THE EFFECT OF NEXT GENERATION SCIENCE STANDARDS PRACTICES ON STUDENTS

by

Timothy John Lies

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 2024

DEDICATION

This paper is dedicated to John Graves, my advisor, for his constant support. I also want to thank Callan Bentley, for being my Science Reader and his feedback. Then I want to thank Michelle Housenga, as she told me about the program, and I fell in love with it. Next, I want to thank my colleagues at Washburn for being very supportive throughout the entire process. Finally, I want to thank my mom and dad, for always supporting my education.

TABLE OF CONTENTS

1. INTRODUCTION & BACKGROUND 1

Context of the Study 1
Focus Statement/Question 2

2. CONCEPTUAL FRAMEWORK 3

The Story Behind Next Generation Science Standards 3
Phenomena and the Science Classroom 4
Modeling and the Science Classroom 5
Implementation Studies of NGSS and Surveys 6

3. METHODOLOGY 8

Demographics 8
Treatment 9
Data Collection and Analysis Strategies 12

4. DATA ANALYSIS 15

Results From the Summative Assessments 15
Results of the Surveys and Interviews 15

5. CLAIM, EVIDENCE, AND REASONING 21

Claims From the Study 21
Value of the Study and Consideration for Future Research 23
Impact of Action Research on the Author 27

REFERENCES CITED 29

APPENDICES 32
APPENDIX A IRB Exemption 33
APPENDIX B Phenomenon and Modeling Sheet 35
APPENDIX C Pre/Post Assessment for Unit 3 Chemical Relationships 38

TABLE OF CONTENTS CONTINUED

APPENDIX D Pre/Post Assessment for Unit 4 Chemical Quantities 50
APPENDIX E Unit Survey 59
APPENDIX F Student Interview Questions 61

LIST OF TABLES

Table Page

1. Data Triangulation Matrix 14

LIST OF FIGURES

Figure Page

1. A Broken Food Plate 10
2. Example of Student's First Attempt at Explaining the Plate Phenomenon 11
3. Survey results for Chemical Relationships 16
4. Survey results for Chemical Quantities 16
5. Comparison of Survey Results by Category 20
6. Example of Student's Second Attempt at Explaining the Plate Phenomenon 27
7. Example of Student's Third Attempt at Explaining the Plate Phenomenon 27

ABSTRACT

The purpose of the research project was to determine the impact of using Next Generation Science Standard practices on students. This consisted of the treatment unit containing a phenomenon at the beginning, and students making and then modifying a model of that phenomenon as their understanding changed throughout the unit. This was compared to a non-treatment unit which consisted of the curriculum as has been implemented in the past. Students were given a pre-test before each unit, as well as surveys and interviews on student experiences after the completion of each unit. The results were that students performed better on the non-treatment unit summative assessment than they did on the treatment unit. In addition, while the treatment unit did have increases in categories of student experiences, they were not statistically significant. The non-treatment unit did have a statistically significant increase in the personalization of learning for the student experience. The content of the two units were dissimilar, which could help explain the difference. The treatment was introduced part way through the school year, and so was a new and different experience. Finally, only a portion of the practices were used, instead of drawing from the full wealth of tools. In conclusion, I would say that this research supports what I and most of my colleagues already believe to be true. The idea that the Next Generation Science Standards are valuable for students, but there needs to be a place for some of the more traditional techniques as well. A blending of the old with the new is what I believe will serve learners the best.

CHAPTER ONE

INTRODUCTION & BACKGROUND

Context of the Study

Washburn High School is in Minneapolis, Minnesota, in an area known as Tangletown because of its many winding roads. The current plan in Minneapolis is to institute the Minnesota adaptation of the Next Generation Science Standards (NGSS) fall of 2024. Therefore, I want to get ahead of the game and start transitioning some of my curriculum early. My capstone project is centered around integrating NGSS into my practice.

The plan for my capstone project is based on the idea of the NGSS and the components that make it up. These consist of the Disciplinary Core Ideas (DCI), Science and Engineering Practices (SEP), and the Crosscutting Concepts (CCC). The DCI are similar to the standards of years past, but NGSS articulates them on the basis of performance. The SEP are techniques that are to be used throughout the curriculum for implementation. The CCC are themes that tie the various subjects together. My main question will be based on the use of NGSS practices with students. This means that one of the pieces of data collected were unit summative assessments. I performed student interviews to look at student perception and self-assessed confidence in the unit. The final piece would be student surveys to look at the outlook of the classes in general when it comes to these units.

Focus Statement/Question

My focus was, How does using Next Generation Science Standards practices affect students?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

The Story Behind Next Generation Science Standards

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, introduced the NGSS in 2013, starting a shift in science curriculum across the United States. NGSS took advantage of the fact that in 2013 many states were already adopting standards in math and language arts. This meant that they were also in a good position to consider adopting new standards in K-12 science education as well. The project grew from the realization that there was a large amount of room for improvement in science education (National Research Council, 2012).

In the past, science standards were seen as covering a small amount of a lot of topics. NGSS changed the narrative to focus more on depth instead of breadth. There are now only four main standards for the physical sciences. Each of these main standards is broken down into five to eight performance expectations. For example, chemistry now has a performance expectation tied to making models showing changes in the nuclei of atoms and energy release during nuclear reactions. In the past, there were a couple of standards tied to nuclear changes, and now there is only one (NGSS Lead States, 2013).

One of the first articles I read investigated the idea of what and how students learn. They focused on the idea that when students are learning through the experience of problem-solving, they can learn both content and problem-solving strategies. As the SEPs are more focused on the process of science, they encourage the students to adapt their thinking to new situations as they arrive. These are linked more with the idea of students discovering the knowledge on their own through problem solving. This may be more challenging with younger elementary students. One of the big proponents brought forward for Problem-Based Learning is the idea that it increases intrinsic motivation in students (Hmelo-Silver, 2004).

Phenomena and the Science Classroom

According to the site, The Wonder of Science, a phenomenon is an event that is usually observable, engaging, complex and aligned to your content (The Wonder of Science, n.d.). It works best at the beginning of an instructional unit to catch the students' attention and for a more inquiry-based approach. The idea is to have them observe the phenomenon and discuss their observations. This is often followed by the students crafting questions to investigate. An issue with this can arise if the students do not ask questions that the teacher is prepared to investigate. It makes learning matter as students are learning about things that happen in the real world. One of the ways to investigate phenomena is to have them develop models to figure out how something works. Phenomena also allows for students to be assessed based on applying their learning to new situations. The teacher is now testing the ability of students to transfer their knowledge, instead of memorizing facts and figures. Phenomena-based learning focuses more on learning, and less on a specific task or target (VanTassel, 2024).

In addition, phenomena work great at engaging students' attention and sparking their curiosity. One of the big ideas around phenomena is that they help the students connect scientific concepts to their own experiences. Another key piece with phenomena is that it can encourage students to explore concepts from various fields at that same time leading to a more holistic understanding of science. Phenomena also create opportunities for students to work together and encourage them to ask more and deeper questions. Finally, as it is a more process-oriented process it helps them learn that scientists ask questions, formulate hypotheses, perform experiments, and create explanations (Studies Weekly, 2023).

Modeling and the Science Classroom

One of the SEPs is having students develop and use models. This often begins with students using models to try to explain a phenomenon. This phenomenon should be tied back to one of the standards that is to be covered. Then students use evidence to revise their models. One of the ways it may be revised is through the inclusion of symbols appropriate to the content to support their reasoning. Creating these rich learning opportunities deeply draws on the abilities and experiences of the teacher, which can be challenging for teachers that are just starting out. Models once again tie back to phenomena as one of the main purposes is to describe, explain and predict phenomena. Models are also useful in helping students understand scientific mechanisms that may be difficult to explain with just words (Park et al., 2019).

Another article talks about how most people are already familiar with models, as they often use them in their everyday lives. Think of things like maps, globes, and model planes, trains, and automobiles. Models simply act as a substitute for the real thing. In science, models are used to make predictions such as using of weather maps to help predict weather patterns. Models also help scientists in working with objects either too small or large to be seen, don't exist anymore, or never been created. Oftentimes scientists' ideas are made visible through the use of models. Scientific models can range from simple diagrams to simulations for complex processes. Even in traditional science, students are introduced to all sorts of models such as the Bohr model of the atom, and even the periodic table itself. Transferring this over to students, you can see that when they develop, test and revise models, that this encourages them to articulate and communicate their own thoughts and ideas. Switching over to deliberately incorporating models will take time (Huncosky, 2024).

Implementation Studies of NGSS and Surveys

One study focused on a set of curricula called KnowAtom which is specifically designed around the NGSS. It is a complete K-8 science curriculum including professional development. The study at Northeastern University examined how NGSS affected staff and students who used KnowAtom. It showed an increase in collaboration, academic vocabulary, discourse, participation, and an improvement in test scores (Jenks, 2021). Another study looked specifically at the impact that NGSS has on English Language Learner (ELL) students. This study examined how NGSS focuses on the idea that science needs to be equally accessible to all students. It was a case study where students were exploring patterns in the Earth's surface. There are ELL students in practically every class in Minnesota, so it is essential to make the material accessible to them. This also ties into what has been learned in the past about proficiency in the technical aspects of language (such as science) taking the largest amount of time to learn (Miller et al., 2015).

Another study surveyed students to be able to collect larger amounts of general information. This article investigated students' conceptions of learning science through augmented reality. The study found that students did have an overall positive reaction to it. A technique learned from this was the idea of separating the questions into positive and negative reactions to assist with data analysis. This allowed for a more thorough exploration into the thoughts of the students involved (Cheng, 2018).

Another action research project examined NGSS and its effects on student and teacher learning. The study explored how students improved in their ability to identify and use the various practices that make up the NGSS practices. However, it did not appear to lead to significant gains in content areas. This study was based directly around NGSS practices, and so this gives an example of what that looks like (Lloyd, 2017). A final study investigated where chemistry classes are currently covering the concepts of the NGSS. It shows that while chemistry classes do a good job of working with the various aspects of science, they do not do a good job of incorporating the engineering practices of the NGSS. Science is about understanding how things work, and engineering is about using that knowledge to develop technology. This helps establish where things are before the implementation of the NGSS and explains why it needs to be implemented (Boesdorfer, 2016).

There are several key ideas things that can be drawn from these various readings. Science classes are great at covering scientific topics but are less well adapted at tying engineering practices into it. That is one of the motivators behind the NGSS. The NGSS is specifically designed to aid students in the most at-risk groups, such as ELL students. It can be more challenging as those same students can struggle when it comes to self-designated learning (SDL) which can be a big piece of this type of Problem-based learning (PBL). In addition, while surveys are great for getting large amounts of data from classes, it is important to include both positive and negative inclination questions to allow for full data analysis. There is also some conflicting data on whether test scores increase with NGSS. It does seem to lead to greater understanding of the pieces of NGSS as well as participation in the class.

CHAPTER THREE

METHODOLOGY

Demographics

Washburn High School had a student body of approximately 1,690 students in the 2023-24 school year. I would describe the school culture as open-minded and accepting. I say this as I see the diversity of cultures and perspectives embraced by the student population. It is an International Baccalaureate world school, but we also offer Advanced Placement and College in the School classes as well. It was in the top 20% of all schools in Minnesota for overall test scores in the 20-21 school year. Our ethnic diversity is 59% White, 18% Black, 17% Hispanic, 3% Asian, 2% two or more races, and 1% Native American. This gives it a diversity score of 0.60 which is above the state average of 0.57. It has a graduation rate of 91%. Free/reduced lunch students make up about 29% of the student body (Public School Review.com, 2024). The school area has a median income of $144,826, median rent of $1,509, and a median home value of $567,514 (Niche, 2024).

I taught four sections of chemistry, and one section of forensics. Both courses enroll 10th through 12th graders. The class I chose for my capstone project was my chemistry class. I selected this class as I have had it since I started teaching full-time, and I felt comfortable modifying the curriculum as needed. Most of the students in class are juniors with a small number of sophomores and seniors. The academic abilities of the class ranged from students who were taking all advanced rigor courses except for this one, to students who were on an Individualized Education Plan (IEP) for learning disabilities who were also English Language

Learners (ELL). The class climate uses daily and weekly routines with a somewhat relaxed and caring atmosphere. The four sections of chemistry this year had a total of around 120 students.

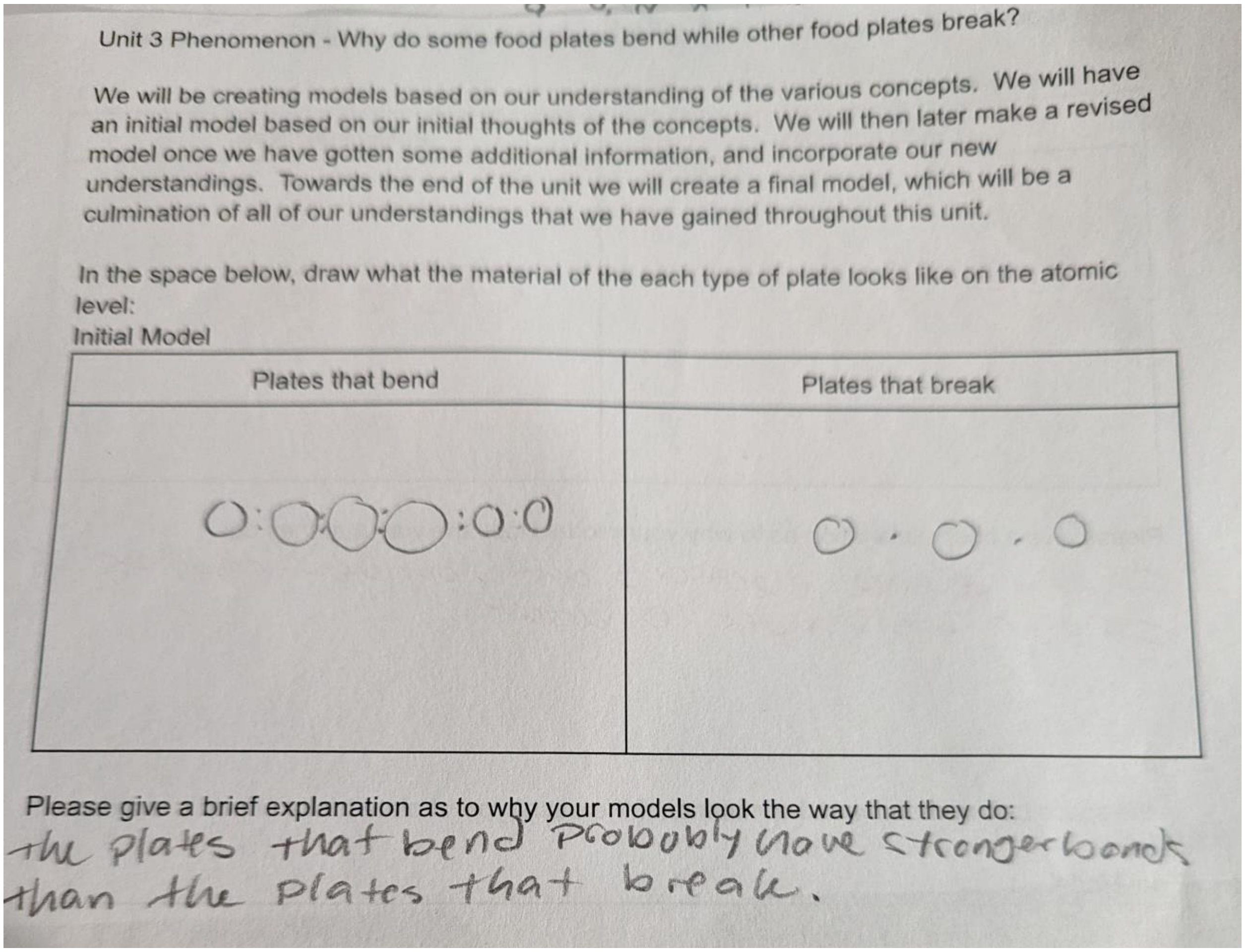
Treatment

To ensure proper implementation, IRB exemption status was applied for and approved before the collection of any data (Appendix A). Before the treatment and non-treatment periods, students had been introduced to the ideas of the Science and Engineering Practices (SEPs) and Crosscutting Concepts (CCC) using materials retrieved from The Wonder of Science (2024). Both the treatment and non-treatment periods consisted of one unit of chemistry. This consisted of having the students review materials on the SEPs and CCCs. They then had to make brief presentations on an individual SEP or CCC with a partner. These were shared throughout all the classes to ensure that all the SEPs and CCCs were covered, and also to give multiple perspectives on each one.

The research was conducted over two units of the curriculum. The non-treatment unit was on chemical quantities. It was a unit that was fairly concrete, with most of the material being primarily concerned with calculations. We covered molar mass, percent composition, multiple step conversions, and formulas. The treatment unit was on chemical relationships. It was a unit that was still fairly concrete, but a little more abstract. We covered the periodic table and periodic trends, as well as names and formulas for ionic and covalent compounds. For the purposes of this study, these units were considered similar in content difficulty and were compared as being equivalent. Both units used materials that I have used in the past such as guided practices, formative assessment quizzes, and Kahoots for review. A Kahoot is an online software that allows students to individually answer questions from the material from a computer or phone.

There was a pre-test to show prior knowledge at the start of each unit and a summative assessment given at the end. The non-treatment unit was taught with no instruction related to NGSS concepts. The treatment unit was taught using NGSS concepts. The treatment unit began with a phenomenon that examined the way different food plates break (Appendix B). Students were given time to construct a model to explain the phenomenon. Students were then given two more opportunities to update their models based on new ideas they have developed during the unit. Starting with a phenomenon, then making, and developing models tied to it are large pieces of the implementation of NGSS. Here is an example of a food plate breaking and an example first attempt of the explanation from a student (Figures 1 & 2).

Figure 1. A broken food plate.



Unit 3 Phenomenon - Why do some food plates bend while other food plates break?

We will be creating models based on our understanding of the various concepts. We will have an initial model based on our initial thoughts of the concepts. We will then later make a revised model once we have gotten some additional information, and incorporate our new understandings. Towards the end of the unit we will create a final model, which will be a culmination of all of our understandings that we have gained throughout this unit.

In the space below, draw what the material of the each type of plate looks like on the atomic level:

Initial Model

Plates that bend	Plates that break

Please give a brief explanation as to why your models look the way that they do:

the plates that bend probobly have stronger bonds than the plates that break.

Figure 2. Example of Student's First Attempt at Explaining the Plate Phenomenon

Data Collection and Analysis Strategies

The first source of data for this research was the Pre/Post Assessment for Unit 3 Chemical Relationships for the treatment unit (Appendix C). This was the same unit assessment that I have used in the past and was originally developed for use across the district. It was a multiple-choice assessment that was administered using Google Forms on Google classroom. This was the process that students have used since the beginning of the year. A change for the research was that they were given the same assessment at the beginning of each unit as a pre-test to assess prior knowledge. This was primarily done to allow for a normative gains test, as each unit in chemistry is unique. However, it also allowed me to determine that students truly were understanding the materials significantly better after the unit as compared to before. The data was gathered from Google Forms and put into Excel for processing. The assessments were processed for the scores of all students with the names removed.

Results of this post assessment for Chemical Relationships were compared to the non-treatment unit Pre/Post Assessment for Unit 4 Chemical Quantities (Appendix D). This was once again the same unit assessment that I have used in the past and is a multiple-choice assessment. This was the process that students have used since the beginning of the year. A change for the purposes of the research in this capstone project was that they were given the same assessment at the beginning of each unit as a pre-test to assess prior knowledge. This was once again primarily done to allow for a normative gains test, as each unit in chemistry is unique. However, it did once again allow for determining that students understood the material significantly better after the unit as compared to before. The data was gathered from Google Forms and put into Excel for processing. The assessments were processed for the scores of all students with the names removed. When a difference was found between the two units, a t-test was performed to establish whether the difference was statistically significant. As the two tests were out of a different number of points, the scores were converted into percentages to allow for a t-test. By comparing two units within the same year, this allowed me to compare the same students to themselves. T-tests and normative gains were performed to be able to more reliably compare two different units, by looking at how the units improved in themselves, and how they improved compared to each other.

To be able to ascertain the general views of the students about the unit, the Chemical Relationship and Chemical Quantities Surveys were given to all students (Appendix E). These were given using a Google Form on their Google class and were collected both anonymously and voluntarily. The surveys involved eight different questions that investigate the following: Learning, Preparedness, Ownership, Enjoyment, Challenge, Thinking, Student Voice, and finally Engagement. They used a 4-point Likert scale, which consisted of strongly agree, agree, disagree, strongly disagree. They were formatted this way, so students were not allowed to be neutral and needed to choose a direction. The data was gathered from Google Forms and put into Excel for processing. In this instance the data was processed for each individual question to identify the scores with the names removed, and a comparison was made between the two units. If a difference was found between any questions for the two units, a t-test was performed to establish whether the difference was statistically significant.

To be able to get more specific information on the views of students about a unit, Chemical Relationship + Chemical Quantities Student Interviews were conducted voluntarily (Appendix F). Students were chosen at random with two high achieving, two average, and two that need more support. Only students that have gotten parental consent can take part in this as I was instructed by my administrator. The questions investigated the same areas and were very similar to the survey questions, but this time students were asked to state why they felt the way they stated. The interviews consisted of eight questions as well. The data was collected through use of a Google doc. The data was processed by individual questions, but this time it was used to support or refute the data gathered from the unit surveys.

Table 1. Data Triangulation Matrix.

Focus Question	**Data Source #1**	**Data Source #2**	**Data Source #3**
How does using Next Generation Science Standards practices affect students?	Chemical Relationships and Chemical Quantities Pre- and Post-Assessments	Chemical Relationships + Chemical Quantities Surveys	Chemical Relationships + Chemical Quantities Student Interviews

CHAPTER FOUR

DATA ANALYSIS

Results From the Summative Assessments

The results of the Unit 3 Chemical Relationships Pre/Post Assessment yielded a pre-assessment average of 41% and a post-assessment average of 81%. The results of normalized gains indicated a score of 0.68, which was considered a medium gain (Hake, 1998). When students were asked if they felt prepared for the assessment, one student said, “I did, I feel I studied a good amount, and the review sheet was very helpful.” Another student stated “Yeah, probably because of the gizmos, formative assessments and guided practices.”

The results of the Unit 4 Chemical Quantities Pre/Post Assessment yielded a pre-assessment average of 35% and a post-assessment average of 88% (Figure 2). The results of normalized gains indicated a score of 0.82, which is considered a high gain (Hake, 1998). A t-test was then performed to compare Chemical Relationships to Chemical Quantities. The results indicated a statistically significant difference between the two units ($p=0.005$). When students were asked if they felt prepared for the assessment, one student said “Yeah, the kahoot and review helped. I spent time working to understand it more.” Another student stated “Yeah, I did. I feel like I studied a good amount, I did good on the Kahoot, and that helped as well.”

Results From the Surveys and Interviews

The results of the Chemical Relationships and Chemical Quantities Surveys showed some differences (Figures 3 & 4). The results were then analyzed for themes. The themes identified were learning, personalization, engagement, and rigor, because they showed the greatest similarity as a result of the treatment.

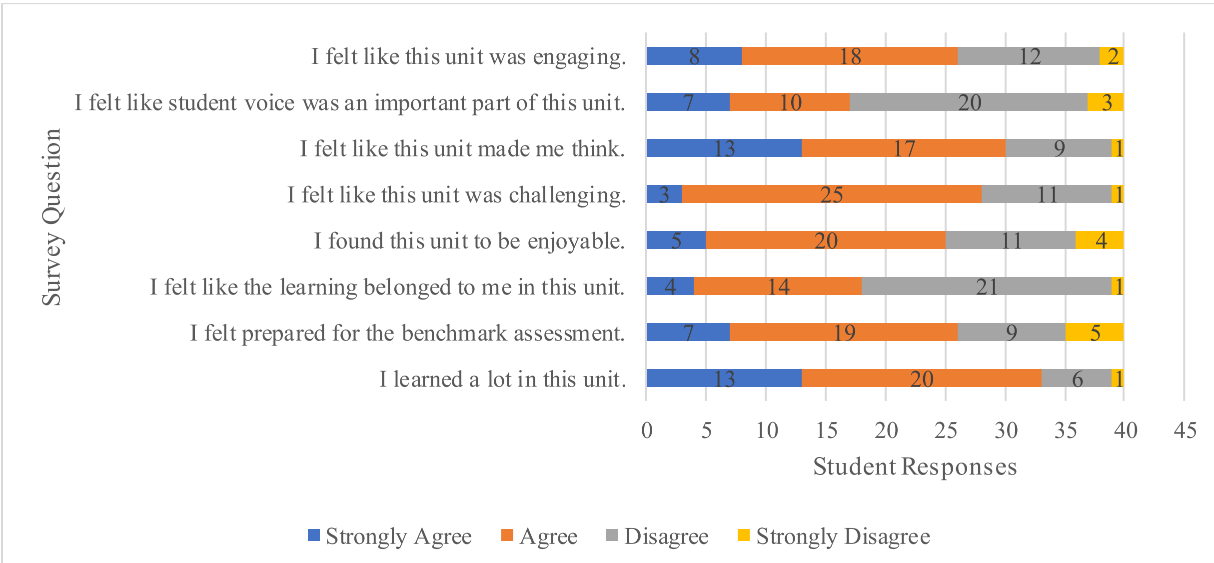


Figure 3. Survey results for Chemical Relationships, (*n*=40).

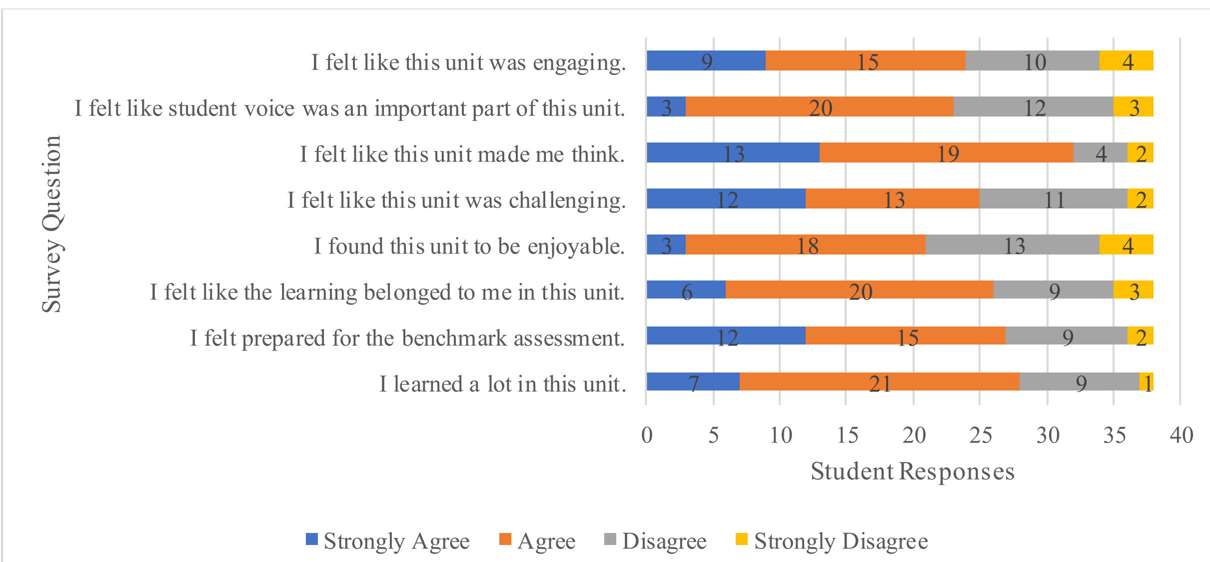


Figure 4. Survey results from Chemical Quantities, (*n*=38).

Learning Category

I learned a lot and I felt prepared for the benchmark assessment were categorized as learning. For I learned a lot, there was just under a 10% decrease in Agree and Strongly Agree responses from Chemical Relationships to Chemical Quantities. For I felt prepared for the benchmark assessment, there was just over a 6% increase in Agree and Strongly Agree responses from Chemical Relationships to Chemical Quantities. In comparing the learning category between the units, the results were that Chemical Relationships had an average score of 3.06 out of 4 on the Likert scale while Chemical Quantities had an average of 2.93. I performed a chi-squared test on these values, and got a p-value of 0.73, which is higher than 0.05. This means I cannot reject the null hypothesis that the treatment did not have effect on student learning experiences. For the Chemical Relationships interviews, a student from the top third stated they "took the pre-test and didn't know much. Enjoyed the naming." A student from the middle third stated they felt prepared due to "the practice test." Finally, a student from the bottom third stated "no" they didn't feel like they learned a lot. This student gave simpler responses as they are an English Language Learner. For the Chemical Quantities interviews, students in the bottom third were unwilling to be interviewed a second time. A student from the top third stated that "there were some things that I didn't get a handle on, but I don't think so." when it came to the unit being challenging. A student from the middle third stated that "umm, I would say I did, kind of, felt like we went faster, and spending more time with the explanations would have been beneficial."

Personalization Category

I felt like the learning belonged to me in this unit and I felt like student voice was an important part of this unit were categorized as personalization. For I felt like the learning belonged to me in this unit, there was just over a 23% increase in Agree and Strongly Agree responses from Chemical Relationships to Chemical Quantities. For I felt like student voice was an important part of this unit, there was just over an 18% increase in Agree and Strongly Agree responses from Chemical Relationships to Chemical Quantities. In comparing the personalization category between the units, the results were that Chemical Relationships had an average score of 2.53 out of 4 on the Likert scale while Chemical Quantities had an average of 2.68. I performed a chi-squared test on these values, and got a p-value of 0.0119, which is lower than 0.05 stating that I can reject the null hypothesis that the treatment did not have effect on student personalization experiences. It could be stated that it had a negative effect. For the Chemical Relationships interviews, a student from the top third stated they "don't think we spoke much in class. Not really." A student from the middle third stated they felt the learning belonged to them as "it really depended on how hard we worked to get the grade we deserved." Finally, a student from the bottom third stated "yes" they did feel like student voice was an important part of the unit. For the Chemical Quantities interviews, a student from the top third stated that when it comes to the learning belong to them "I guess so." A student from the middle third stated that "you always asked if we were following and would ask if we needed more time for stuff."

Engagement Category

I found this unit to be enjoyable and I felt like this unit was engaging were categorized as engagement. For I found this unit to be enjoyable, there was just over a 7% decrease in Agree and Strongly Agree responses from Chemical Relationships to Chemical Quantities. For I felt like this unit was engaging, there was just over a 2% decrease in Agree and Strongly Agree responses from Chemical Relationships to Chemical Quantities. In comparing the engagement category between the units, the results were that Chemical Relationships had an average score of 2.73 out of 4 on the Likert scale while Chemical Quantities had an average of 2.64. I performed a chi-squared test on these values, and got a p-value of 0.90, which is higher than 0.05 stating that I can not reject the null hypothesis that the treatment did not have effect on student engagement experiences. For the Chemical Relationships interviews, a student from the top third stated when it came to being enjoyable “Somewhat. Some of it was finicky. The math parts were finicky. It wasn’t terrible.” A student from the middle third stated, “it was ok.” Finally, a student from the bottom third stated “no” they didn’t feel it was enjoyable. For the Chemical Quantities interviews, a student from the top third stated that “I think it was fairly enjoyable. The labs were fun to do. The work was reasonable.” A student from the middle third stated that “Yeah I thought it was interesting, it was nice that it built off of each other.”

Rigor Category

I felt like this unit was challenging and I felt like this unit made me think were categorized as rigor. For I felt like this unit was challenging, there was just over a 4% decrease in Agree and Strongly Agree responses from Chemical Relationships to Chemical Quantities. For I felt like this unit made me think, there was just over a 9% increase in Agree and Strongly Agree responses from Chemical Relationships to Chemical Quantities. In comparing the rigor category between the units, the results were that Chemical Relationships had an average score of 2.9 out of 4 on the Likert scale while Chemical Quantities had an average of 3.0. I performed a chi-squared test on these values, and got a p-value of 0.20, which is higher than 0.05 stating that I cannot reject the null hypothesis that the treatment did not have effect on student rigor experiences. For the Chemical Relationships interviews, a student from the top third stated when it came to being challenging "Yeah, it involved a lot of different tasks. It covered a lot of topics." A student from the middle third stated, "I thought it was challenging, but not too challenging." Finally, a student from the bottom third stated "no" they didn't feel it made them think. For the Chemical Quantities interviews, a student from the top third stated that "because it was new things I had to think about how to do them I guess." A student from the middle third stated that "I thought some parts were easier than others, but it had a good balance" (Figure 5).

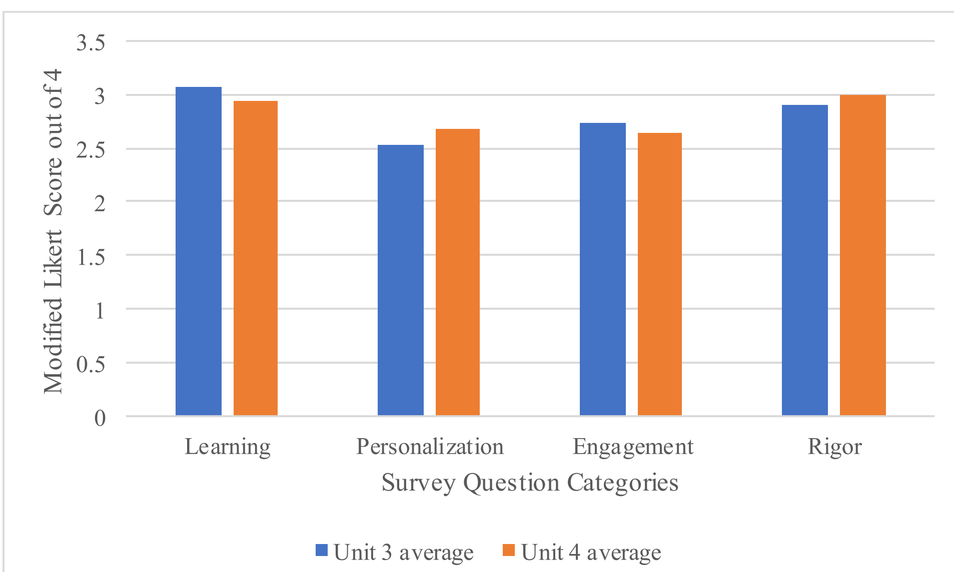


Figure 5. Comparison of survey results by category, (*n*=40,38).

CHAPTER FIVE
CLAIM, EVIDENCE, AND REASONING

Claims From the Study

From the data, the following claims were made.

1. Students performed better on Unit 4 Chemical Quantities than they did on Unit 3 Chemical Relationships.
2. Student attitude was not significantly different for most categories in comparing the units.
3. Student attitudes were higher in the personalization category for Chemical Quantities than Chemical Relationships.

My first claim was that students performed better on the summative assessment of the Chemical Quantities than on the Chemical Relationships. As shown by the gain of averages and the t-test, students performed statistically significantly better on the Chemical Quantities than on the Chemical Relationships. I believe this is mostly due to students being unfamiliar with the process during the Chemical Relationships. In addition, the Chemical Relationships was more abstract, whereas the Chemical Quantities was more concrete. Finally, the Chemical Quantities was later, and so students may have been more confident in their scientific skills in general as the year progressed. When asked about the how challenging the Chemical Quantities was a student stated, "I would say it was challenging, not crazy challenging, but in comparison to other units, yes." Another student stated, "Some stuff was pretty easy, and there were other parts that took longer to learn." I was honestly somewhat surprised that students were saying that the Chemical Quantities was more challenging, because they performed better on it. However, they did take more time to complete the Chemical Quantities assessment. This could indicate that they took longer to process the questions but came to a fuller understanding in the end.

My second claim was that student attitude was not significantly different in most categories between the two units. By comparing the averages, Chemical Relationships scored higher in the categories of Learning and Engagement, while Chemical Quantities scored higher in the category of Rigor. However, when p-tests were performed, it was found that there was not a significant enough difference in these categories to reject the null hypothesis of the treatment not causing a difference. When asked if they learned a lot in Chemical Relationships, a student stated, “I learned a lot more than I would have if I hadn’t taken it.” When asked if Chemical Quantities was challenging, a student stated, “It was challenging.” I was not really surprised by these results. They are not dramatically different units, and so therefore I would expect to get fairly similar results between the two of them when it comes to student experiences.

My final claim was that students had better student experiences in the personalization category of the survey questions in the Chemical Quantities than in the Chemical Relationships. As stated earlier, in some categories students had a better experience with the Chemical Relationships, and some categories students had a better experience with the Chemical Quantities. For most categories, it was a small enough difference to not allow us to reject the null hypothesis of it not having an impact. The only exception was in the personalization category. Here students had a statistically significantly better experience in the Chemical Quantities than they did in the Chemical Relationships. I think that this comes down to the unit involving more practical skills, and so students had more opportunities to express themselves during practice. When asked if they felt like student voice was an important part of this unit, a student stated

"Yeah I did. I liked getting to hear where other students were at, and that is an easy thing in this class." When asked if they felt like the learning belonged to them, a student stated "Yeah, I think so. There were different ways to understand the principles and how they applied to the work we were doing." Considering the units were similar, I was surprised to see such a difference between the two units in this category. Especially given the fact that it was personalization, and if anything, personalization should have been higher in Chemical Relationships as that included the phenomenon to make it more relatable.

Value of the Study and Consideration for Future Research

I would say the main value of this study was showing that there is still a place for students learning curriculum using more traditional methods of teaching. After having spent most of a year using a curriculum that was centered around the next generation science standard practices, I was only able to cover a small fraction of the material that I had in the past. I did, however, get to see the value in using the new techniques, as it did present the curriculum in a richer fashion for the students to engage in. I believe and many of my colleagues agree that the future truly needs to be a combination of the old and the new to more fully meet the diverse needs of our students. It also allowed me to start working with the practices of the next generation science standards. Since this is the direction that science is moving for Minnesota, it is very important to start becoming more comfortable with the various aspects involved with them. Finally, it really let me see the willingness of my students to help me in my research. When it came to sharing student examples of the modeling sheets, every student that I asked said that had no problem with me sharing them to further my research.

The first consideration I would say for future research would be an expansion of what was done in this research project. I compared two units of chemistry to each other. However, one unit was based around more abstract concepts, while the other was based around more concrete concepts. It would be great to do two treatment units, and two non-treatment units. One of which was more concrete and one of which was more abstract. This way the researcher would be able to get a more complete picture of the various relationships. The other recommendation would be to start with the treatment units at the beginning of the year, and then do the non-treatment units. This way the students are not comparing the treatment units to prior units of the year and have only the fresh perspective to work with.

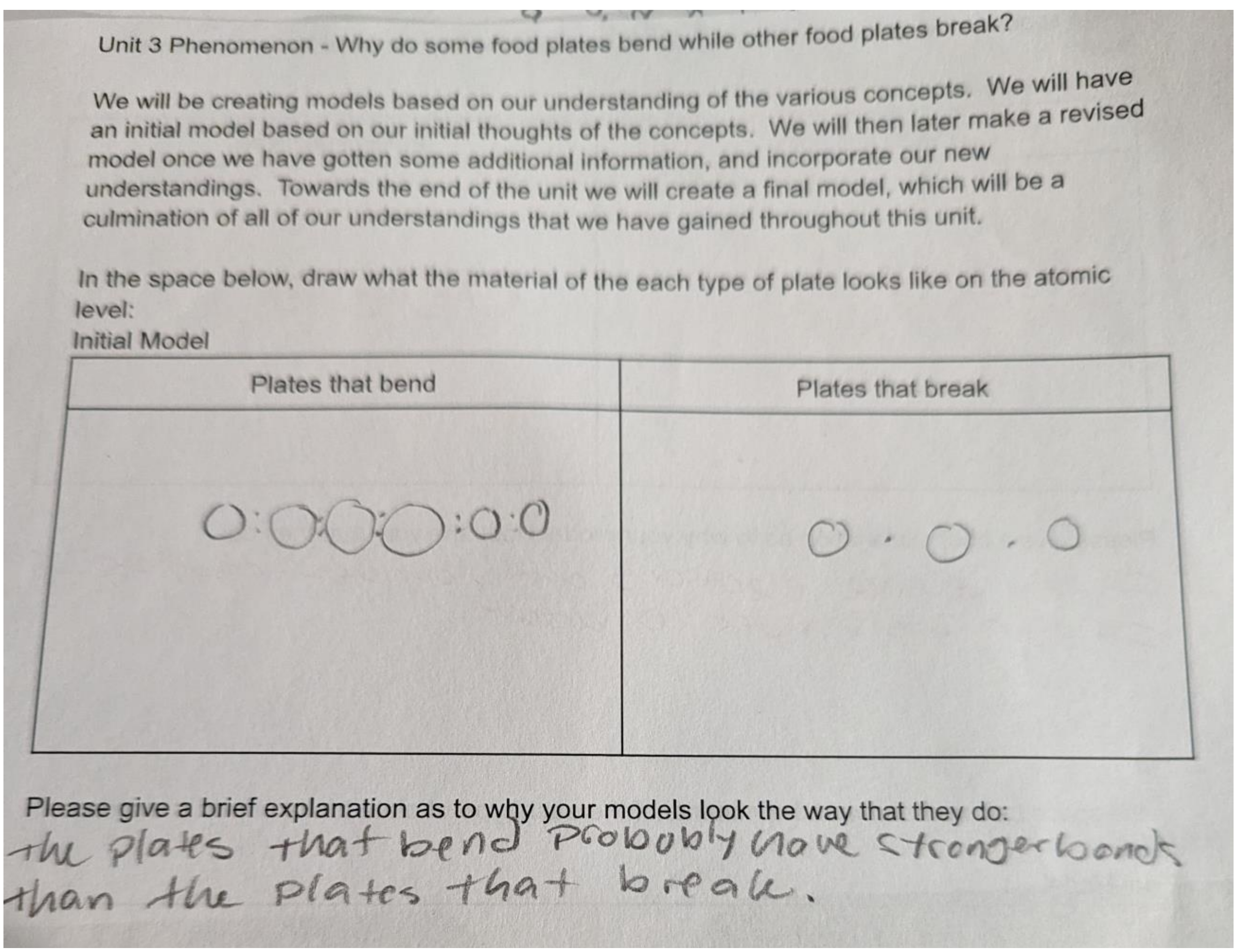
Another consideration would be the idea of the Science and Engineering Practices (SEPs) and Crosscutting Concepts (CCCs). This is the first year that I have intentionally talked about them. However, it really was only a surface level introduction. Students read about the various SEPs and CCCs, using the resources provided to them from The Wonders of Science (2024). The students then created brief explanations for each of them in a group. These explanations were then shared throughout the various classes so that students had access to all of them. Students engaged in the process, but I do not feel that it was truly meaningful. I did not take the necessary time to help them internalize the ideas and give them a greater value.

I cannot say that student understanding of the SEPs and CCCs improved. They were presented with the information, but it was not given enough importance for them to begin to internalize it. No assessments were given to ascertain where their level of understanding of the CCCs and SEPs was, and so I cannot say whether they improved or not. It is likely that most students forgot all the terms and ideas within a few weeks of going through the explanations. In addition, they were not brought up in the curriculum as we progressed, so there were no anchors for it there either.

The professional development that we have received on NGSS has been at the surface level as well. Worse than that, it has been that same surface level understanding once a year for the past 5 years in a row. Paul Andersen has done a marvelous job of bringing resources together showing all the pieces of the Next Generation Science Standards. I am hoping that next year I can put a larger focus on the SEPs and CCCs, so that they have value for the students. My current plan is to have the students work in groups to create presentations based around the SEPs and CCCs. They would then present them in small groups enough times to ensure that they saw presentations related to all the pieces.

The final consideration would be the use of phenomenon itself. It is the anchor to which all the material in a unit should be tied back to. I have used a phenomenon as part of an individual activity before that I designed myself. Unit phenomena were provided in the year that I worked with the storylines. Storylines are where the curriculum is developed around anchoring phenomena, and students are looking at various driving questions tied to the phenomenon. This was my first attempt at creating a phenomenon for a unit. I wanted it to be something that all students would be familiar with. That is why I chose the idea of plates. Plates are something that are used across all cultures that I can think of. Plates are also dropped regularly, and so students have experienced some plates breaking, while other plates only seem to bend briefly and then recover.

Modeling also ties very directly into the use of phenomenon. When I used the storylines, students were supposed to update their model after every lesson. This meant students were expected to create between 10-15 models in a unit. This quickly led to fatigue, and non-participation. That is why I chose 3 times. An initial, a developing, and a final. This way they could see progress along the way, but without it becoming tiring. Students did a good job of engaging in this process, with most students participating. Students also asked to get a copy of the paper to catch up if they missed it when we worked on it earlier. When it came to using examples for my research, students made me very proud. Every student that I asked if I could use it as part of my research by removing the name agreed even when told that it was completely voluntary. I have included the rest of the student example to show growth (Figure 1 from p. 10 & Figure 6 & 7).



Unit 3 Phenomenon - Why do some food plates bend while other food plates break?

We will be creating models based on our understanding of the various concepts. We will have an initial model based on our initial thoughts of the concepts. We will then later make a revised model once we have gotten some additional information, and incorporate our new understandings. Towards the end of the unit we will create a final model, which will be a culmination of all of our understandings that we have gained throughout this unit.

In the space below, draw what the material of the each type of plate looks like on the atomic level:

Initial Model

Plates that bend	Plates that break

Please give a brief explanation as to why your models look the way that they do:

the plates that bend probably have stronger bonds than the plates that break.

Figure 2 from p. 11. Example of Student's First Attempt at Explaining the Plate Phenomenon

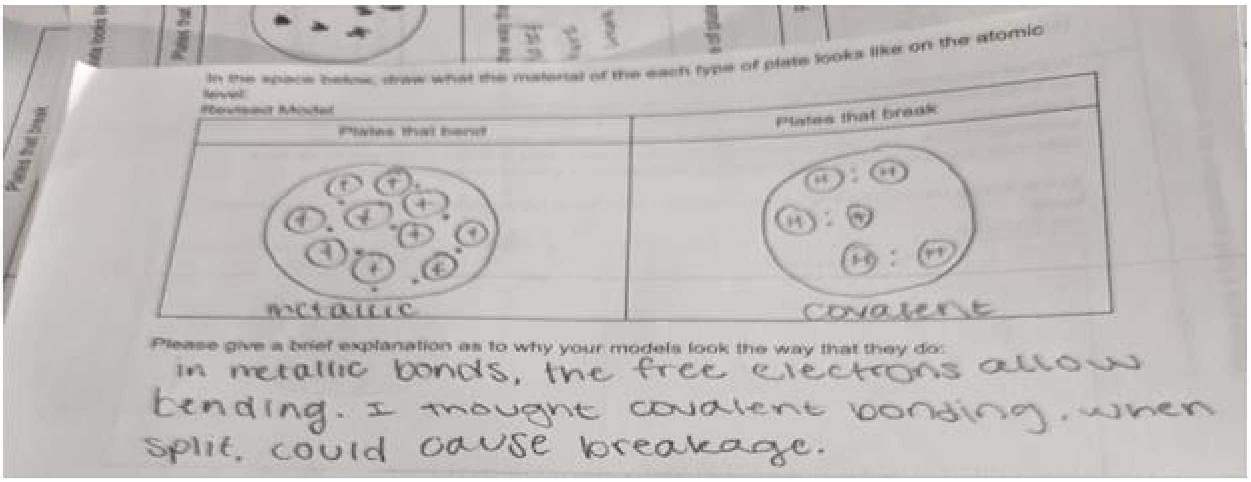


Figure 6. Example of Student's Second Attempt at Explaining the Plate Phenomenon

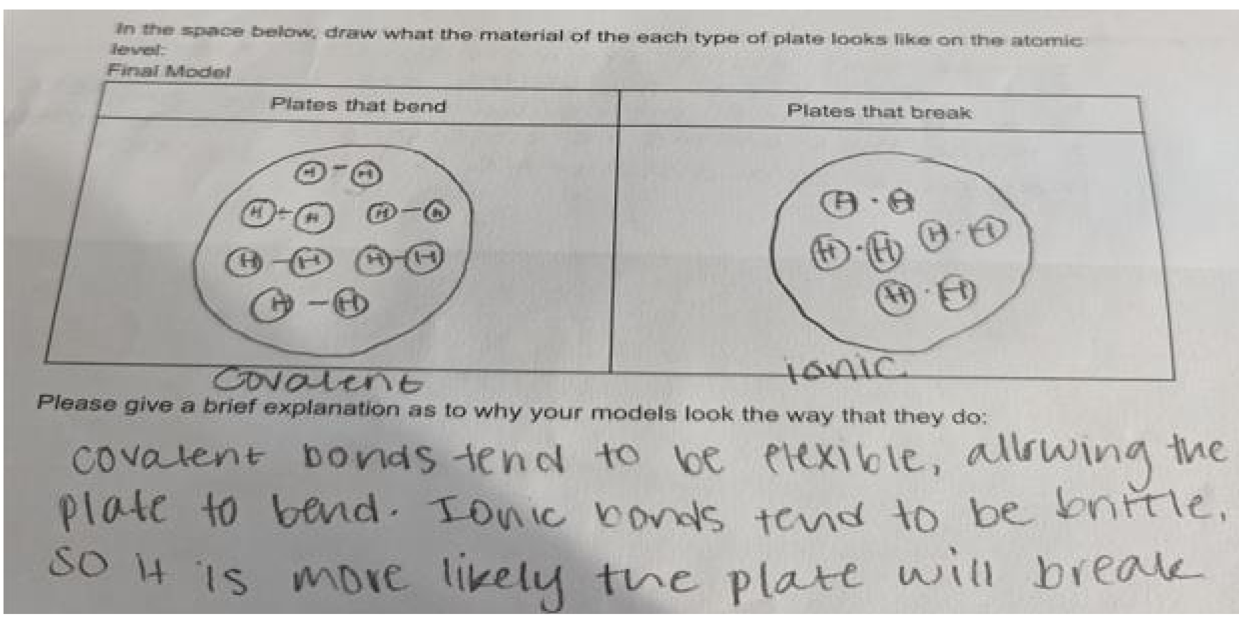


Figure 7. Example of Student's Third Attempts at Explaining the Plate Phenomenon

Impact of Action Research on the Author

The first impact of the action research is that I was very surprised to find that students performed better on the non-treatment Chemical Quantities than on the treatment Unit 3

Chemical Quantities. Even though the Chemical Quantities consisted of fewer questions, they were overall more challenging questions. In addition, students spent significantly more time completing the summative assessment for the Chemical Quantities. In the past, that usually meant that students did not perform as well. This was not the case, and they did significantly better. Another part is that the big idea behind the next generation science standards is to make knowledge more transferable. This means that assessments are usually going to be far less multiple choice, and more short answer/essay. Part of me wonders if I would have seen different results if the assessments were also designed with next generation science standards in mind. The final piece is that the next generation science standard practices need to be a fully encompassing system. I only used a small portion of that with the phenomenon and modelling. Once students become more familiar with the new system, I think it will start impacting them more positively.

REFERENCES CITED

REFERENCES CITED

Boesdorfer, S. & Staude, K. (2016). Teachers' practices in high school chemistry just prior to the adoption of the next generation science standards, school science and mathematics 116 (8), 442-458.

Cheng, K (2018). Surveying students' conceptions of learning science by augmented reality and their scientific epistemic beliefs *Eurasia Journal of Mathematics, Science, and Technology Education,* 14 (4), 1147-1159.

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

Hmelo-Silver, C. (2004). Problem-based learning: what and how do students learn? *Educational Psychology Review*, 16 (3), 235-266.

Huncosky, K. (2024). Developing and using models to makes sense of science. *McGraw Hill Education,* 1-8.

Jenks, R. (2021). New research results on NGSS curriculum effects on students and teachers KnowAtom's Blog https://www.knowatom.com/blog/new-research-results-on-ngss-curriculum-effects-on-students-and-teachers

Lloyd, A. (2017). Assessing the next generation science standards and its effects on student and teacher learning. [Action Research Project, Montana State University]. Theses and Dissertations at Montana State University (MSU). https://scholarworks.montana.edu/xmlui/handle/1/10071

Miller, E; Januszyh, R & Lee, O. (2015). NGSS in action. *Science and Children*, 53 (2), 64-70.

National Research Council (2012). *A Framework for K-12 science education: practices, crosscutting concepts, and core ideas.* Washington, D.C.: National Academies Press.

NGSS Lead States (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Niche (2024). https://www.niche.com/k12/washburn-senior-high-school-minneapolis-mn/

Park, B; Rodriguez, L & Campbell, T (2019). Using models to teach science *The ScienceTeacher,* November/December 2019 (4), 8-11.

Public School Review. (2024). https://www.publicschoolreview.com/washburn-high-school-profile/55419

REFERENCES CITED CONTINUED

Studies Weekly (2023). Why use NGSS phenomena-based learning to teach science? https://www.studiesweekly.com/why-teach-ngss-science/

VanTassel, N (2024). Phenomenon: What every lesson must start with and why https://iexplorescience.com/what-every-lesson-must-start-with-and-why/

The Wonder of Science. (n.d.). Retrieved from https://thewonderofscience.com/

APPENDICES

APPENDIX A

IRB EXEMPTION

Hello Lies, Timothy,

Your protocol was reviewed by the IRB and has been approved.

PI: Lies, Timothy
Approval Date: 12/15/2023
Title: Effect of Next Generation Science Standards Practices on Students

Protocol #: 2023-1183-EXEMPT
Review Type: Exemption
Expiration Date: 12/12/2028

Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.

APPENDIX B

UNIT 3 CHEMICAL RELATIONSHIPS PHENOMENON AND MODELING SHEET

Unit 3 Phenomenon - Why do some food plates bend while other food plates break?

We will be creating models based on our understanding of the various concepts. We will have an initial model based on our initial thoughts of the concepts. We will then later make a revised model once we have gotten some additional information, and incorporate our new understandings. Towards the end of the unit we will create a final model, which will be a culmination of all of our understandings that we have gained throughout this unit.

In the space below, draw what the material of the each type of plate looks like on the atomic level:
Initial Model

Plates that bend	Plates that break

Please give a brief explanation as to why your models look the way that they do:

In the space below, draw what the material of the each type of plate looks like on the atomic level:
Revised Model

Plates that bend	Plates that break

Please give a brief explanation as to why your models look the way that they do:

In the space below, draw what the material of the each type of plate looks like on the atomic level:
Final Model

Plates that bend	Plates that break

Please give a brief explanation as to why your models look the way that they do:

APPENDIX C

PRE/POST ASSESSMENT FOR UNIT 3 CHEMICAL RELATIONSHIPS

Unit 3 Benchmark Assessment

Each question is worth 1 point.

* Indicates required question

1. Email *

First Name

2. First Name *

Last Name

3. Last Name *

Period

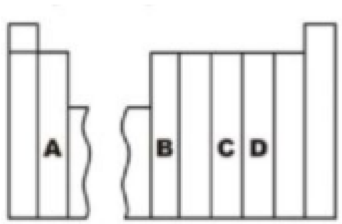
4. Period *

Mark only one oval.

- Period 1
- Period 2
- Period 3
- Period 6

Test Questions

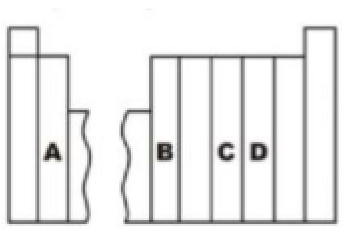
5. Use the portion of the periodic table below to answer the question: Which region of the table has elements with only two valence electrons? * 1 point



Mark only one oval.

- A
- B
- C
- D

6. Use the portion of the periodic table below to answer the question: Which region of the table has elements with only five valence electrons? * 1 point

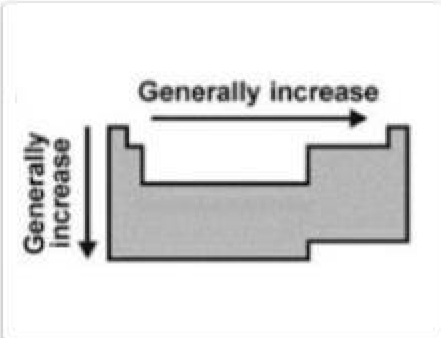


Mark only one oval.

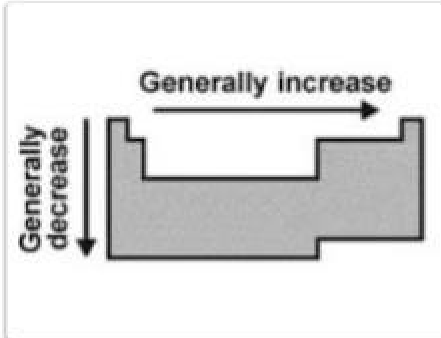
- A
- B
- C
- D

7. Which diagram shows the trends in electronegativity? * 1 point

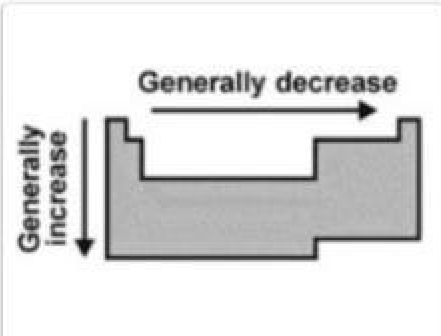
Mark only one oval.



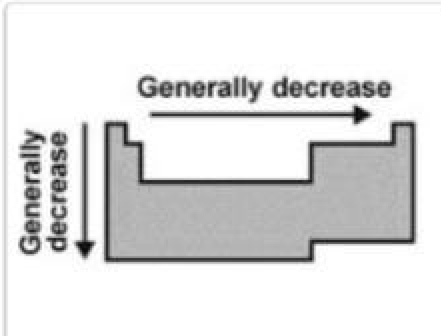
Option 1



Option 2



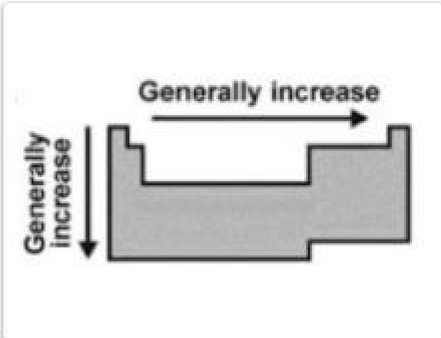
Option 3



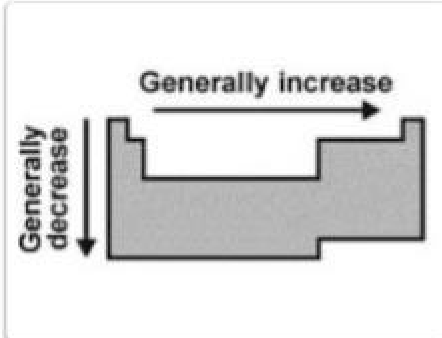
Option 4

8. Which diagram shows the trends in atomic size? * 1 point

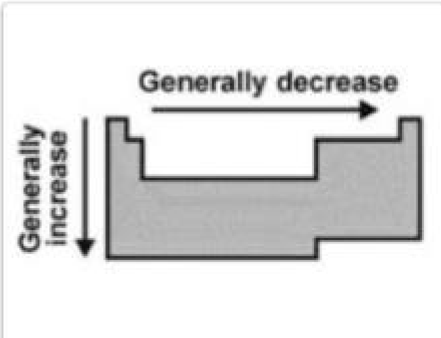
Mark only one oval.



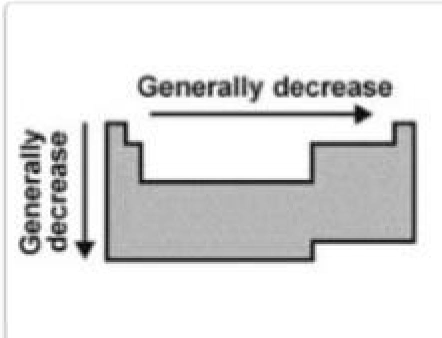
Option 1



Option 2



Option 3



Option 4

9. Elements in the same group have * 1 point

Mark only one oval.

- similar chemical properties.
- different chemical properties.
- the same atomic radius.
- the same state of matter.

10. Sodium forms a +1 ion, whereas fluorine forms a -1 ion. This is because sodium has _______ than fluorine. * 1 point

Mark only one oval.

- a smaller radius
- higher electronegativity
- lower ionization energy

11. Element Y has an electronegativity between 3 and 4. Which element could be element Y? * 1 point

Mark only one oval.

- Na
- Ba
- O
- Sc

12. Atoms form chemical bonds in an effort to * 1 point

Mark only one oval.

- have even numbers of valence electrons.
- reach a stable octet.
- add electrons to the valence shell.
- remove electrons from the valence shell.

13. What is the ionic charge that will be formed by unknown element X? * 1 point

Mark only one oval.

- ◯ 6-
- ◯ 2-
- ◯ 2+
- ◯ 6+

14. * 1 point

What is the correct formula for the compound formed from Ba^{+2} and Cl^{-1}?

Mark only one oval.

Ba_2Cl	$BaCl_2$
Option 1	Option 2
$BaCl_3$	$BaCl^{+1}$
Option 3	Option 4

15. Magnesium (electron configuration: 2.8.2) will most likely form an ion with a charge of * 1 point

Mark only one oval.

- 6+
- 2+
- 6-
- 2-

16. The chemical bond between nitrogen and chlorine is likely * 1 point

Mark only one oval.

- covalent
- ionic
- metallic

17. Which of the following is a Lewis dot structure for hydrogen iodide (HI)? * 1 point

Mark only one oval.

Option 1

Option 2

Option 3

Option 4

18. An unknown compound is found to be brittle, crystalline, and conducts electricity when dissolved in water.This unknown compound is most likely a(n) _______________ compound. * 1 point

Mark only one oval.

- covalent
- ionic
- metallic

19. Compared to magnesium chloride (an ionic compound), glucose (a covalent compound) has a __________ melting point. * 1 point

Mark only one oval.

- higher
- lower
- similar

20. * 1 point

Which is the correct name for the compound $(NH_4)_2S$?

Mark only one oval.

- Nitrogen Hydrogen Sulfate
- Ammonium (II) Sulfate
- Ammonium Sulfide
- Diammonium Sulfide

21. *

1 point

What is the correct name for P_2O_5?

Mark only one oval.

- ( ) Phosphorus (V) Oxide
- ( ) Phosphorus Oxide
- ( ) Diphosphorus Pentoxide
- ( ) Phosphorus (II) Oxide (V)

22. What is the correct formula for the compound sodium phosphate? *

1 point

Mark only one oval.

Na_3PO_4

( ) Option 1

Na_3P

( ) Option 2

$NaPO_3$

( ) Option 3

23. What is the correct formula for calcium bromide? * 1 point

Mark only one oval.

$CaBr$

- Option 1

$CaBr_2$

- Option 2

Ca_2Br

- Option 3

APPENDIX D

PRE/POST ASSESSMENT FOR CHEMICAL QUANITIES

Unit 4 Benchmark Assessment

Each question is worth 1 point.

* Indicates required question

1. Email *

First Name

2. First Name *

Last Name

3. Last Name *

Period

4. Period *

   Mark only one oval.

   - Period 1
   - Period 2
   - Period 3
   - Period 4

Test Questions

5. *

1 point

What is the molar mass for $Ca(OH)_2$?

Mark only one oval.

- 57.1 grams
- 59.1 mole
- 74.1 g/mole

6. *

1 point

How many moles of Ag are there in 4.5×10^{23} atoms of Ag?

Mark only one oval.

- 0.75 mole
- 0.75×10^{23} mole — Option 2
- 2.7×10^{24} mole — Option 3
- 2.7×10^{47} mole — Option 4

7. * 1 point

What is the molar mass for the compound $CaBr_2$?

Mark only one oval.

- 120 g/mole
- 200 moles
- 200 g/mole
- 240 grams

8. * 1 point

The molar mass of Na_2O is 62.0 g/mol. What is the mass of 3.75 moles of Na_2O?

Mark only one oval.

- 16.5 g
- 146 g
- 173 g
- 233 g

9. * 1 point

How many moles are in 110 g of CO_2?

Mark only one oval.

- 0.40 moles
- 2.5 moles
- 3.9 moles
- 4800 moles

10. * 1 point

The molar mass of $C_6H_{12}O_6$ is 180 g/mol. How many molecules are in 358.3 grams of $C_6H_{12}O_6$?

Mark only one oval.

1.2×10^{24} molecules

Option 1

3.0×10^{23} molecules

Option 2

3.9×10^{28} molecules

Option 3

11. * 1 point

What is the mass of 50.0 L of NO_2 gas at STP?

Mark only one oval.

- 20.6 g
- 24.3 g
- 103 g

12. * 1 point

Element	Percent Composition
C	37.50%
H	12.50%
O	50.00%

What is the empirical formula for this substance?

Mark only one oval.

CHO

Option 1

CH_4O

Option 2

$C_3H_{12}O_3$

Option 3

C_3H_4O

Option 4

13. * 1 point

The molar mass of $Mg_3(PO_4)_2$ is 263 g/mol. What is the percent composition for magnesium in $Mg_3(PO_4)_2$?

Mark only one oval.

- 28 %
- 34 %
- 43 %

14. * 1 point

What is the percent composition of oxygen in $FeSO_4$?

Mark only one oval.

- 10.53 %
- 42.13 %
- 53.40 %
- 66.67 %

15. * 1 point

What is the molecular formula for a compound with an empirical formula of CH and a molar mass of approximately 78 g/mole?

Mark only one oval.

C_3H_6

Option 1

CH_4

Option 2

C_6H_6

Option 3

16. * 1 point

A compound has an approximate molar mass of 194 g/mole and a percent composition of 49.48% C, 5.19% H, 16.48% O and 28.85% N. What is the molecular formula of the compound?

Mark only one oval.

$C_7H_6O_3N_4$

Option 1

$C_8H_{10}O_2N_4$

Option 2

$C_9H_{12}O_2N_3$

Option 3

APPENDIX E

UNIT SURVEY

Unit Survey

The results of this survey are completely anonymous and voluntary. There will be no impact on your grade whether you participate or not. It will only be used for comparison of the treatment unit to the non-treatment unit.

Answer each of the following questions based on your own feelings and experiences. For each question you will put a rating between 1-4.

1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

1) I learned a lot in this unit.
2) I felt prepared for the benchmark assessment.
3) I felt like the learning belonged to me in this unit.
4) I found this unit to be enjoyable.
5) I felt like this unit was challenging.
6) I felt like this unit made me think.
7) I felt like student voice was an important part of this unit.
8) I felt like this unit was engaging.

APPENDIX F

STUDENT INTERVIEW QUESTIONS

Student Interview Questions

1) Did you feel like you learned a lot in this unit? Why or why not?

2) Did you feel prepared for the benchmark assessment? Why or why not?

3) Did you feel like the learning belonged to you in this unit? Why or why not?

4) Did you find this unit to be enjoyable? Why or why not?

5) Did you feel like this unit was challenging? Why or why not?

6) Did you feel like this unit made you think? Why or why not?

7) Did you feel like student voice was an important part of this unit? Why or why not?

8) Did you feel like this unit was engaging? Why or why not?