THE 5E MODEL OF LEARNING

IN A CHEMISTRY CLASSROOM

by

Mercedes Lippert

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

I would like to thank Kittatinny Regional High School for supporting professional development and making this degree possible. Thanks also to my chemistry classes during the 2021-22 school year at Kittatinny, who beared with me during my research project. Thank you to Dr. John Graves, my project advisor, and to Dr. Amanda Mattson, my science reader. And last but not least, I would like to thank my family, especially my husband Ernesto, who encouraged me through this process, and my adult kids, who are the lights of my life: Mechu, Patrick, and Ernesto.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The 5E model of learning includes five stages: engage, explore, explain, evaluate, and elaborate. The focus of my action research was to study the effect of the 5E model of learning on student learning and retention in chemistry. The study also investigated its effect on students' attitudes towards science and inquiry. During the duration of the study, two chemistry units were taught to two high school chemistry classes consisting of a total of 35 students. One class was taught one unit with the 5E model while the other class was taught using traditional methods, and then the classes were swapped for the next unit. Average test scores among treatment and non-treatment groups were not very different. However, lower-level students largely benefitted from following the 5E model. Students' attitudes towards science and inquiry improved after treatment. I'm looking forward to further incorporating the 5E model in a chemistry classroom throughout the school year.

INTRODUCTION AND BACKGROUND

Context of the Study

I'm a science teacher at Kittatinny Regional High School (KRHS) in Newton, New Jersey. KRHS is a regional school serving five districts: Fredon, Hampton, Sandyston, Stillwater, and Walpack. It is a public school which had 903 students in grades 7-12 during the 2019-2020 school year, according to the New Jersey Department of Education Report Card. During that same year, 51.0% of the students were female while 49.0% of the students were male, with less than 1% of students being non-binary and/or of undesignated gender. About 12.0% of the student population is economically disadvantaged, 13.5% of students have disabilities, 0.9% of students were homeless, and there were no English Learners at that time. That school year, 91.5% of students were White, 5.3% Hispanic, 0.7% Black or African American, 1.3% Asian, 0.3% Native American or Pacific Islander, and 1.0% belonged to two or more races. Out of the 903 students, 16 of them were shared-time students with Sussex County Technical School (Official Site of the State of New Jersey, Department of Education, 2020).

I have taught at KRHS for the past twelve years, which is all of my teaching career. My schedule changes from year to year depending on class numbers and the needs of the school. I have taught different levels of introductory physical science, college prep biology, seminar in science, college prep chemistry, Chemistry in the Community, and Advanced Placement (AP) Chemistry.

KRHS has nine forty-minute periods per day with five minutes in between classes. Home room is part of the first period, making it a few minutes longer when announcements are short, and ninth period is one minute longer for end of the day announcements.

The state of New Jersey adopted the Next Generation Science Standards (NGSS) in 2014. Our school has been slow in adapting to these new standards. Some teachers have adapted a few lessons, but no one has fully transitioned to the NGSS. I think that the 5E model is a great tool that can help me integrate phenomena and storylines aligned to the NGSS.

Focus Statement/Question

My focus question was, How does using the 5E model of learning impact student learning and retention in chemistry?

My sub-question was the following:

1. How does the implementation of the 5E model affect students' attitudes towards science and inquiry?

CONCEPTUAL FRAMEWORK

History of the Development of the 5E Instructional Model

The 5E instructional model is grounded on the constructivist learning theory, which states that students build or construct new ideas on top of their old ones (Tonseenon, 2017). The model originates from cognitive psychology, which is the branch of psychology dedicated to studying mental processes (Duran & Duran, 2005). This instructional practice is also based on best practices in science learning, which among others, include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics, information and computer technology, and computational thinking, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information (Llewellyn, 2013).

Around the turn of the 20th century, the German philosopher Johann Friedrich Herbart thought that the main purpose of education was the development of character, and that this process begins after sparking students' interest. He suggested that conceptual understanding and interest are fundamental to teaching, and that there are two types of interest: one based on social interactions and another one based on interactions with the natural world. Herbart's instructional model, therefore, starts with the formation of concepts by allowing students to discover relationships between what they already know, and new ideas presented to them, in which the teacher serves as a guide. In the next step the teacher explains ideas and concepts, and finally the students demonstrate their knowledge by applying the concept to different situations. His model has been used for more than 100 years, and it is one of the first methodical pathways to teaching (Bybee et al., 2006).

In the 1930s, John Dewey introduced an instructional model based not only on experiences and prior ideas but also on reflective thinking. In this model, the teacher presents students with a confusing or perplexing situation, helping them to identify the problem, and allowing the students to form a hypothesis and test it before arriving to a conclusion (Bybee et al., 2006).

After Dewey, and during the era of curriculum reform in the United States in the 1950s and early 1960s, other models of learning surged. One of these models, developed by Robert Karplus and J. Myron Atkin, was based on guided discovery. This model, adapted by the Science Curriculum Improvement Study (SCIS), has three phases: Exploration, Invention, and Discovery. In the mid-1980s, the Biological Sciences Curriculum Study (BSCS) developed the 5E instructional model, in which the three phases of the SCIS model essentially became its three middle phases (Bybee et al., 2006).

The 5E Instructional Model

The 5E instructional model, as its name implies, consists of five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. During the first stage of the model, Engagement, the teacher presents a question, event, or problem in order to spark students' interest. Once students are engaged, they feel the need to Explore. During exploration activities the teacher acts as a facilitator while students are actively involved in the activity. For the next phase, students give their own Explanations with the help of the teacher. It's important for students to be involved in other experiences that Elaborate the concepts learned, transferring concepts to new situations or problems. Finally, students show their newly acquired skills or understanding through Evaluation (Bybee et al., 2006).

This model is very dynamic, as it's often necessary to go through different stages a few times before going forward. This also allows for flexibility, as teachers may want to provide additional engagement before starting a different phase of the cycle. The 5E model is cyclical in nature, and it supports learning as a continuous process (Figure 1) (Duran & Duran, 2005).

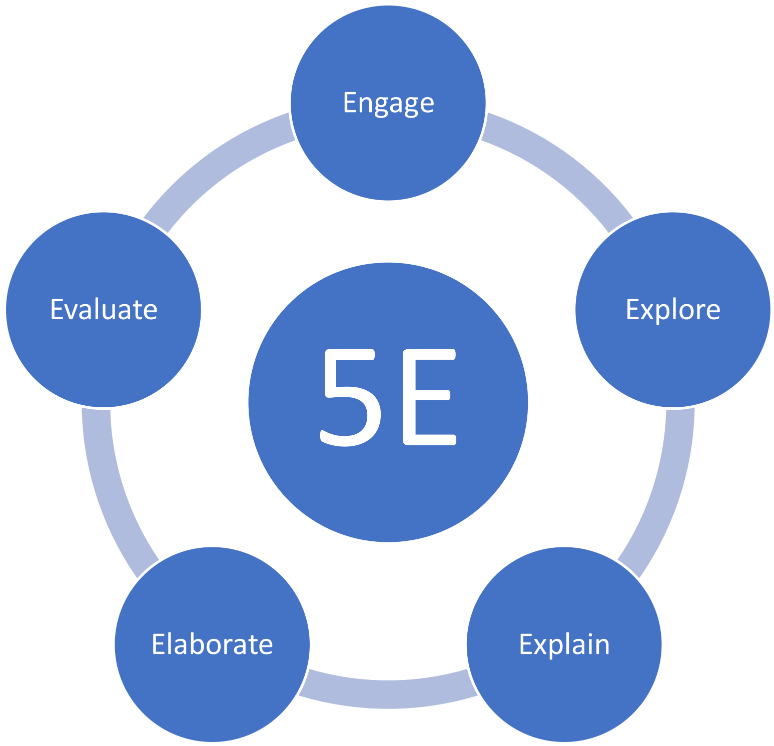

Figure 1. Cyclical nature of the 5E model – Adapted from Chitmann-Booker & Kopp, 2013.

<u>Phases of the 5E Model</u>

The 5E model may be applied to a single science lesson, a unit of study, or even an entire semester or yearlong curriculum (Bybee et al., 2006). The five phases are Engagement, Exploration, Explanation, Elaboration, and Evaluation. The following summarizes the purpose of each phase and gives examples of activities that could be done during each of them (Table 1).

Table 1. Summary of the 5Es.

Phase	Purpose	Examples
Engagement	• Generate interest • Stimulate curiosity • Raise questions • Tap into prior knowledge	• Asking a question • Showing a discrepant event • Defining a problem
Exploration	• Investigate questions to propose solutions	• Hands-on activities • Conduct experiments • Do simulations
Explanation	• Learning facts and information • Students explain with the help of the teacher	• Student presentations • Reading assignments • Teacher lecture • Guest speaker
Elaboration	• Build concepts • Transfer of knowledge	• Additional hands-on activities • Use of media sources • Asking questions
Evaluation	• Assess understanding	• Summative test • Project

Use of the 5E Model in Science

The 5E Model has been widely used since its inception in the late 1980s due to several reasons. It gives teachers a way to be more effective in the classroom, it is easy to use, and it aligns itself with the natural process of learning (Bybee, 2015). Students whose teachers use the 5E model of instruction show more engagement in learning activities and take more responsibility for their own learning (Chitmann-Booker & Kopp, 2013).

The quantitative and qualitative demands of today's science standards and curricula can easily be met through the use of the 5E model of instruction. The 5E model supports inquiry in the science classroom, which is beneficial to students. In order for students to be confident, competent, and productive citizens, they need to be able to communicate and collaborate with others, apply critical thinking, and be creative. The 5E model gives students the opportunity to develop these 21st century skills and become scientifically literate (Chitmann-Booker & Kopp, 2013).

Use of the 5E Model in Chemistry

Chemistry plays a vital task in our daily life, and everyone should appreciate the role that chemists and the chemical industry have in it. For this to happen, an essential understanding of chemistry is necessary, but many students feel that chemistry is hard to learn. This is especially true when students' attitudes are not conducive to learning. Even though there has been a lot of research on chemistry education, a typical chemistry classroom still consists of students passively listening to a teacher (García-Martínez & Serrano-Torregrosa, 2015).

There have been several studies in which the 5E model has been applied in chemistry classrooms. Although one of these studies found the 5E learning model to be more effective in improving student achievement but no difference in students' attitudes towards chemistry (Sen & Oskay, 2016; Supasorn & Promarak, 2015), others (Kiser, 2021) did find significant improvement in both areas, while others had mixed results in student understanding of chemistry (Watt, 2013); further studies found a decrease in misconceptions (Salyani et al., 2019). Holloway (2015) recommends chemistry teachers to utilize the 5E model instead of traditional teaching methods.

METHODOLOGY

Demographics

Kittatinny Regional High School (KRHS) is a 7-12 school located in a fringe rural area in Sussex County, specifically in Newton, New Jersey. KRHS is a regional high school serving five districts: Fredon, Hampton, Sandyston, Stillwater, and Walpack. It is a public school which had 986 students during the 2021-2022 school year, spread out throughout the five grades. More than 90% of the student population is white, 5.3% is Hispanic, 1.3% is Asian, and 0.7% is Black or African American. Typically, about 50% of students in KRHS go to a four-year college and about 30% enroll in community college, with the rest of them going into the military or directly into the work force (NJ Department of Education, 2020).

During the 2021-2022 school year I had two chemistry college preparatory classes which consisted of 34 students in total (19 in my 7th period class and 15 in my 9th period class). Two students in my 7th period class had an individualized education program (IEP) and two other students had a 504 plan. Two students in my 9th period class had a 504 plan.

Treatment

The research methodology for this project received an exemption by Montana State University’s Institutional Review Board and compliance for work with human subjects was maintained (Appendix A). The goal of my research project was to evaluate student learning and retention in chemistry using the 5E Model of Learning and to study its impact on students’ attitudes towards science and inquiry. My action research project spanned two units during parts of the second and third marking periods of the 2021-2022 school year. For one of the units, my 9th period class was taught in my traditional way and the 7th period class followed the 5E Learning Model, being this the treatment class. For the other unit, the treatment class was swapped; my 9th period class used the 5E Learning Model while the 7th period class was taught as I normally taught.

During the 5E units, students on the treatment class were introduced to a phenomenon as part of the Engagement part of the model, and then they went through the other parts of the cycle (Explore, Explain, Elaborate, and Evaluate) with the teacher as a facilitator. The non-treatment class was exposed to more traditional teaching practices, in which the teacher lectures and presents information from that unit.

Data Collection and Analysis Strategies

I collected data from the following instruments:

- Pre/Post Summative assessments for each of the units covered.
- Pre/Post Science Attitude Likert survey.
- Student surveys.

We covered two units during the time my action research plan was implemented, Ionic Bonding and Compounds and Covalent Bonding and Compounds, with Metallic Bonding as a mini project in between them. These units included bond formation, properties of compounds (bonds), naming and writing compounds, etc. We had pre- and post-assessments for these units, consisting both of multiple-choice questions as well as open-ended ones.

Students in both classes were asked to take an Ionic Compound Pre-Test, which had ten multiple-choice questions and ten open-ended questions. The same Ionic Compound Post-Test was taken after completing the unit; it was worth 30 points (Appendix B). Normalized gain and other statistics like mean and standard deviation were calculated using information obtained from these pre- and post-assessments. A box and whisker plot was made with the data. Finally, a t-test was used to compare results from the treatment vs. non-treatment classes.

For the second unit, students took the same Covalent Compound Pre-Test and Post-Test. This quiz was worth 15 points and it consisted of three multiple-choice questions and eight open-ended questions (Appendix C). Normalized gain and other statistics like mean and standard deviation were calculated using information obtained from these pre- and post-assessments. A box and whisker plot was made with the data. Finally, a t-test was used to compare results from the treatment vs. non-treatment classes.

For added data analysis, treatment and non-treatment groups were further divided into a lower-level and a higher-level subgroup, based on their pre-test scores. In general terms, if the pre-test score was less than 10%, the student was classified as a lower-level student, and if the student had a higher score, they were classified as a higher-level student. Average post-test scores were compared.

The Science Attitude survey I used was a Likert type survey with twelve questions and a scale of 1-4, where 1 meant strongly disagree, 2 meant disagree, 3 meant agree, and 4 meant strongly agree. Each question had a follow-up open-ended question asking students to explain their answer, making the survey twenty-four questions long. This survey, therefore, was analyzed for Likert-type questions (scale 1-4) and open-ended questions (qualitative). The same Science Attitude survey was used before and after treatment in both classes (Appendix D). The Science Attitude survey gathered data on students' attitudes towards science and inquiry. Distribution of results for each of the questions was found and these distributions were analyzed. Qualitative data from students' open-ended answers was grouped into different categories.

Finally, student surveys were conducted after doing the Post-treatment Science Attitude Survey. The survey questions were specifically directed to the 5E model of learning vs. traditional learning, including what students liked better, their favorite activity or activities from each of the units, and what they thought of the 5E model. Different questions were asked to my students in 7th period (Appendix E) and 9th period (Appendix F) due to the different units in which they had the treatment. These surveys were used to look for patterns and grouped into different categories. The data collection instruments are summarized in the triangulation matrix shown below (Table 2).

Table 2. Data Triangulation Matrix.

Focus Question	Data Source 1	Data Source 2	Data Source 3
How does using the 5E model of learning impact student learning and retention in chemistry?	Pre/Post Assessments (Ionic & Covalent)	Science Attitude open-ended questions	Student Surveys
How does the implementation of the 5E model affect students' attitudes towards science and inquiry?	Science Attitude Likert-type questions survey	Science Attitude open-ended questions	Student Surveys

DATA ANALYSIS

Results

Test scores in post-tests increased significatively for the Ionic Compounds and Bonds Unit in both treatment and non-treatment groups. The average score out of 30 points for post-tests in the treatment group increased from 4.47±2.01 to 20.84±5.80 (*n*=19), while in the non-treatment group it increased from 2.87±1.41 to 21.53±6.24 (*n*=15). The normalized gain expressed as the average of gains for the post-test in the treatment class was 0.64±0.25, while this same measure for the non-treatment class was 0.69±0.22, which means that in both cases there was a medium gain (Hake, 1998). A t-test of averages for post-content test scores compared to pre-content test scores in both treatment and non-treatment groups for both units showed significantly higher scores in 95% of students ($p<0.05$, *N*=34) (Figures 2 & 3).

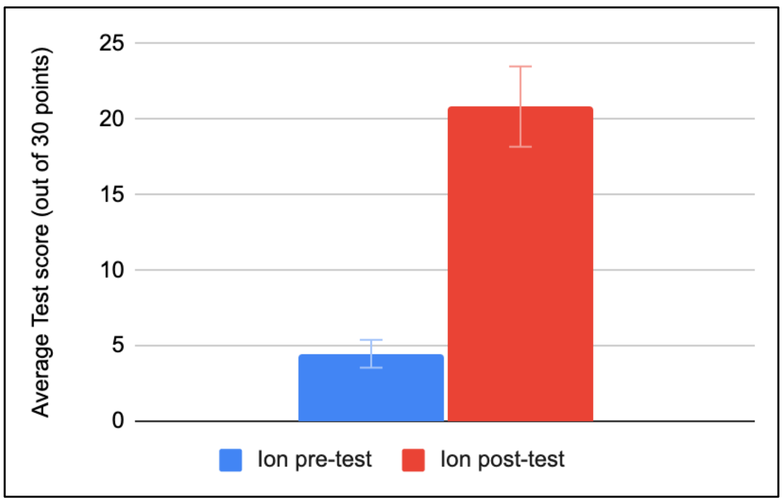

Figure 2. Average pre- and post-content scores for the Ionic Bonds and Compounds Unit, using the 5E model, (*n*=19).

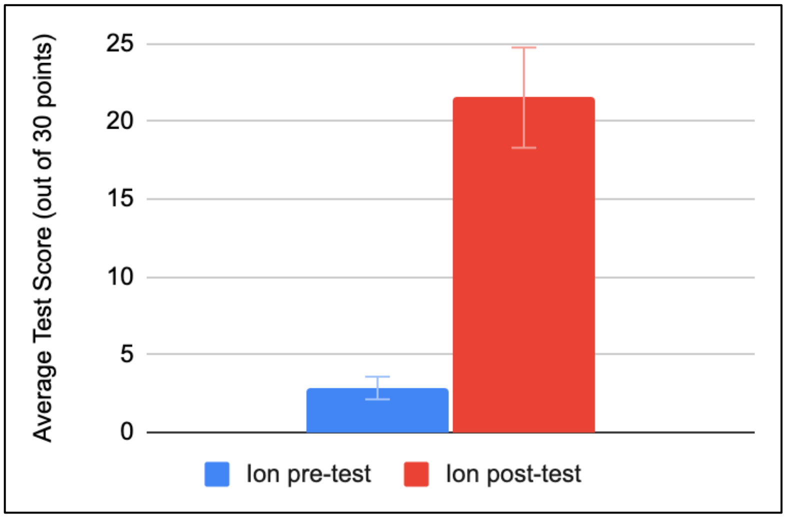

Figure 3. Average pre- and post-content scores for the Ionic Bonds and Compounds Unit, using the traditional teaching model, (*n*=15).

Test scores in post-tests increased significatively for the Covalent Compounds and Bonds Unit in both treatment and non-treatment groups. The average score out of 15 points in the treatment group increased from 1.6±0.25 in the pre-test to 12.47 ±0.45 in the post-test (*n*=15), while the increase in the non-treatment group was from 2.64 ±0.34 to 12.53 ±0.43 (*n*=18). The normalized gain expressed as the average of gains for the post-test in the treatment class was 0.81±0.13, while this same measure for the non-treatment class was 0.80±0.15, which means that in both cases there was a high gain (Hake, 1998). A t-test of averages for post-content test scores compared to pre-content test scores in both treatment and non-treatment groups for both units showed significantly higher scores in 95% of students ($p<0.05$, *N*=34) (Figures 4 &5).

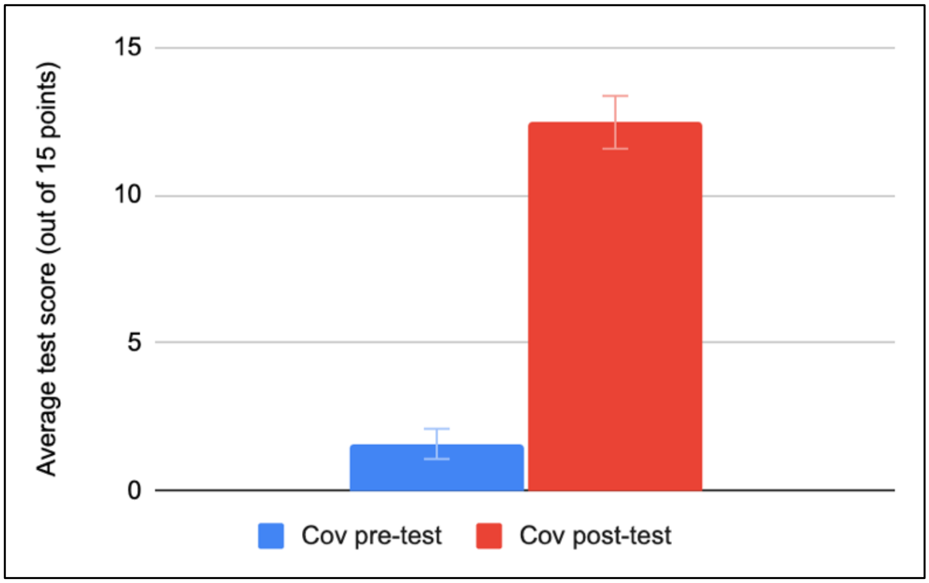

Figure 4. Average pre- and post-content scores for the Covalent Bonds and Compounds Unit, using the 5E model, (*n*=15).

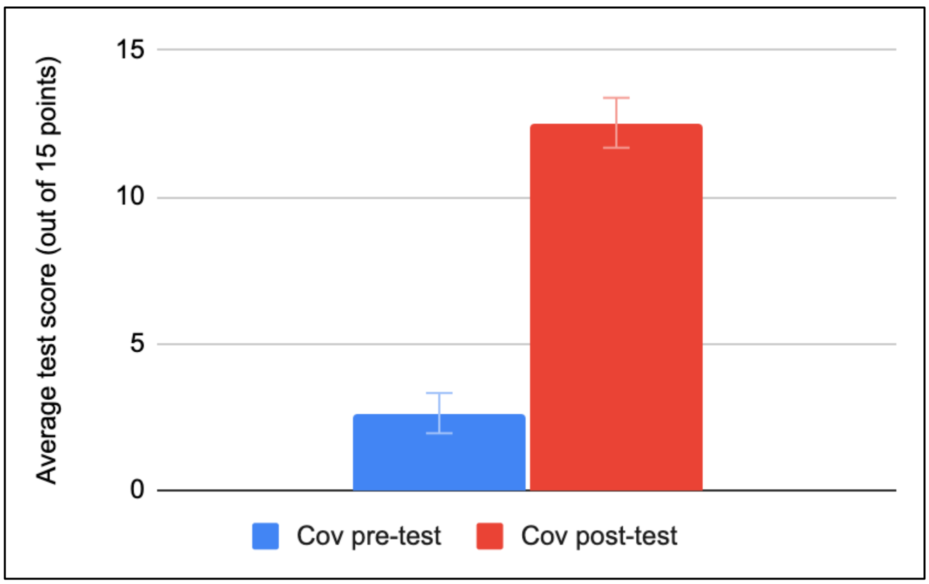

Figure 5. Average pre- and post-content scores for the Covalent Bonds and Compounds Unit, using the traditional teaching model, (*n*=19).

Combining both units and converting into percent the scores for the post-test scores, it's shown that the post-test scores were higher than the pre-test scores in both the treatment and the non-treatment groups for both units. The average score for the treatment groups increased from 13.04±6.88 to 75.49±17.53 (*N*=34) while the non-treatment group average score had an increase from 13.94±8.72 to 78.18±17.35 (*n*=33). The spread and average for the post-test scores were similar for the 5E model and for traditional teaching. No significative difference was found between the means of the post-test scores for the treatment and non-treatment units (p=0.487); in fact, the average post-test score was slightly higher in the non-treatment group than in the treatment group (Figures 6 & 7).

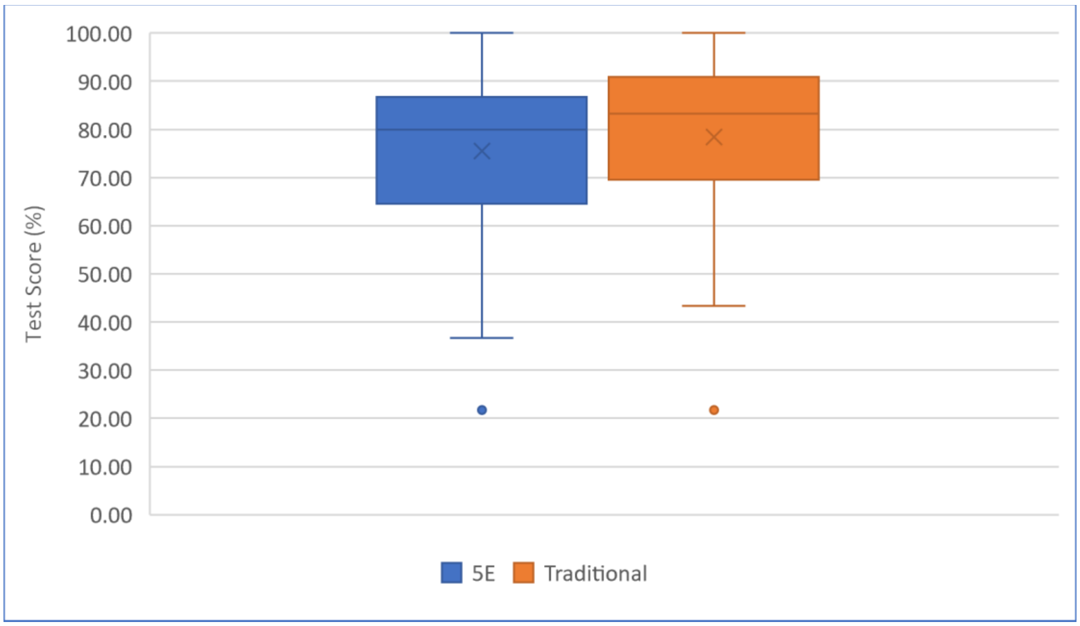

Figure 6. Box and whisker plot of post-test scores, combined, 5E vs. traditional, (*N*=34).

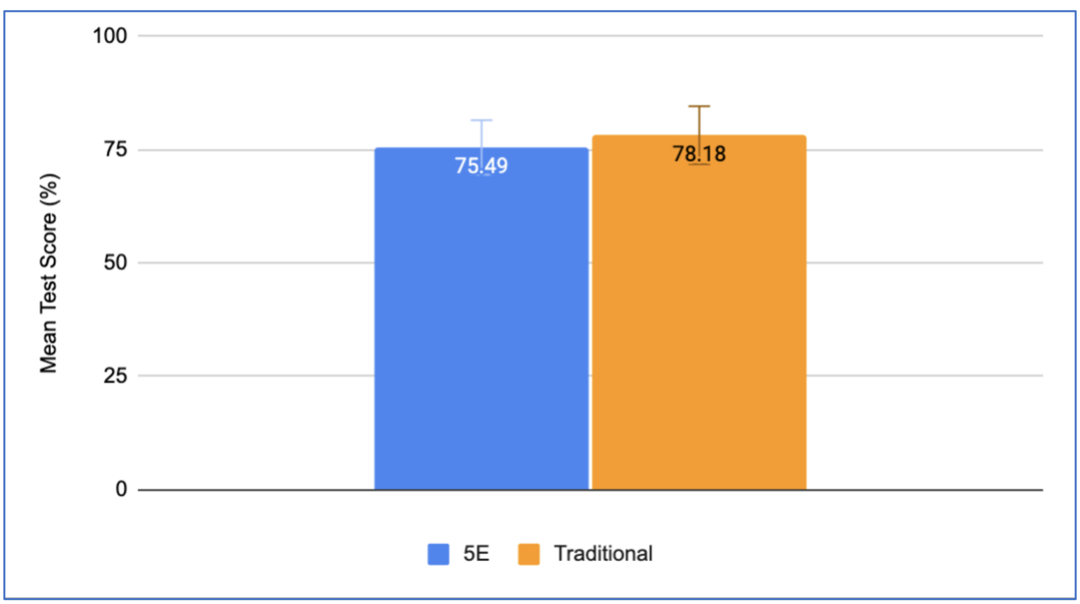

Figure 7. Average post-test scores with error, combined, 5E vs. traditional, (*n*=33).

Treatment and non-treatment groups were divided into lower and higher subgroups, based on pre-test scores. The mean scores for the Ion post-test for both subgroups was very similar in the treatment group (69.58% vs. 69.39%), while in the non-treatment group the mean scores for the higher subgroup was substantially higher than in the lower subgroup (78.00% vs. 59.33%). The results' dispersion was also found to be higher in the lower subgroup in the non-treatment unit (Figure 8). The same results were found in the Covalent post-tests, although the difference was not as noticeable as in the Ionic post-tests.

Figure 8. Comparison of Ionic post-test results between subgroups and between treatment and non-treatment groups, (*N*=34).

In student surveys I asked students what their favorite and least favorite activities were for both units; students were able to elect more than option. For the Ionic Compounds and Bonds Unit in the treatment unit, 78.9% of students chose "looking at crystals" (used in the Engage phase) as their favorite activity. The "Mixing Solutions" activity was the favorite part of the unit for 66.7% for students in the nontreatment group; only 52.6% of students in the treatment group chose this as their favorite activity. More than 66% of students in both classes chose taking notes and going through slides as their least favorite activity. As for the Covalent Compounds and Bonds Unit, only 46.7% of the students in the treatment group liked their engaging activity (plate demo by the teacher), but one of the students who didn't chose it as a favorite said that it was because “I wanted to do it that day but we had to wait.” About 60% of students in both groups said that their least favorite activities were doing worksheets and taking notes.

The Science Attitude survey showed some changes in students’ perceptions towards science. Quotes included in the next paragraphs were taken from the open-ended questions on the Science Attitude Survey as well as from Student Surveys. In general, students enjoyed going to chemistry class and liked science better after having been introduced to the 5E model of learning. They also thought science wasn’t as hard after this. During the pre-survey, 68% of students (*N*=34) thought science was too hard; after treatment, this number decreased to 53% (*n*=33) (Figure 9).

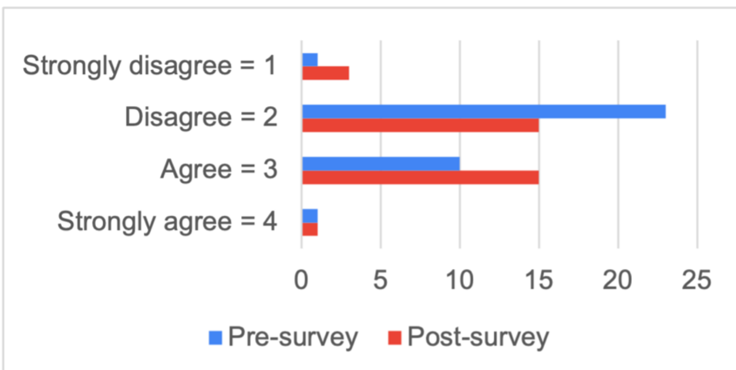

Figure 9. Number of students thinking that science is too hard, before treatment (pre-survey, *N=34*) and after treatment (post-survey, *n*=33).

More students enjoyed going to chemistry class after having been learning through the 5E model; one student said that “Chem is my favorite class” and another stated that “I look forward to finding out what we are doing everyday (sic) because I know we always do something interesting.” On the whole, students also liked doing labs better after working with the 5E model of learning. The percent of students who enjoyed doing labs increased from 54% to 62% (Figure 10). One student said, “I can’t stay engaged when we’re just talking” and another added “the hands-on labs are fun” while another student expressed that “taking notes and going through slides is just so boring.” Another student said, “the hands-on activities help me have more of an understanding" (of chemistry concepts) and a different student added "I like the hands-on activities where I can be involved and have more of an understanding."

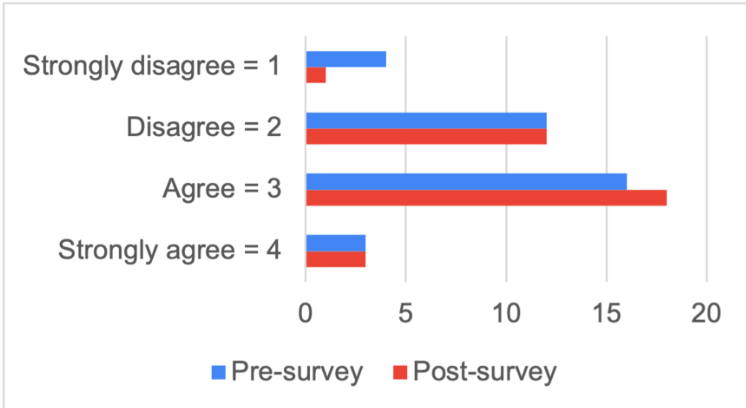

Figure 10. Number of students who enjoyed doing labs, before treatment (pre-survey, *N*=34) and after treatment (post-survey, *n*=33).

Students' confidence in understanding chemistry concepts increased from 49% to 62% (Figure 11). One of the students said, " I think I learned this stuff really well and I do understand it" and another said, "In subjects of chemistry like formula identification, I am a fast learner, and am very confident in being able to execute the steps needed in order to do things like that." One other student said, "I've understood most topics recently."

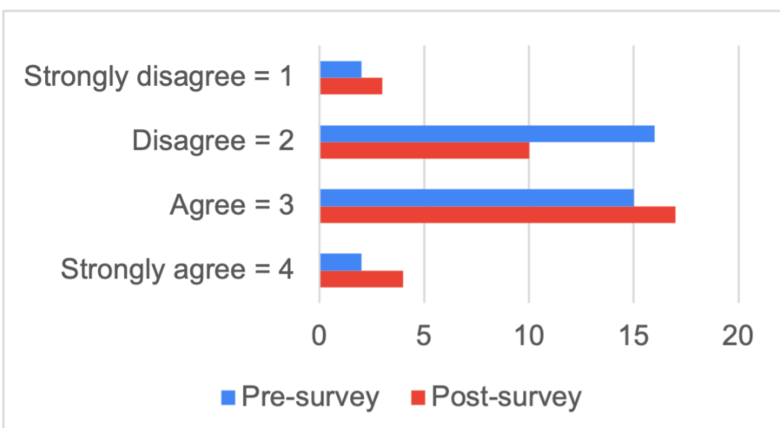

Figure 11. Number of students who were confident in understanding chemistry concepts before treatment (*N*=34) and after treatment (*n*=33).

Students' perceptions towards science and chemistry, specifically, got better after treatment (Figure 12). This general trend was seen in almost every question on the Science Attitude Survey. The only question in which result pre- and post- survey were relatively the same was in the question related to pursuing a career in a science field, although more students strongly agreed to it instead of just agreeing. However, more students wanted to learn more about chemistry than what was learned in class before the treatment than after the treatment. Overall, students had a positive attitude towards the 5E model. Even though a lower number of students enjoyed going to chemistry class after treatment, one student said, "I love this chemistry class, it is really enjoyable and fun."

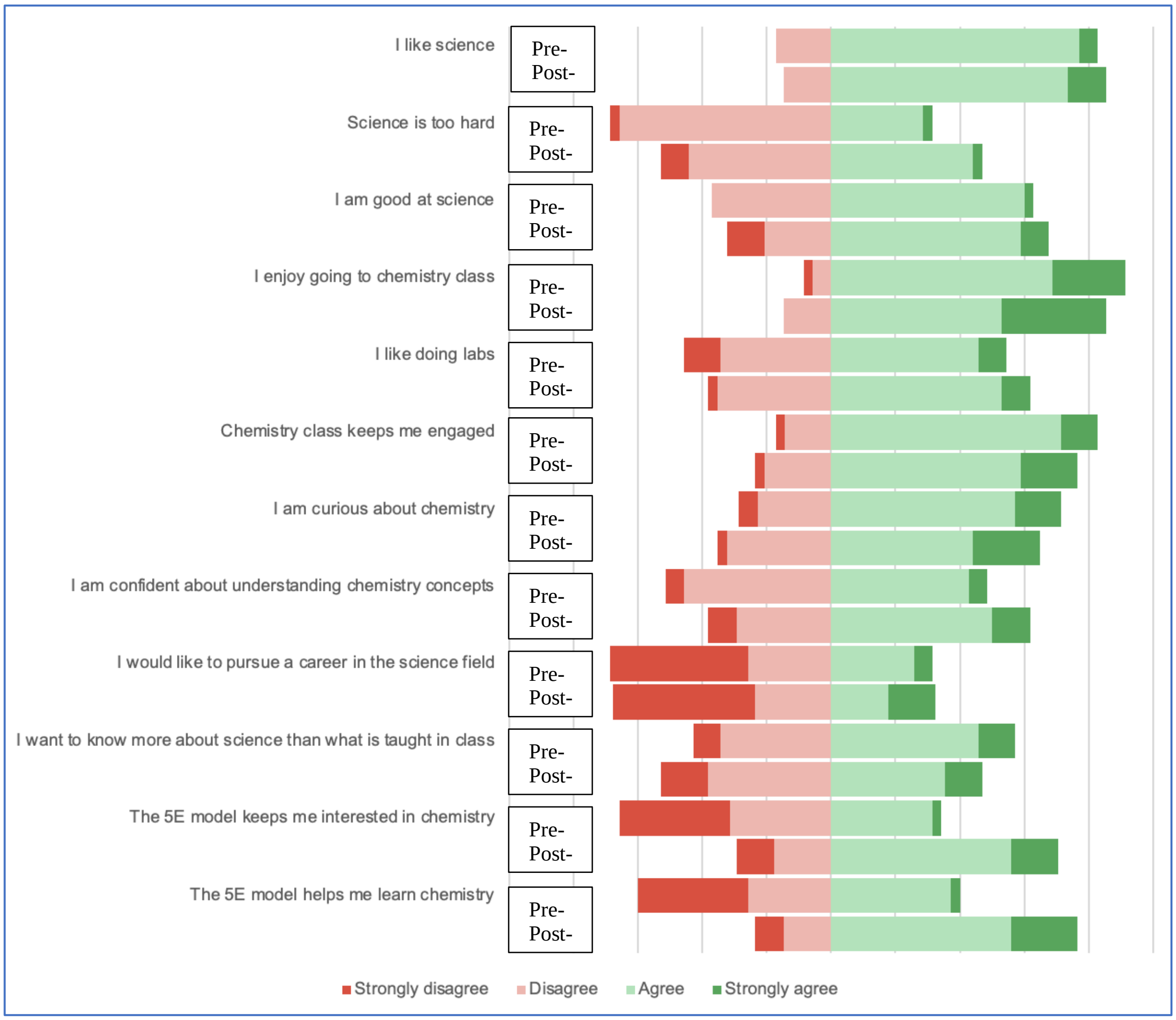

Figure 12. Stacked bar graph comparing students' perceptions towards science, pre- (*N*=34) and post-treatment, (*n*=33)

CLAIMS, EVIDENCE, REASONING

Claims From the Study

Test results and surveys indicate that students were more comfortable coming to chemistry class and doing labs after they were introduced to the 5E model of learning. Even when there isn't a noticeable difference between post-test scores between the treatment and the non-treatment groups, students' attitudes did change towards a more positive view of science, chemistry, and labs in general.

The results in post-tests for both chemistry units studied during this research project, Ionic and Covalent Bonds and Compounds, showed no difference in scores for the student population as a whole. The mean test scores for the treatment groups showed no noticeable difference with the nontreatment groups. Identical tests were used as pre-tests and post-tests for both units. The average score for pre-tests in the Ionic unit (N=34) was 12.5%; this score increased to a 69.5% in the treatment group (n=19) and to 71.8% in the nontreatment group (n=15). For the Covalent Unit, the average pre-test score was also 12.5% (n=33); this score was increased to an 83.1% in the treatment group (n=15) and to 83.5% in the nontreatment group (n=19). In this regard, there was no observable difference between both groups, as both improved scores in the same way and in a very similar way.

However, when separating students into two different level subgroups based on their pre-test score, there are some differences that could have been easily lost had this not been done. In the Ionic Unit, for the 5E model, average post-test scores were practically the same: 69.4% for the lower-level group (n=11) and 69.6% for the higher-level group (n=8). On the other hand, average post-test scores for the lower-level group with traditional teaching was only 59.33% (n=5) and 78.0% (n=10) for the higher-level subgroup. The same phenomenon could be seen for the Covalent Unit, although it wasn't as obvious as in the previous unit; this could have been to the fact that the Covalent tests was only worth 15 points as compared to 30 in the Ionic Unit. In the treatment group, the lower-level average post-test score was 82.5% (n=8) and 83.8% for the higher-level subgroup (n=7). While in the nontreatment group, average post-test scores for the lower sublevel was 80.3% (n=10) and 87.5% for the higher-level subgroup (n=8). Additionally, the spread of grades in post-test scores is also greater in the lower subgroups who had a traditional approach to teaching. According to my results, lower-level students in college preparatory chemistry classes benefit greatly from a 5E teaching model. The 5E model eliminates the "bias" towards higher-level students, who tend to do better in science, and gives lower-level students new opportunities to do better.

For the most part, students liked activities that were hands-on and those in which they had more liberty to follow their own interests and procedures as compared to the ones in which they just had to take notes or do worksheets. Students found the labs and activities "fun," "engaging," and "enjoyable." One student stated that "looking at those crystals was very cool, and I liked seeing the variety between different ionic compound crystals; then getting to answer the questions we asked was something I liked because I got to learn about things that I was interested in," and another student said that "doing the work myself is fun to do." One more student said that "it was pretty cool being able to identify and learn from the labs," one conveyed that "it all was pretty entertaining," and a third student responded that "the activity kept me engaged."

In regard to students' attitudes towards science and inquiry, it is also clear that the 5E model engages them more. Students enjoyed the hands-on and self-directed activities provided by the 5E model more than traditional teaching methods. After the short time the research project lasted, students' attitudes visibly improved towards science and chemistry in general. Some students said they “got bored” and “lost focus” during traditional teaching, but that they found labs and hands-on activities “fun” and “engaging.”

Value of the Study and Consideration for Future Research

When I first started seeing the post-test results, I was a bit frustrated because students genuinely like the 5E model, although the average post-test scores were basically the same for treatment and nontreatment groups. During the Statistics Bootcamp course, it was suggested that I divide my groups into different sublevels based on students’ scores on pre-tests. And this is when I could quantitatively prove that the 5E model helps lower-level students in a college preparatory chemistry classroom. The fact that the 5E results showed less variability than the traditional teaching was very interesting to me, and I take it as a positive outcome. The way I see it, higher level students, at least in my action research project, were already going to be successful regardless of the teaching method, but the 5E model contributed to a better outcome for lower-level students. In other words, the 5E model “levels the playing field” for everyone and there is no “bias” for higher-level students’ success. It will be important for me to attend the needs of these higher-level students as well, possibly differentiating some activities, especially during the Elaborate and the Evaluate phases of the 5E cycle.

For the duration of the action research project, students’ attitudes towards science and chemistry improved, even during the second half of the school year, when I thought I had already helped many of them have a better understanding and mindset about science during the first half of the year. I think that using the 5E model throughout the school year will help me implement the NGSS better, as well as improve students’ attitudes towards science and help students understand and retain concepts better.

Impact of Action Research on the Author

I enjoyed conducting this project in my classrooms. It was hard for me, especially at the beginning, because I do like to have things under control, have all my chemistry classes on the same page, and know what to expect each day. Doing the 5E model with one class and traditional teaching with the other was challenging in the sense that we were not on the same page, we were performing different activities, and sometimes I didn't know where the 5E model would lead. Looking back, I now feel more comfortable with the 5E model, and I think that I will be using it throughout the school year for my chemistry classes, albeit sometimes modified. It follows a pattern that integrates and coordinates itself with the NGSS, following a storyline about a phenomenon (engage phase). One of the aspects I enjoyed the most was to have students discover a concept, during the exploration phase, even before I gave them the explanation about it. I always like to connect science concepts to real-life scenarios, and the elaborate phase gave me the chance to do this as well.

This was my twelfth year teaching, and my teaching style has drastically changed since I began the MSSE program. I had always been very traditional in my teaching style, with prepared PowerPoint slides, worksheets, homework, and the weekly kitchen-recipe labs. These past couple of years, which might have started with our adoption of the NGSS, have made me more of an observer in the class more than just supplying knowledge, making my classes more learner-centered, but obviously still leading the way and helping students. Implementation of the 5E model helped accelerate this change in me as a teacher. The MSSE program and this research project have also made me more reflective upon what I do and say every day in class. I want to be a better teacher for my students every day, spark their interest in science, and inspire my students to be their best.

REFERENCES CITED

Bybee, R. (2015). *The BSCS 5E instructional model*. National Science Teachers Association.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carlson Powell, J., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. https://media.bscs.org/bscsmw/5es/bscs_5e_full_report.pdf

Chitman-Booker, L., & Kopp, K. (2013). *The 5Es of inquiry-based science*. Shell Education Publishing, Inc.

Duran, L. B., & Duran, E. (2004). The 5E instructional model: A learning cycle approach for Inquiry-based science teaching. *Science Education Review*, *3*(2), 49–58.

García-Martínez, J., & Serrano-Torregrosa, E. (2015). *Chemistry education*. Wiley-VCH Verlag GmbH & Co.

Hake, R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics course. *American Journal of Physics, 66*(1), 64-74.

Holloway, C. E., Jr. (2015). *Teacher's level of inquiry-based chemistry and student's attitude about high school chemistry* [Doctoral Thesis, University of Alabama]. ProQuest One Academic. https://www-proquest-com.proxybz.lib.montana.edu/dissertations-theses/teachers-level-inquiry-based-chemistry-students/docview/1698251599/se-2?accountid=28148

Kiser, J. (2021). *Use and analysis of 5e inquiry activities in online general chemistry courses* [Doctoral dissertation, University of South Carolina]. ProQuest One Academic. https://www-proquest-com.proxybz.lib.montana.edu/dissertations-theses/use-analysis-5e-inquiry-activities-online-general/docview/2572554752/se-2?accountid=28148

Llewellyn, D. J. (2013). *Teaching high school science through inquiry and argumentation.* SAGE Publications Inc.

NJ Department of Education. (2020). *NJ school performance report*. Official Site of the State of New Jersey; NJ Department of Education. https://rc.doe.state.nj.us/school/detail/37/2465/050/overview

NJ Department of Education. (2020). *NJ school performance report*. Official Site of the State of New Jersey. Department of Education. https://rc.doe.state.nj.us/1516/37/2465/000.html

Sen, S., & Oskay, O. O. (2016). The effects of 5E inquiry learning activities on achievement and attitude toward chemistry. *Journal of Education and Learning*, *6*(1), 1. https://doi.org/10.5539/jel.v6n1p1

Supasorn, S., & Promarak, V. (2015). Implementation of 5E inquiry incorporated with analogy learning approach to enhance conceptual understanding of chemical reaction rate for grade 11 students. *Chemistry Education Research and Practice*, *16*(1), 121–132. https://doi.org/10.1039/c4rp00190g

Tonseenon, K. (2017). The effects of 5E learning cycle model on achievement and science lessons design ability of science student teachers. *International Society for Engineers and Researchers (ISER)*. https://www.worldresearchlibrary.org/up_proc/pdf/864-150054041336-39.pdf

Watt, M. A. H. (2013). *Effect of the 5E instructional model on student understanding and engagement in high school chemistry* [Capstone Project, Montana State University]. Theses and Dissertations at Montana State University (MSU). https://scholarworks.montana.edu/xmlui/bitstream/handle/1/2833/WattM0813.pdf?sequence=1&isAllowed=y

APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD MSU EXEMPTION LETTER

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:
Application Number:
****

DATE of SUBMISSION: November 29, 2021

Address each section – do not leave any section blank.

I. INVESTIGATOR:

Name: **Mercedes Lippert**
Home or School Mailing Address: **77 Halsey Road, Newton, NJ 07860**
Telephone Number: **862-251-1768**
E-Mail Address: **mlippert@krhs.net**
DATE TRAINING COMPLETED: __**2/27/2021**____ *[Required training: CITI training; see website for link]*

Investigator Signature ________________Mercedes Lippert____________________________

Name of Project Advisor: **John Graves**
E-Mail Address of Project Advisor: **carl.graves@ecat1.montana.edu**

II. TITLE OF RESEARCH PROJECT: **The 5E Model of Learning in a Chemistry Classroom**

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

The purpose of the study is to analyze how the 5E model of learning affects student achievement and engagement in my chemistry science classes. Currently I have two advanced college preparatory chemistry 1 classes. The plan is to do the research project for about ten weeks (mid-January to end of March). For about half the time I will be teaching one of my classes (period 7) in a traditional way and the other class (period 9) following the 5E model of learning; for the second half, the classes will be swapped, and my period 7 will be using the 5E model while my period 9 class will be taught in a traditional way.

Students will be taking regular assessments and doing regular activities, as well as being graded as they always do, but in addition to this, they will be taking a science attitude pre- and post-survey (the same one) designed with the purpose to analyze their engagement and attitudes in the different environments (5E model vs. traditional teaching). Identification of all students will be kept strictly confidential. Most of the students involved in the research will remain unidentified in any way. However, six students will be randomly chosen to answer a few questions about their experiences. Nowhere in any report or listing will students' last names or any other identifying information be listed.

There are no foreseeable risks or ill effects from participating in this study. All treatment and data collection falls within what is considered normal classroom instructional practice. Furthermore, participation in the study can in no way affect grades for this or any course, nor can it affect academic or personal standing in any fashion whatsoever. Participation in the study is voluntary, and students are free to withdraw consent and to discontinue participation in the study at any time without any prejudice from me.

APPENDIX B

PRE/POST IONIC BONDS AND COMPOUNDS ASSESSMENT

Ionic Compounds Pre- and Post-Assessment

The respondent's email (**null**) was recorded on submission of this form.

* Required

1. Email*

____

2. What kind of ions do halogens tend to make? * (1 pt.) *Mark only one oval*

- +1
- +2
- -1
- -2
- They don’t make ions

3. What kind of ions do noble gases tend to make? * (1 pt.) *Mark only one oval*

- +1
- +2
- -1
- -2
- They don’t make ions

4. What kind of ions do group 2 elements tend to make? * (1 pt.) *Mark only one oval*

- +1
- +2
- -1
- -2
- They don’t make ions

5. What kind of ions do metals tend to make? * (1 pt.) *Mark only one oval*

- cations
- anions
- They don’t make ions

6. Which group of the periodic table tends to gain two electrons? * *Mark only one oval*

- Group 6A (or 16)
- Group 8A (or 18)
- Group 2A (or 2)
- Group 1A (or 1)

7. What charge do ionic compounds have? * (1 pt.) *Mark only one oval*

- Positive
- Negative
- They have no charge
- It depends on the compound

8. What is a cation? * (1 pt.) *Mark only one oval*

- A negative ion
- A positive ion
- A cat with weird eyes

9. How are anions formed? * (1 pt.) *Mark only one oval*

- By losing electrons
- By gaining electrons

10. Which elements tend to form more than one type of ion? * (1 pt.) *Mark only one oval*

- Halogens
- Alkali metals
- Noble gases
- Transition metals

11. Match the compounds with their correct names*(3 pts.)

	copper (I) oxide	copper (II) oxide	copper oxide	sodium chloride	chlorine so diumide	magnesium sulfate	magnesium sulfide
NaCl							
MgS							
CuO							

12. Give the formula for iron III hydroxide*

____

13. Give the formula for magnesium nitrite*

____

14. Give the formula for potassium cyanide*

____

15.Which two ions (with their respective charge, formula, and name) make up calcium nitride?* (2 pts.)

____

____

16. Explain what an ionic bond is and how it's formed* (2 pts.)

____

____

____

17. When are roman numerals used in the name of a compound (or ion)?* (2 pts.)

____

____

18. Explain how ionic compounds are named* (2 pts.)

____

____

____

19. What is a subscript and what does it represent in a formula?* (1 pt.)

____

____

____

20. Explain why some elements tend to form ions* (2 pts.)

____

____

____

21. List at least three characteristics of ionic compounds* (3 pts.)

____

____

____

APPENDIX C

PRE/POST COVALENT BONDS AND COMPOUNDS ASSESSMENT

Covalent Compounds Pre- and Post-Assessment

The respondent's email (**null**) was recorded on submission of this form.

* Required

1. Email*

____

2. In covalent compounds, electrons are: * (1 pt.) *Mark only one oval*

- given away
- accepted
- shared
- flying around all cations equally

3. Covalent compounds are between:* (1 pt.) *Mark only one oval*

- two non-metals
- two metals
- a metal and a nonmetal
- any elements on the periodic table

4. Which are the diatomic elements?* (2 pts.)

____

____

5. Covalent compounds are also called _______________ compounds:* (1 pt.)

6. Name the following compound:* (1 pt.) BF_3

____

7. Name the following compound:* (1 pt.) P_4S_3

____

8. Give the formula for sulfur hexafluoride* (1 pt.)

____

9. Which element has a triple bond with another atom of the same element?* (1 pt.)

____

10. How many electrons make the bond between two atoms of oxygen? * *Mark only one oval*

- ◯ two
- ◯ four
- ◯ six
- ◯ eight

11. List at least three characteristics (properties) of covalent compounds* (3 pts.)

____

____

____

12. Explain why some covalent bonds are polar and others are non-polar* (2 pts.)

____

____

____

APPENDIX D

SCIENCE ATTITUDE SURVEY

Science Attitude Survey (pre- and post-)

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

* Required

1. I like science * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

2. Briefly explain your answer to the previous question*

____

____

3. Science is too hard * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

4. Briefly explain your answer to the previous question*

____

____

5. I am good at science * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

6. Briefly explain your answer to the previous question*

____

____

7. I enjoy going to chemistry class * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

8. Briefly explain your answer to the previous question*

____

____

9. I like doing labs * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

10. Briefly explain your answer to the previous question*

____

____

11. Chemistry class keeps me engaged * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

12. Briefly explain your answer to the previous question*

____

____

13. I am curious about chemistry * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

14. Briefly explain your answer to the previous question*

____

____

15. I am confident about understanding chemistry concepts * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

16. Briefly explain your answer to the previous question*

____

____

17. I would like to pursue a career in the science field * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

18. Briefly explain your answer to the previous question*

____

____

19. I want to know more about science than what is taught in class * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

20. Briefly explain your answer to the previous question*

____

____

21. The 5E model keeps me interested in chemistry* *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

22. Briefly explain your answer to the previous question*

____

____

23. The 5E model helps me learn chemistry * *Mark only one oval*

- Strongly disagree
- Disagree
- Agree
- Strongly agree

24. Briefly explain your answer to the previous question*

____

____

APPENDIX E

STUDENT SURVEY FOR PERIOD 7

Student Survey (period 7)

1. What was your favorite part(s)/activity(ies) from the Ionic Compounds Unit?
    a. Looking at crystals under the microscope
    b. Watching videos about making table salt
    c. Learning about the crystal cave in Mexico
    d. Finding answers to your questions on crystals
    e. “Mixing Solutions” lab
    f. Taking notes and going through slides
    g. Making ionic compounds using cards (red/blue)
    h. Finding whether a substance was ionic or covalent
    i. Other
2. Please explain your previous answer
3. What was your LEAST favorite part(s)/activity(ies) from the Ionic Compounds Unit?
    a. Looking at crystals under the microscope
    b. Watching videos about making table salt
    c. Learning about the crystal cave in Mexico
    d. Finding answers to your questions on crystals
    e. “Mixing Solutions” lab
    f. Taking notes and going through slides
    g. Making ionic compounds using cards (red/blue)
    h. Finding whether a substance was ionic or covalent
    i. Other
4. Please explain your previous answer
5. What was your favorite part(s)/activity(ies) from the Covalent Compounds Unit?
    a. Taking notes and going through slides
    b. Doing worksheets
    c. Finding whether a substance was ionic or covalent
6. Please explain your previous answer
7. What was your LEAST favorite part(s)/activity(ies) from the Covalent Compounds Unit?
    a. Taking notes and going through slides
    b. Doing worksheets
    c. Finding whether a substance was ionic or covalent
8. Please explain your previous answer

APPENDIX F

STUDENT SURVEY FOR PERIOD 9

Student Survey (period 9)

1. What was your favorite part(s)/activity(ies) from the Ionic Compounds Unit?
    a. "Mixing Solutions" lab
    b. Taking notes and going through slides
    c. Making ionic compounds using cards (red/blue)
    d. Finding whether a substance was ionic or covalent
    e. Other
2. Please explain your previous answer
3. What was your LEAST favorite part(s)/activity(ies) from the Ionic Compounds Unit?
    a. "Mixing Solutions" lab
    b. Taking notes and going through slides
    c. Making ionic compounds using cards (red/blue)
    d. Finding whether a substance was ionic or covalent
    e. Other
4. Please explain your previous answer
5. What was your favorite part(s)/activity(ies) from the Covalent Compounds Unit?
    a. Taking notes and going through slides
    b. Doing worksheets
    c. Finding whether a substance was ionic or covalent
    d. Mrs. Lippert's demo on plate
    e. Plate activity
    f. Playing with models of atoms to make molecules
6. Please explain your previous answer
7. What was your LEAST favorite part(s)/activity(ies) from the Covalent Compounds Unit?
    a. Taking notes and going through slides
    b. Doing worksheets
    c. Finding whether a substance was ionic or covalent
    d. Mrs. Lippert's demo on plate
    e. Plate activity
    f. Playing with models of atoms to make molecules
8. Please explain your previous answer