomes in student understanding and scores, as well as attitudes going into the assessment. Since the question is asking about how visual representation impacts students understanding and scores, I would be curious to see how they would perform if the formative assessment was more visual representation-based vs traditional test based.

Impact of Action Research on the Author

Working through this process was an important and valuable experience for me as a younger teacher. It pushed me as an educator to explore my own teaching styles and be more intentional in what I included in the lesson as well as how the content is taught. I realized that some content is better explored via visual representation and allows kids to be curious and explore while some is better taught through a more traditional means. For instance, having students explore molarity through making solutions, finding the concentrations and making observations was more valuable to them and helped them better understand vs. me just trying to explain that molarity is moles per litter. Using visual representation for solution stoichiometry was not as helpful to students and even become more confusing, so that was an area I think more traditional lecture paired with a lab would have been a better approach for them.

This experience also gave me a new insight to the importance of how letting students explore, ask questions, and build curiosity can help them build better skills as students and gain a deeper understanding of the material rather than just giving them the information via lecture or textbook and moving on. Adding visual representation, especially manipulatives and demonstrations was a great way to get students involved in doing and learning science rather than just sitting and learning science. Visual representations did take more time and thus stretched the units out longer, but by the end students had a better understanding, better attitude and more curiosity towards the course then if I had just lectured and moved on. As well, this process helped me gauge the truly important skills and materials that needed to be covered throughout the year and that the class is not about getting through the most content but more about engaging the students, keeping them curious, deepening their understanding and building their skills as science students.

Overall, my big takeaways from doing my action research process are I learned to be more intentional about my lesson planning and incorporating more visual representation into all units. Moving forward I want to establish major goal of the activity or lesson, how I hope to execute the lesson and what I hoped the students to gain from the lesson. With that I hope to continue to learn from and reflect on what goes well and what needs to be improved moving forward.

As well I learned that I can always improve and adapt to how I am are serving my students. I learned this year to be more flexible when it came to timing. If my class needed more time to explore or grasp the content, I worked their needed rather than just pushing through. I also tried to always connect what we had done via visual representation to the more lecture-based lessons or vis versa. In the ever-changing world of education, I need to adapt to new methods to help work with the specific group of students in front of me. I am extremely proud of what I have accomplished and learned through this process and I look forward to continuing to grow as a teacher.

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APPENDICES

APPENDIX A

EXEMPTION MSU INSTITUIONAL REVIEW BOARD

MONTANA STATE UNIVERSITY
Request for Designation of Research as Exempt
MSSE Research Projects Only
(6/16/14)

****
THIS AREA IS FOR INSTITUTIONAL REVIEW BOARD USE ONLY. DO NOT WRITE IN THIS AREA.
Confirmation Date: 12/21/21 Mark T. Quinn
Application Number:
****

DATE of SUBMISSION: 12/ 10 /2021

-Okay as exempt
-MSSE Classroom assessment
-Little/no risk
-Principal approved
-No concerns
MQ 12/21/21

Address each section – do not leave any section blank.

I. INVESTIGATOR:

Name: **Sydney Aaron Finkbohner**

Home or School Mailing Address: **3800 S Pierce St, Denver CO 80235**

Telephone Number: **970-819-6817**

E-Mail Address: **sydney.finkbohner@coloradoacademy.org**

DATE TRAINING COMPLETED: February 28, 2021 *[Required training: CITI training; see website for link]*

Investigator Signature ___*Sydney Finkbohner*______

Name of Project Advisor: (Carl) John Graves

E-Mail Address of Project Advisor: carl.graves@ecat1.montana.edu

II. TITLE OF RESEARCH PROJECT: **The Effects of Incorporating Visual Representation Daily into The Science Classroom**

III. BRIEF DESCRIPTION OF RESEARCH METHODS (If using a Survey/Questionnaire, provide a copy)

To test how visual representation improves students' outputs on assessments and their attitude towards the science class I will be conducting a nontreatment unit and two treatment unit. Through the nontreatment unit, the students will learn through lecture, basic pictures and demonstration when needed, but daily visual representation will not be included. Students will still get the opportunity to work with peers and do practice problems together as well as do labs that are part of the typical unit. In the treatment unit, each day accompanied with the teacher presentation will be either an interactive video, manipulative, demonstration, infographic or concept map, or exploration lab to help give visualization to the topics we will be learning. The treatment unit will still include the typical unit lab and peer work on practice problems.

Before the unit, all students will be asked to fill out a student's attitude survey. The survey questions are done on the Likert Scale (Strongly agree, Agree, Neutral, Disagree, strongly disagree). The question

APPENDIX B

WHAT DOES A MOLE LOOK LIKE- NONTREATMENT UNIT LAB

Lab: What does a mole look like (and taste like)?

This lab will be graded on not only correct calculations, but also the clarity and organization of your data and calculations. Yes, significant figures are important here. And you must show your work. You cannot just put an answer.

Purpose:

Procedure and data:

1. Water:

- Weigh out 1 mole of water. Show work that indicates how you know how much this is.

- Find the volume of this amount of water. Show that amount here.

- The density of water is 1 g/mL. Do the above two pieces of data prove that to be true? Explain.

- How many molecules of water are in this quantity of water?

2. Chalk:

- Weigh a piece of chalk: ____________
- Chalk is calcium carbonate. Write the formula for calcium carbonate: ___________
- Find the molar mass of chalk: ________________

- How many moles of chalk are in the stick of chalk?

- Will one mole of chalk be more or less that one stick of chalk? Find out how many sticks of chalk it takes to get a mole. Hint: Start your calculation with 1 mole and use your above answers as conversion factors.

3. Salt:

- Find the molar mass of table salt, sodium chloride: ______________

- Weigh out 1 mole of sodium chloride into a beaker. Compare its volume to the volume of water in a mole- just decide whether it's bigger or smaller, no need to measure. What does this tell you about the size of sodium chloride molecules compared to the size of water molecules?

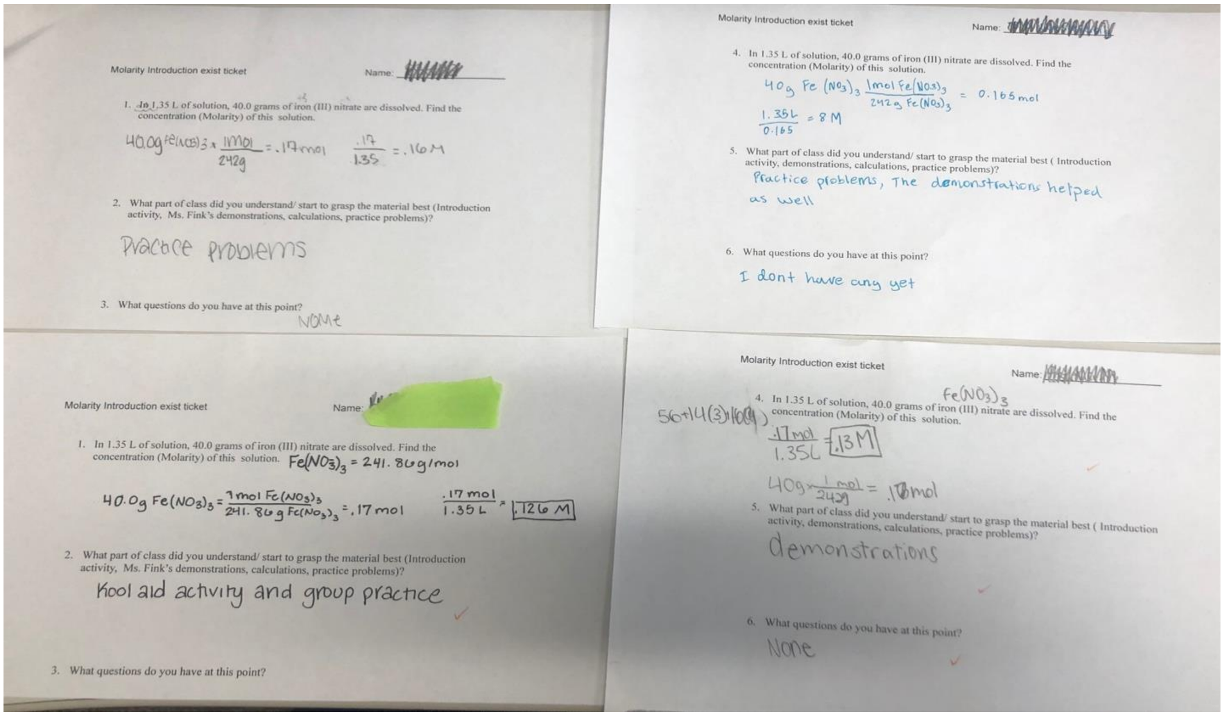
4. Sugar:

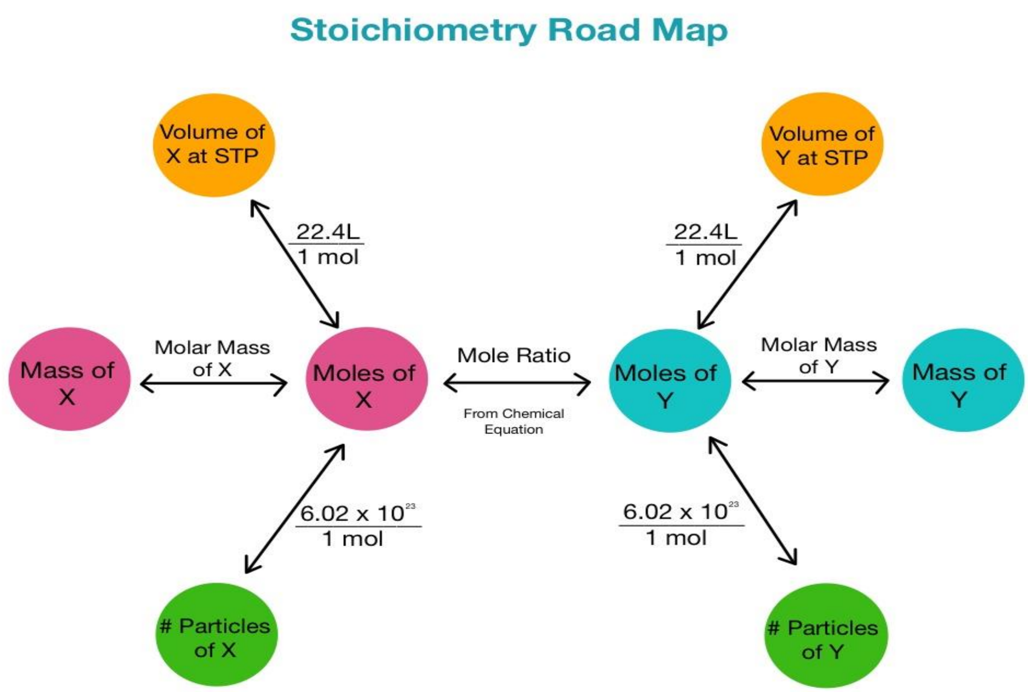
- Find the molar mass of sugar, $C_6H_{12}O_6$: ______________________
- Weigh a piece of candy (if you intend to eat it, keep it in the wrapper). Record the mass. __________
- Assuming the candy is pure sugar, which it almost is, how many moles of sugar are in your sample?
- Is this piece of candy more or less than one mole of sugar? How many pieces would it take to get one mole of sugar? Enjoy!

5. Find the number of chalk molecules in your signature (written in chalk on the sidewalk or lab table). **Show data and calculations that lead to your answer**. You will need to write large and press hard to get enough chalk in your signature to be significant.

APPENDIX C

EXAMPLES OF FORMATIVE DATA: EXISIT TICKETS, FLOW CHARTS, AND QUIZZES


Molarity Introduction exist ticket
Name: [redacted]
1. In 1.35 L of solution, 40.0 grams of iron (III) nitrate are dissolved. Find the concentration (Molarity) of this solution.
2. What part of class did you understand/ start to grasp the material best (Introduction activity, Ms. Fink's demonstrations, calculations, practice problems)?
Pracoce problems
3. What questions do you have at this point?
NOMe
Molarity Introduction exist ticket
Name: [redacted]
4. In 1.35 L of solution, 40.0 grams of iron (III) nitrate are dissolved. Find the concentration (Molarity) of this solution.
5. What part of class did you understand/ start to grasp the material best (Introduction activity, demonstrations, calculations, practice problems)?
Practice problems, The demonstrations helped as well
6. What questions do you have at this point?
I dont have any yet
Molarity Introduction exist ticket
Name:
1. In 1.35 L of solution, 40.0 grams of iron (III) nitrate are dissolved. Find the concentration (Molarity) of this solution.
Fe(NO3)3 = 241.86g/mol
2. What part of class did you understand/ start to grasp the material best (Introduction activity, Ms. Fink's demonstrations, calculations, practice problems)?
Kool aid activity and group practice
3. What questions do you have at this point?
Molarity Introduction exist ticket
Name: [redacted]
4. In 1.35 L of solution, 40.0 grams of iron (III) nitrate are dissolved. Find the concentration (Molarity) of this solution.
.17mol / 1.35L = .13M
40g x 1 mol / 242g = .1?mol
5. What part of class did you understand/ start to grasp the material best (Introduction activity, demonstrations, calculations, practice problems)?
demonstrations
6. What questions do you have at this point?
None


Stoichiometry Road Map
Volume of X at STP
Volume of Y at STP
22.4L / 1 mol
22.4L / 1 mol
Mass of X
Molar Mass of X
Moles of X
Mole Ratio
From Chemical Equation
Moles of Y
Molar Mass of Y
Mass of Y
6.02 x 10^23 / 1 mol
6.02 x 10^23 / 1 mol
Particles of X
Particles of Y

Stoichiometry Quiz:(A) **Name:__________________**

Butane (C_4H_{10}) burns according to the following UNBALANCED equation (that means you better balance it).

C_4H_{10} + O_2 → H_2O + CO_2

1. How many moles of oxygen gas are required to react with 2.40 moles butane?

2. How many grams of water form from 2.40 moles butane burning completely?

3. Find the % yield if 32.8 grams of water are actually formed.

4. If 64.3 g carbon dioxide form, how many grams of butane burned?

APPENDIX D

PRETEST: WHAT DO YOU KNOW ABOUT DIMENTIAL ANALYSIS?

Be sure to put units on your answers and show ALL of your work

A. Convert to appropriate units. Show all of your work if you want credit!!

Conversion Factors can be found on the last page. Please only use those conversation factors provided.

1. A worm crawled 72 cm in a day. How many kilometers is this?

2. A car travels 72.6 miles. How many centimeters does the car travel?

3. A piece of silver weighs 4.5 lbs. Find the volume in L, of this piece of silver?

B. Moles: Show your work on these conversions and put units on your answers.

(Hint: For questions that have molecules, You will need to write out the correct form of the molecule and find the molecular mass)

4. If you had 9.90 x 10^{22} molecules of iron (IV) carbonate, how many grams of iron (IV) carbonate is this?

5. How many **kg** of copper (III) oxide would 0.0560 moles weigh?

6. A piece of slate is used as a pencil to write on a sidewalk. Slate is made of silicon tetroxide. Prior to writing on the sidewalk the piece of slate weighed 10.74 g. After drawing a diagram, the slate weighed 8.48 grams. Find the moles of slate in the drawing.
    a) How many molecules of silicon tetroxide are in the drawing?

7. A large piece of cobalt (III) sulfate weighs 1.2 grams. How many molecules of cobalt (III) sulfate are in the sample?

Useful information:

1 yard = 3 feet	1 mile = 1.609 km	1000 m___ = 1 m
1 foot = 12 inches	Density of silver = 9.5 g/mL	100 c___ = 1 ____
1 pound = .454 kg	Density of silver = 9.5 g/mL	1000 ___ = 1 k____
1 inch = 2.54 cm	Density of gold = 20.3 g/mL	6.02 x 10^{23} “things” = 1 mole
1 mile = 5280 ft	Density of gold = 20.3 g/mL	1 mL = 1 cm^3

APPENDIX E

PRETEST: WHAT DO YOU KNOW ABOUT STOICHOMETRY?

Useful diagram:

gram A – mole A — mole B – gram B

1. $4NH_{3(g)} + 5O_{2(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(l)}$
a) Calculate the number of moles of Oxygen that is required to react with 10 g of NH_3?

b) Calculate the mass of water that is made if you start with 15 moles of Oxygen?

c) Is your answer in part a or part b consider the theoretical yield? Explain your answer

2. 5.65 grams of Calcium Fluoride and Silver Nitrate are mixed to form Silver Fluoride and Calcium Nitrate
   a) Write out and balance the reaction, including states of matter in your answer (s,l g, aq).

   b) Find the grams of participate formed?

   c) If, in the lab, 3.99 grams of participate is formed, find the percent yield

3. A solution of Copper (II) Nitrate reacts with a Solution of Sodium Phosphate to form solid Copper (II) Phosphate and aqueous sodium sulfate.

   a) Write a balanced equation for this reaction. Include subscripts for states of matter (s, l, g, aq).

   b) How many moles of copper (II) Nitrate are needed to produce 0.524 moles of sodium sulfate?

c) How many grams of copper(II) Phosphate will be produced when 400 g copper(II) Nitrate reacts?

Choice #1 (max score of 100%): 5.65 grams of Hydrogen Sulfate and 7.44 grams of Strontium (II) Chloride are separately dissolved in water and then mixed.

Please label your work with the question number so I know what I am looking at.

1. Write out the reaction including states of matter (s, l, g, aq). Identify the participate formed.
2. Determine the limiting reagent
3. Find the grams of precipitate formed.
4. If, in the lab, 5.99 grams of precipitate are formed, find the percent yield.

Choice 2 (max score of 85%): $CaF_{2(aq)} + AgNO_{3(aq)} \rightarrow AgF_{(s)} + Ca(NO_3)_{2(aq)}$

1. Balance the above reaction.
2. You begin with 5.66 grams of EACH starting substance. Determine the limiting reagent
3. Find the grams of Silver(I) Fluorine formed.
4. If, in the lab, 5.25 grams of precipitate are formed, find the percent yield.

APPENDIX F

PRETEST: WHAT DO YOU KNOW ABOUT SOLUTIONS: MOLARITY?

Be sure to show all your work if you want to receive full credit

NO_3^{-1} **PO_4^{-3}** **$C_2H_3O_2^{-1}$**

1. Find the molarity of a solution made from 45.4 grams of magnesium nitrate trihydrate in 560. mL of total solution.

2. How many grams of iron (III) oxide will need to dissolve in 3.25 L of solution to make a solution with a concentration of 1.75 M?

3. 7.75 grams of acetic acid neutralizes 27.5 mL of calcium hydroxide. Find the concentration of the base

4. Find the grams of aluminum hydroxide required to neutralize 250mL of 3.2M hydrofluoric acid

Titration:
You will be performing a titration with oxalic acid dihydrate on an unknown concentration of sodium hydroxide. Remember that oxalic acid is $H_2C_2O_4$. You will use 1.0-1.5 grams of the acid and ABOUT 100 mL of water. **DON'T FORGET THE INDICATOR - the phenolphthalein!** Your goal will be to calculate the concentration of the sodium hydroxide. I will calculate the % error.

1. Write the balanced neutralization reaction (yes this is the same one you have been using though all your practice)

2. Write the unknown letter of your base. _____________

3. Record the mass of oxalic acid dihydrate ____________

4. Record the beginning and ending volumes of the sodium hydroxide. Be clear and put units on your data.

5. Calculate the molarity of the base.

APPENDIX G

UNIT TEST: DIMENTIONAL ANYLSIS

Be sure to put units on your answers and show ALL of your work

A. Convert to appropriate units. Show all of your work if you want credit!! Conversion Factors can be found on the last page. Please only use those conversation factors provided.

1. A worm crawled 72 cm in a day. How many kilometers is this?

2. A car travels 72.6 miles. How many centimeters does the car travel?

3. A piece of silver weighs 4.5 lbs. Find the volume in L, of this piece of silver?

B. Moles: Show your work on these conversions and put units on your answers. (Hint: For questions that have molecules, You will need to write out the correct form of the molecule and find the molecular mass)

4. If you had 9.90×10^{22} molecules of iron (IV) carbonate, how many grams of iron (IV) carbonate is this?

5. How many **kg** of copper (III) oxide would 0.0560 moles weigh?

6. A piece of slate is used as a pencil to write on a sidewalk. Slate is made of silicon tetroxide. Prior to writing on the sidewalk the piece of slate weighed 10.74 g. After drawing a diagram, the slate weighed 8.48 grams. Find the moles of slate in the drawing.
   a) How many molecules of silicon tetroxide are in the drawing?

7. A large piece of cobalt (III) sulfate weighs 1.2 grams. How many molecules of cobalt (III) sulfate are in the sample?

Useful information:

1 yard = 3 feet	1 mile = 1.609 km	1000 m___ = 1 m
1 foot = 12 inches	Density of silver = 9.5 g/mL	100 c___ = 1 ____
1 pound = .454 kg	Density of silver = 9.5 g/mL	1000 ___ = 1 k____
1 inch = 2.54 cm	Density of gold = 20.3 g/mL	6.02×10^{23} "things" = 1 mole
1 mile = 5280 ft	Density of gold = 20.3 g/mL	1 mL = 1 cm^3

APPENDIX H

UNIT TEST: STOICHIOMETRY

You must show your work to receive credit. Read the questions carefully.
Useful diagram:

gram A – mole A — mole B – gram B

1. $2NaOH_{(aq)} + CO_{2(g)} \longrightarrow Na_2CO_{3\,(aq)} + H_2O_{(l)}$
   a) Calculate the number of moles of Carbon Dioxide that is required to react with 10 g of sodium hydroxide?
   b) Calculate the mass of water that is made if you start with 15 moles of carbon dioxide?
   c) Is your answer in part a or part b consider the theoretical yield? Explain your answer

2. When solid iron (III) sulfide is heated in a chamber full of hydrogen gas, solid iron metal and gaseous dihydrogen sulfide are produced.
   a) Write a balanced equation for this reaction. Include subscripts for states of matter (s, l, g, aq).
   b) How many moles of iron (III) sulfide are needed to produce 0.524 moles of dihydrogen sulfide?
   c) How many grams of dihydrogen sulfide will be produced when 400 g iron (III) sulfide reacts?

3. 5.65 grams of copper (II) chloride is mixed with sodium carbonate to form sodium chloride and copper (II) carbonate.
   a) Write out and balance the reaction, including states of matter in your answer (s,l g, aq)
   b) Find the grams of participate formed?
   c) If, in the lab, 3.99 grams of participate is formed, find the percent yield

***You have **two** options for the limiting reagent problem: I will only grade ONE, so don't do all three and have me choose which one is better for you. Think about what you know and what you feel comfortable with and decide. ***

- **Choice 1 is worth a maximum of 100%:** Need to write out reactions and solubility rules will be used.
- **Choice 2 is worth a maximum of 85%:** Reaction is written out for you. No solubility rules needed. You will need to balance the reaction. (can get max 10.25 pt if everything is done correctly)

The options are up front - come and grab the one that you want.

Choice #1 (max score of 100%): 5.65 grams of Hydrogen Sulfate and 7.44 grams of Strontium (II) Chloride are separately dissolved in water and then mixed.

Please label your work with the question number so I know what I am looking at.

1. Write out the reaction including states of matter (s, l, g, aq). Identify the participate formed.
2. Determine the limiting reagent
3. Find the grams of precipitate formed.
4. If, in the lab, 5.99 grams of precipitate are formed, find the percent yield.

Extra Credit Opportunity +2 pt

1. Determine the grams of excess reagent that remains after the reaction is complete.

Choice 2 (max score of 85%): $CaF_{2(aq)} + AgNO_{3(aq)} \rightarrow AgF_{(s)} + Ca(NO_3)_{2(aq)}$

1. Balance the above reaction.
2. You begin with 5.66 grams of EACH starting substance. Determine the limiting reagent
3. Find the grams of Silver(I) Fluorine formed.
4. If, in the lab, 5.25 grams of precipitate are formed, find the percent yield.

Extra Credit Opportunity +2pt

1. Determine the grams of excess reagent that remains after the reaction is complete.

APPENDIX I

UNIT TEST SOLUTIONS: MOLARITY

Be sure to show all your work if you want to receive full credit

NO_3^{-1} **PO_4^{-3}** **$C_2H_3O_2^{-1}$**

1. Find the molarity of a solution made from 45.4 grams of calcium nitrate tetrahydrate in 560. mL of total solution.

2. How many grams of Cobalt (III) oxide will need to dissolve in 3.25 L of solution to make a solution with a concentration of 1.75 M?

3. 7.75 grams of nitric acid neutralizes 27.5 mL of strontium hydroxide. Find the concentration of the base

4. Find the grams of acetic acid required to neutralize 250mL of 3.2M lead (II) hydroxide?

Titration:

You will be performing a titration with oxalic acid dihydrate on an unknown concentration of sodium hydroxide. Remember that oxalic acid is $H_2C_2O_4$. You will use 1.0-1.5 grams of the acid and about 100 mL of water. **DON'T FORGET THE INDICATOR - the phenolphthalein!** Your goal will be to calculate the concentration of the sodium hydroxide. I will calculate the % error.

1. Write the balanced neutralization reaction (yes this is the same one you have been using though all your practice)

2. Write the unknown letter of your base. _____________

3. Record the mass of oxalic acid dihydrate _____________

4. Record the beginning and ending volumes of the sodium hydroxide. Be clear and put units on your data.

5. Calculate the molarity of the base.

APPENDIX J

HOW DO YOU LEARN BEST IN CHEMISTRY?

NONCONCEPT PRETREATMENT INTERIVEW QUESTIONS

This interview is completely voluntary and will in no way affect your grade or class standing.

1. How do you feel about Chemistry? Please explain
2. Why is science important? Please explain
3. How do you best learn (visual aids, lectures, hands on, reading)?
    a. What activate(s) during chemistry class help you learn the concepts the best? Please Explain
4. If you could change one thing about the Chemistry class, what would it be and why?
5. Do you think you would do better in chemistry, worse in chemistry or the same in chemistry if you had more demonstrations to help support the concepts? Why?
6. Do you think you would do better in chemistry, worse in chemistry or the same in chemistry if you had more manipulatives to help support the concepts? Why?
7. Do you think you would do better in chemistry, worse in chemistry or the same in chemistry if you had more diagrams and flow charts to help support the concepts? Why?
8. Is there anything else you would like to add about the science class that you would like me to know?

APPENDIX K

HOW DO YOU FEEL YOU LEARNED IN CHEMISTRY?

NONCONCEPT POSTTREATMENT INTERIVEW QUESTIONS

This interview is completely voluntary and will in no way affect your grade or class standing.

1. How do you feel about Chemistry? Explain
2. What activates during chemistry class help you learn the concepts the best? Explain
3. If you could change one thing about the Chemistry class, what would it be? Explain
4. How was did demonstrations in chemistry make you feel about science? Why?
    a. After seeing a demonstration, do you think you are better understanding the concept, understand the concept worse, or understand the concept the same as you were when you didn't use demonstrations?
5. How was did manipulatives in chemistry make you feel about science? Why?
    a. After seeing a manipulative, do you think you are better understanding the concept, understand the concept worse, or understand the concept the same as you were when you didn't use manipulatives?
6. How was did using concept maps and diagrams in chemistry make you feel about science? Why?
    a. After seeing a concept maps and diagrams, do you think you are better understanding the concept, understand the concept worse, or understand the concept the same as you were when you didn't use concept maps and diagrams?
7. Is there anything else you would like to add about the science class that you would like me to know?

APPENDIX L

STUDENTS ATTITUDE ABOUT THE CLASS AND LEARNING STYLES SURVEY

Pre and Post treatment Survey

Student Attitude pretreatment and Posttreatment Survey

This survey is completely voluntary and will in no way affect your grade or class standing.

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I like Science					
I learn chemistry best when lectured					
I learn science when there are visuals, like videos, hands on activates, or flow charts					
I learn science by reading from a text book					
I learn science by discussing with peers after lectures					
I like when I can discover through hands out activities					
My attitude towards Chemistry is more positive when there are visual aids to help my learning					
I am curious about Chemistry					
I feel more confident in science when I can see if visually					
I feel I did better on my assessments due to visual aids					

1. Please describe what you learned/know about (insert topic here)?

2. Please give an example of (insert topic here) to the best of your ability. You can use words, a drawing, refer to manipulatives you might use, etc.? Why di you choose to present your example in that way?

APPENDIX M

TEACHER OBSERVATIONS JOURNAL ENTRIES

2/9

S. Excitment: less excitment about chemistry but did like playing with food 3. it gave them a good intro

partication: N/A.

groupwork: Worked well with eachother and pickup on ratios well with smaub man

deeper thought: did question relation to chem. currious about how this could relate.
did mention it seemed like cooking.

Attitude: They were great, loved to to hands on 3 food

eager to do the work.

2/11

Excitment: Still excited about food from last class. Excited to see it coming back to class stuff (chem.)

purtiation: Student engaged in qustion about 15-16 students working to connect the showman to the stociometry
· enjoyed talking toperes about.

deeper: not quite at level to guge this

Attitude: Averge. class was a bit more lecture but still present and hadency