

USING STORYLINES TO INCREASE STUDENT PERFORMANCE IN THE
CHEMISTRY CLASSROOM

by

Jacquelyn Caryl Curran

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of

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in

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DEDICATION

I dedicate this paper to my mother and father for all of their love and support.

ACKNOWLEDGMENTS

A big thank you to all of the influential teachers in life, especially my husband, Dan.

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ABSTRACT

The purpose of this classroom research project was to determine whether using storylines as a means for providing context and coherence within a chemistry unit would have a positive impact on student understanding as indicated by performance on unit assessments. A storyline refers to the sequence of events through which a unit surrounding an anchoring event or phenomena unfolds. Storylines provide structure, ground content, and guide students in making connections between not only important learning objectives, but also within a larger context. During this classroom research project, 38 out of 60 students were exposed to instruction using storylines. While, another 23 students received traditional instruction. Results of pre- and post-assessment scores of the two groups were then compared, along with student self-assessment surveys, interviews, and feedback form responses.

Upon analysis of pre- and post-assessment scores, results indicated that for the particular unit of study, the incorporation of an overarching storyline did not have a significant impact on student understanding. However, in looking at student self-assessment surveys, interviews, and feedback form responses, it is clear which types of activities students found to be the most beneficial to their overall learning experience. This valuable information can be utilized in future applications.

INTRODUCTION AND BACKGROUND

Coherence is defined as, “a logical interconnection” or “overall sense of understandability” (Dictionary.com LLC, 2018).). F. James Rutherford (2000), from the American Association for the Advancement of Science, in his writing, *Coherence for High School Science*, writes that

[Coherence] has to do with relationships. Things are coherent if their constituent parts connect to one another logically...or in some other way to form a whole. Coherence calls for the whole of something to make sense in light of the parts, and the parts to make sense in light of the whole (Rutherford, 2000, p. 33).

Rutherford goes on to state, “Scientific ideas presented without conceptual coherence have little chance of enduring in the minds of students” (p. 31).

Providing students with a coherent science experience through which they can make connections both within a unit or course, as well as across grade bands, has become an area of increasing focus over the past decade with the creation of the Next Generation Science Standards being as a framework for this change in the United States. Desire to provide a coherent science experience that focuses as much on the practice of science as it does on science content has been fueled by the poor performance of United States students on international assessments. There are many potential ways in which to provide this type of coherence and quality of science education to students. One promising way of doing so is with the incorporation of storylines as a guide for the learning process. According to the Next Generation Science Storylines project out of Northwestern University, a storyline is “a coherent sequence of lessons, in which each step is driven by student questions that arise from their interactions with phenomena” (Rser, Novak,

McGieill, & Voss, What Are Storylines, para. 1). Storylines guide the flow of lessons within a unit and continuously connect content back to an anchoring event or phenomena that students are attempting to explain. Storylines are teacher guided, but driven by student questions, and utilize scientific investigations and reasoning to gather evidence in order to explain the anchoring event or phenomena. The use of storylines in the science classroom is a relatively new concept in the US that currently has little supporting research. Despite this, storyline exemplars and information presented by storyline advocates provides an intriguing argument for their potential effectiveness in the science classroom. For this reason and due to my desire to increase overall student understanding and attitude towards chemistry in my classroom, I have decided to incorporate storylines into my curriculum.

Demographics

I currently teach freshman level biology and sophomore level chemistry courses at Middleton High School in Middleton, Wisconsin. Middleton is a suburban community with a population of around 17,500. Our high school consists of 2026 students, almost equally distributed between ninth and twelfth grade. About ten percent of our high school population consists of students with learning disabilities. While, about two percent of our school population is classified as English Learners (ELs) who come from a variety of countries and backgrounds. Finally, although our community is rather affluent, 16.5% of our school population can be considered economically disadvantaged (Wise DASH).

I teach two sections of biology and three sections of chemistry. Classes run on a rotating A-B schedule and are 87 minutes in length, meaning classes meet two to three

times a week. I chose to focus my classroom research project on my three chemistry sections, as efforts to incorporate storylines into our biology curriculum have been anecdotally successful. As a result, I wanted to more formally assess the success of my efforts as I work to incorporate storylines into my chemistry classroom.

My first block chemistry class consists of 24 students, who range drastically in terms of skill level and ability. Due to our school's special education service model, all of our students, including the ten percent of students with learning disabilities, are spread out between our classes. As a result, my chemistry classes consist of students who range from those who could be considered honors level to those whom have alternative learning goals that are dictated by their Individualized Education Plans (IEPs). I have two students in first block chemistry who have identified learning needs and have IEPs. These two students are assisted by a para-educator and due to the fact that these students receive significantly modified assessments, I choose to not record their assessment results as part of this research project. In addition, one of my first block students is a frequent non-attender. For this reason, her results were also omitted from this research project. In total, 21 students from first block were assessed and submitted end of unit feedback. In terms of ethnicity, the overall ethnic makeup within first block mirrors that of our school as whole.

My other two classes, second and seventh block, are similar to each other in terms of makeup. Both are co-taught sections with two teachers usually present in the classroom. My special education co-teacher and I share instruction and assessment tasks equally. In second block, there are two students with identified learning needs and IEPs

and one student with a 504-accommodation plan. We also have one English Learner. In this block, 22 out of the 26 students' assessment/survey results were analyzed due to frequent non-attendance by three of the students and the alternative learning goals set for a fourth student. In seventh block, there are three students with IEPs and one with a 504-accommodation plan. In this block, only 17 of 24 students' assessment and survey results were analyzed for various reasons--non-attendance, significant modification requirements, absences on the day of the survey/feedback response, etc.

Overall, my classrooms have a positive classroom culture and are very student centered in nature. Students sit within pod groups or at lab benches with the same team groups for the whole class period. Groups are switched and mixed-up on a unit basis. There is very little focus on direct instruction. Instead, inquiry and hands-on learning play a huge role within our classroom. Students white board and practice sharing their ideas frequently. Students do struggle with chemistry content and often this struggle influences their attitudes towards the class as a whole. A common question that can be heard is, "But why do I have to learn this?" My hope is that the incorporation of storylines into our curriculum will provide students with an answer to this question.

Despite slight differences between my three chemistry classes, I felt that these three sections were similar enough to serve as comparison to one another. For the purposes of this classroom research project, I chose to use first and seventh block as my treatment group. These two groups were presented bonding unit content with an overarching storyline. Second block served as a comparison group. Students in this block were not presented with a storyline, but participated in all other classroom activities and

lessons experienced by the treatment group. Students in both treatment and comparison groups received the same pre- and post-assessments, as well as the same follow-up survey, interview questions, and feedback form.

Timing of Instruction

This classroom research project took place at the end of the first semester during the last unit before a cumulative semester final. Throughout the first semester, students in all three chemistry classes were exposed to the following topics: gas laws, the nature of matter, physical and chemical changes, atomic structure, periodic table organization, and nuclear chemistry. Students in all groups experienced storylines in three of the five prior units. The unit students were taking part in at the time of this research involved the topics of valence electrons, shapes and polarity, and intermolecular forces. The storyline that was incorporated into the treatment group classes was one pertaining to the topic of protein folding.

As freshman, all students were exposed to the topic of protein folding in a biology unit on protein synthesis. As part of this unit in biology, students encountered a storyline involving a child named, Maria, who suffered from cystic fibrosis. Throughout the unit, students attempted to explain what causes Maria's cystic fibrosis. Students learned about DNA structure and protein synthesis, as well as about DNA mutations and their implications in protein folding. By the end of the protein synthesis unit, most students could explain that Maria suffers from cystic fibrosis due to a mutation in her DNA and that this mutation results in an error in the amino acid sequence of a specific type of protein in her lung cells. They can also identify that this error in amino acid sequence

leads to misfolded proteins and that if these proteins do not have the correct shape then they cannot do their job correctly, which is to serve as protein channels in Maria's lung cells. Students, however, never get to the molecular level reason as to why an incorrect amino acid sequence can cause protein-folding errors. The Maria storyline used in this classroom research project is meant to bridge the gap between what students have learned previously in biology and new content on bonding presented in their sophomore year chemistry course. The thought is that by working to have students ask questions about and ultimately explain down to the molecular level why this particular type of protein does not take the correct shape, and therefore, functions incorrectly, students will not only expand on prior knowledge, but will also have an anchor to which to link new knowledge. Ultimately, the goal of incorporating this storyline was to see if having a context-based, engaging experience would have an impact on overall student understanding of and attitude towards chemistry content regarding bonding.

Research Aim

The aim of this classroom research project was to assess whether the use of a storyline as an anchor for the unit on bonding increased student performance on the end of unit assessment. Furthermore, I had a desire to assess whether this change in methodology had an impact on students' perceived level of preparedness for an end of unit assessment and their attitudes towards chemistry.

CONCEPTUAL FRAMEWORK

Since the 1970s, a number of comparisons have been made between the United States and other countries in terms of student academic performance, especially in

regards to science education. The Trends in International Mathematics and Science Study (TIMSS) is largest ongoing study of mathematics and science education in the world. According to the most recent TIMSS, which took place in 2015, students from multiple countries, including Russia and China, are outperforming students from the United States in science. In this study, only 12% of eighth grade students in the United States scored in the advanced range based on international benchmarks set by the International Association for the Evaluation of Educational Achievement, in comparison to 14% and 27% for Russia and China respectively. Equally worrisome, when data from past TIMSS results was compared with data from 2015, no significant improvement in overall student performance had been seen by students in the United States since 2003 (Jones, Wheeler, & Centurino, 2015).

Some researchers have begun to link variations in terms of success to differences in methods of science instruction, suggesting that curriculum in United States lacks focus, fails to draw connections between content, and prevents students from having meaningful learning experiences that lead to a deeper understanding of course material (Schmidt, McKnight, & Raizen, 2007). In a report that analyzed results from the 2012 National Survey of Science and Mathematics Education (NSSME), Banilower, Smith, Weiss, Malzahn, Campbell, and Weis (2013), provided evidence that a focus on teacher-directed, assessment-driven learning practices continues to dominant in United States science classrooms. Teachers, across all grade bands, from the 1500 randomly selected US schools that participated in the survey, indicated that over 50% of their classes consisted of the teacher “explaining science ideas in all or nearly all lessons” (p. 79). Further

survey results indicated that this type of instruction occurred on average at least three times per week in roughly 88-96% of the classrooms surveyed; and that in the most current lesson conducted; teacher-directed instruction outweighed any other form of instruction by over 30% (2013).

Findings of research funded by the Spencer Foundation, a private foundation that funds education research with the aim of improving overall understanding of education practice, attempted to identify potential reasons as to why the United States has experienced such little growth in its methods of education. After looking at over 200 interviews along with in-class observations and extensive pieces of archived data, these authors concluded that forces external to education, like politics, have “ultimately reaffirmed the traditional identities and practices of conventional high schools and pulled innovative ones back toward the traditional norm in an age of standardization” (Hargreaves & Goodson, 2006, p. 3). The ultimate effect of this caving to external influences being the overall stagnation of educational practice in the United States and the continued implementation of curricula that require little student engagement and fail to provide meaningful learning experiences.

Individuals invested in science education have been calling for science education reform since the 1950s (Abd-El-Khalick, et al., 2004). However, it has not been until recently that a concerted effort among those in the science education field has taken place to change the path of science education in the United States. This new path rallies around not only student directed learning, but also a coherent science curriculum that provides explicit connections throughout a student’s learning career. The idea being that when

pieces of curriculum are clearly connected together, students are able to create a meaningful conceptual framework that can as a result enhance their overall performance in science (Fortus, Sutherland Adams, Krajcik, & Reiser, 2015).

To meet this aim, *A Framework for K-12 Science Education*, was created in 2010. This document created through the joint effort of the National Research Council (NRC), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and Achieve works to provide a guide that will ultimately help “create science literate citizens whose experience in K-12 education prepares them to engage in issues concerning science...by addressing the need for coherence and promoting science practices and skills” (Pruitt, 2014). *A Framework for K-12 Science Education* states that

Currently, K-12 science education in the United States fails to achieve [the desired outcomes of the Framework], in part because it is not organized systematically across multiple years of school, emphasizes discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done (National Research Council, 2012, p. 1).

In 2013, the creators of the Framework went on to create the Next Generation Science Standards (NGSS). A set of national science standards that attempts to address the predominant concerns of United States science education. The Next Generation Science Standards, like the Framework, are based on decades of research that focus on best practice in science teaching and learning, and center around the ideas of curriculum coherence and student-directed learning. These new standards focus not only on a narrower range of science content that students should learn in greater detail as they progress through identified grade bands (Disciplinary Core Ideas, DCIs), but also on the

skills (Science Practices, SPs) and connections (Cross-Cutting Concepts, CCCs) that are required to sufficiently tie content to meaningful science learning (Pruitt, 2014). The NGSS insists that for true learning to take place in science these three facets of science learning and understanding need to be met. This idea has become known as the Three Dimensions of Science Learning or 3D Learning. Students ultimately show proficiency on these dimensions by using their overarching and interconnected understanding of science content and skills to complete identified performance expectations within their grade band (NGSS Lead States, 2013).

Without a doubt, the performance expectations in the NGSS raise the level of rigor in science classrooms and ask for a different type of learning to take place than has been shown to be present in United States classrooms. Unsurprisingly, many classroom teachers are ill prepared to meet these new demands (Reiser, 2013). As a result, there is a need for the development and implementation of new methods of curriculum and instruction that will serve to meet the standards set by the NGSS and provide a level of coherence among science topics.

One adaptation to science curricula that shows promise is the incorporation of unit level storylines as a basis for teaching NGSS content and skills. At its core, the idea of a storyline is a flow of lessons that connects back to an anchoring event or phenomena. This sequence of lessons differs from traditional instruction methods in that it is student driven, based on science practices, and purposeful. Each lesson is driven by student questions and all lessons provide evidence that ultimately helps explain the anchoring event. This makes storylines a great method for providing inter- and intra-unit coherence

(Reiser, Novak, & Fumagalli, 2015). A storyline can be defined as, “a coherent sequence of lessons, in which each step is driven by students' questions that arise from their interactions with phenomena” (Reiser, Novak, McGill, & Voss, 2017). A storyline includes “the overall sequence of progression of lesson elements that helps students advance towards specific learning goals” (Ermeling & Graff-Ermeling, 2016, p. 23). In order to promote student achievement with the NGSS, storylines must be properly designed. The Next Generation Science Storylines project housed at Northwestern University is “dedicated to providing tools that support teachers in developing, adapting, and teaching with strongly aligned NGSS materials in classrooms around the country” (Reiser, Novak, McGill, & Voss, 2017). The creators of the Next Generation Science Storylines project follow five design principles that drive their construction of storylines in order to achieve the level of meaningful learning called for by the NGSS (Figure 1). Together these five design principles provide a strong basis from which one can further develop a coherent curriculum that is aligned to all three of the dimensions of the NGSS.

Storyline Design Principles
The storyline is driven by <i>students'</i> questions from their interactions with phenomena
At each step, students focus on explaining phenomena or solving problems motivated by their overarching question
At each step, students engage in practices to make progress on their questions and figure out a piece of a science idea (DCI, CCC)
Each step generates another piece of the puzzle
Students put together what they have figured out to explain the anchoring phenomena or solve the anchoring problem

Figure 1. Storyline design principles (Reiser, Fumagalli, Shelton, & Novak, 2017).

The use of storylines within science education is relatively new and few examples exist. Many of them having been created by the Next Generation Science Storylines team and other contributing members. One such example, incorporates many of the disciplinary core ideas pertaining to the topic of evolution along with cross cutting concepts and science practices from the NGSS, and focuses on the story of a girl named, Addie. Addie's non-fiction story of the fight for her life when she becomes infected with antibiotic resistant *Stenotrophomonas* bacteria provides an engaging story through which Reiser and colleagues have students purposely encounter and use science practices. This storyline then provides a meaningful anchor to which students link concepts and other examples of evolution back to (Reiser, Novak, McGill, & Voss, 2017). Another storyline example created by the Next Generation Science Storyline team revolves around the question, "Why do some things get colder (or hotter) when they react?" (Figure 2). These two storyline exemplars and additional guiding materials created by the Next Generation Storylines project served as the inspiration for the Maria storyline used in this classroom research project.

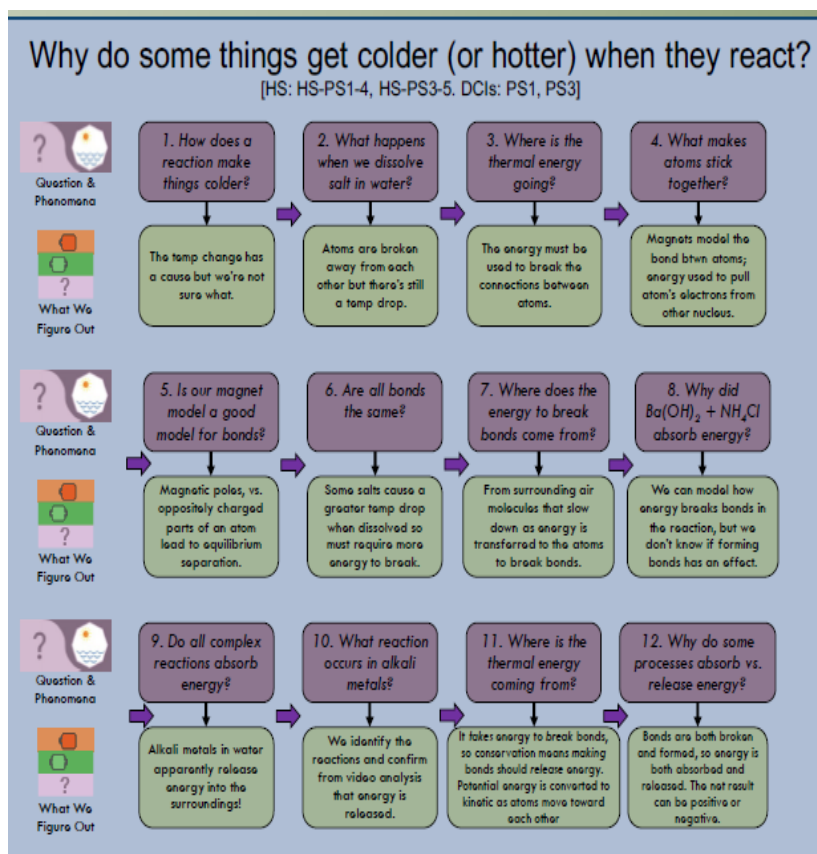


Figure 2. Next Generation Science storyline example (Reiser, Novak, McGill, & Voss, 2017).

There has been limited research done on the effectiveness of using storylines in the science classroom. Many of the most applicable studies have been those done by Hülya Demircioğlu and colleagues. In 2009, Demircioğlu, Demircioğlu, and Calik conducted a research project in Turkey that shows the potential effectiveness of using a context-based approach similar to that of a storyline. This study looked at the effectiveness of a context-based instruction throughout a unit on the Periodic Table. In this study of eighty ninth graders, the treatment group was provided with context-based instruction that included stories, which were focused on the application of course concepts to real world scenarios, while the control group experienced a teacher-directed

method to instruction. Pre- and post-assessment comparisons of these two groups showed a positive impact of the context-based approach in terms of student learning. Researchers also recorded a higher number of student ranking their attitude towards chemistry as positive and saw an increased level of retention of chemistry concepts up to ten weeks after the treatment was given (Demircioğlu, Demircioğlu, & Calik, 2009).

A similar study also by Demircioğlu, Dinc, and Calik (2013), again tested the effectiveness of a context-based approach on learning. In this study, thirty-five sixth grade students in Turkey were exposed to context-based instruction that incorporated relevant stories. Students were first given a pre-assessment to assess their knowledge on the concept of physical and chemical changes. After participating in the unit, students took a similar post-assessment. Again, results indicated a positive influence on overall student performance with pre-assessment results from these students ranging from 9-77%, while post-assessment results ranged from 83-100%.

Despite the lack of evidence pertaining to the use of storylines as a proven way in which to enhance student performance in science, the approach still has many promising features. Firstly, it can be easily linked to the three dimensions of learning called for by the NGSS. With the disciplinary core ideas, science practices, and crosscutting concepts being used in tandem to explain a phenomenon or to provide an evidenced-based answer for the guiding question of the storyline. Secondly, the storyline approach has the ability to promote curriculum coherence both throughout a unit and between units, allowing students to make connections between content and knowledge from prior science learning

experiences. Finally, the storyline approach provides a context for science content for students and an answer to the often-asked question, “Why do we have to learn this?”

METHODOLOGY

The focus of this classroom research project was to assess the effect of using storylines on student understanding and attitude towards chemistry.

Participants

The treatment group included 38 sophomore students spread out almost equally between two separate chemistry courses. One of these courses ran during the first block of a four period day and occurred on the A Day of an alternating A-B schedule. The other ran during the third block of a four-period day but will be referred to within this research as seventh block as it took place on the B day of our school’s A-B schedule. Of the 38 students within this treatment group, 47% were biologically female and 53% were male. Students with IEPs made up 10% of the treatment group. The comparison group took place during the second block on A days and included 22 students, 58% of which were female and 42% of which were male. There were one student with IEP in this comparison group, representing .05% of the comparison group population.

Intervention

The classroom research project was carried out at the end of first semester prior to a cumulative semester final. Students in both the comparison and treatment group had already been exposed to chemistry content regarding gas laws, the nature of matter, physical and chemistry changes, atomic structure, periodic table organization, and nuclear chemistry. Three out of these five previous units had been taught using a

storyline approach for both the comparison and treatment group. The unit that all students were taking part in during this research project revolved around the concepts of valence electrons, shapes and polarity, and intermolecular forces. Prior to starting the unit, students in both the comparison and treatment group received a Bonding Unit Pre-Assessment that consisted of a small number of questions similar to those that would be seen on the end of the unit assessment (Appendix A). These pre-assessments were graded and students were allowed to see their scores. The pre-assessments were then collected.

As the unit progressed, the comparison group received traditional instruction with no incorporation of storyline materials. This curriculum consisted of daily warm-ups, notes, practice worksheets, labs, and daily exits. During this same time, students in the treatment group were also exposed to all of the same learning activities but were additionally introduced to a storyline revolving around the importance of different types of chemical bonding in determining protein structure (Appendix B). Throughout the unit, students in the treatment group linked the content that they were exposed to during the class period to the storyline and worked to determine how bonding influences protein structure.

The storyline used in this classroom research project revolved around a scenario involving a young girl named, Maria, who suffers from cystic fibrosis. All students were familiar with Maria's story having had encountered her during their protein synthesis unit in freshman biology. Throughout the unit of this research project's focus, students first recalled and then expanded on information learned during freshman year. They then made hypotheses and asked further questions about why Maria's proteins are misshapen

and unable to perform their function. Students moved from answering these questions based solely on the idea of DNA mutations to how changes in amino acid sequence affect the shape of a protein. Students, ultimately, ended the unit making the connection that different amino acids have different side chains and that it is the interaction (i.e. forces/bonding) between these side chains that determines the shape of a protein. If the sequence of these side chains is altered due to a DNA mutation, different interactions will potentially occur, changing the shape of the protein, and therefore, impeding proper protein function. This is the reason why Maria is suffering from cystic fibrosis. Throughout this process, students worked to connect chemistry content, regarding different inter- and intramolecular forces, why these forces exist, and the strength of these interactions to Maria's story (Figure 3).

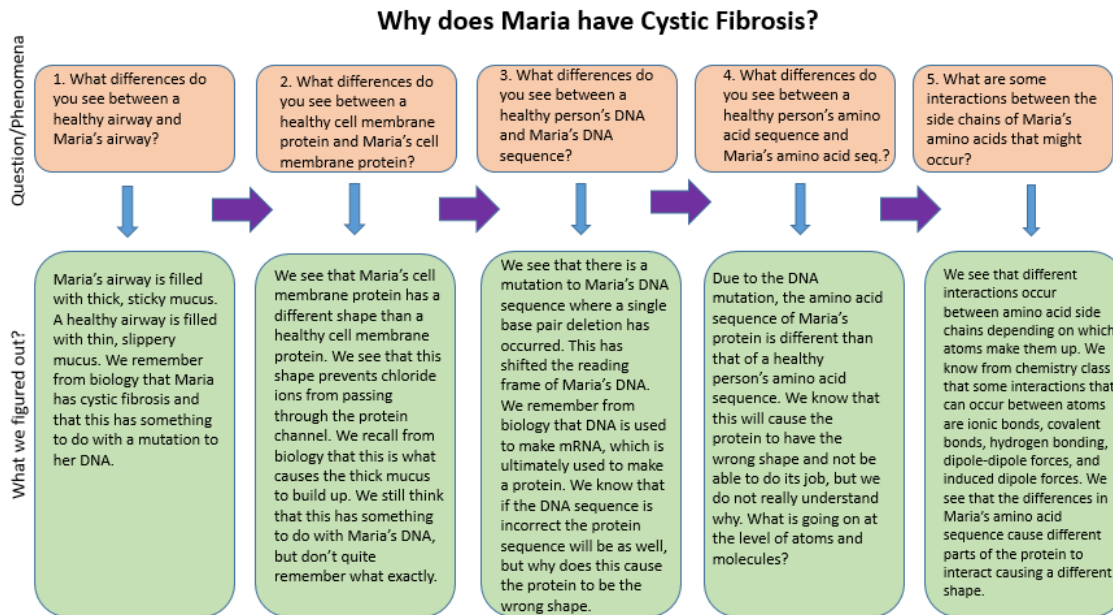


Figure 3. Maria storyline flow chart.

The goal of this classroom research project was to see if the second mode of instruction, which served to provide a greater context for learning chemistry, had any effect on student understanding, perceived level of preparedness, and attitude towards chemistry.

Data Collection

At the end of unit, students in both the comparison group and the treatment group were given the Bonding Unit Post-Assessment (Appendix C). The Bonding Unit Post-Assessment was part of a semester final that contained questions from each of the five units from first semester. The bonding portion of the semester final contained questions similar in amount and skill-level to those given to all students at the beginning of the unit on the pre-assessment. All students were given the full 87-minute class period to complete the semester final in a quiet classroom environment. The use of notes was not allowed.

During the next class period, students picked up the Student Self-Assessment Survey and completed this individually (Appendix D). The majority of self-assessment questions regarded student attitudes toward the use of storylines, or as we called them in class, anchoring events/unit challenges. These questions were applicable to all students, regardless of whether they were in the treatment group or comparison group, because all students had experienced the use of storylines throughout the majority of first semester. The self-assessment also included questions regarding attitude towards other class activities, as well as chemistry in general. Finally, the self-assessment survey asked students to assess their level of preparedness for the unit post-assessment, what steps they

took to prepare, and whether or not they thought that participating in the storyline process had any effect on their level of preparedness.

In an effort to gather a number of more in-depth student responses, six students from the comparison group, as well as six students from the treatment group were asked to participate in student interviews, using the Student Interview Questions (Appendix E). Students for these interviews were identified using their unit post-assessment grades. Two students, a male and a female, who scored above an 85% on the assessment, were randomly selected from both the treatment and comparison group. Another two students, a male and a female, who scored between an 85% and a 70% on the assessment, were also randomly selected from both the treatment and comparison groups. Finally, two students, a male and female, who scored below a 70% on the assessment, were randomly selected from each of the groups. All students participated in the interview in a one on one setting and their responses were recorded using a voice recorder on a cell phone device.

In addition to unit pre- and post-assessment scores, the unit self-assessment survey, and the student interviews, a final method of data collection involving the use of the End of Unit Feedback Form was used (Appendix F). This feedback form asked more open-ended questions regarding how students perceived the unit, as well as how they felt about the use of storylines in general. All students were given time to complete this feedback form in class. These more open-ended responses were then used in addition to other pieces of data to further help address the sub questions regarding whether the use of storylines in the chemistry classroom has an impact on students' perceived levels of

preparedness or their attitude towards chemistry. Table 1 shows a summary of the data collection methods used in this classroom research project.

Table 1
Triangulation Matrix

Focus Question: Does the use of storylines in the science classroom increase the level of content understanding among students?

	Data Source		
Sub question #1: Do students perceive themselves as more prepared for end of assessments if provided the opportunity to connect unit content to real life scenarios using storylines?	End of Unit Self-Assessment	Student Interview Questions	End of Unit Feedback Form
Sub question #2: Do students who are exposed to the storyline approach report positive attitudes towards chemistry more often than students who are not taught with the storyline approach?	End of Unit Self-Assessment	Student Interview Questions	End of Unit Feedback Form

The MSU Institutional Review Board has approved the methodology for this project (Appendix G).

DATA ANALYSIS

During this research project, pre- and post-assessment data for both a treatment ($N=38$) and a comparison group ($N=22$) was collected in order to see if the use of the storyline approach had any impact on student content understanding in comparison to the use of a more traditional approach. Students in both the treatment and the comparison group completed the same pre- and post-assessments. These assessments consisted of mostly multiple-choice questions with some short answer questions (Appendices A and C). Additionally, self-assessment survey data, interview responses, and responses on student feedback forms provided further data for both the treatment and comparison groups (Appendices D, E, and F). These data pieces provided information regarding

students' perceived level of preparedness for the end of the unit assessment, as well as their attitudes towards chemistry class.

At the beginning of our unit on bonding, students in both the treatment and comparison groups took the pre-assessment. Students in each group were provided with the same amount of time in which to complete this assessment. Students were shown their results but were not allowed to keep the pre-assessment document. Students in the treatment group scored a 39% average on the pre-assessment. While students in the comparison group scored an average of 44%. Student success with the multiple-choice portions of the pre-assessment was better than the short answer portions in both cases. Post-assessments scores for both treatment and comparison groups were closer with students in the treatment group scoring a 64% average and students in the comparison group scoring a 65% (Figure 4).

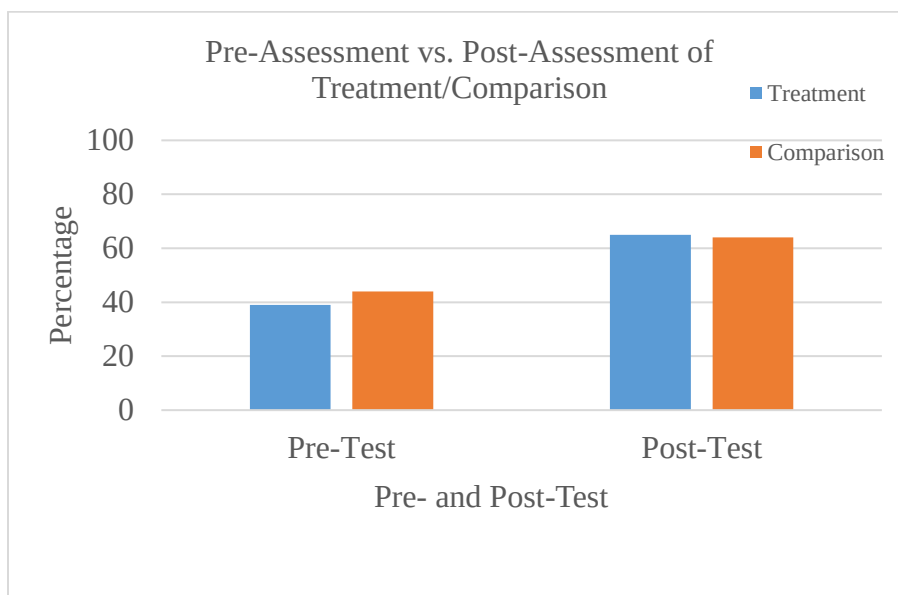


Figure 4. Pre- and post-assessment average scores for treatment and comparison group, (N=38, N=22).

T-tests were performed comparing pre- and post-assessment data of the treatment and comparison groups. In both cases, results indicated that the difference of these mean scores was statistically significant with p-values of .179 and .42 respectively. For this reason, a percent gain score was used to compare data. In comparing pre- and post-assessment data, it can be seen that students in the treatment group on average experienced a higher percentage of growth, 26%, compared to students in the comparison group, 20% (Figure 5). There were also students in both groups who scored worse on their post-assessment than their pre-assessment, indicating no overall amount of growth.

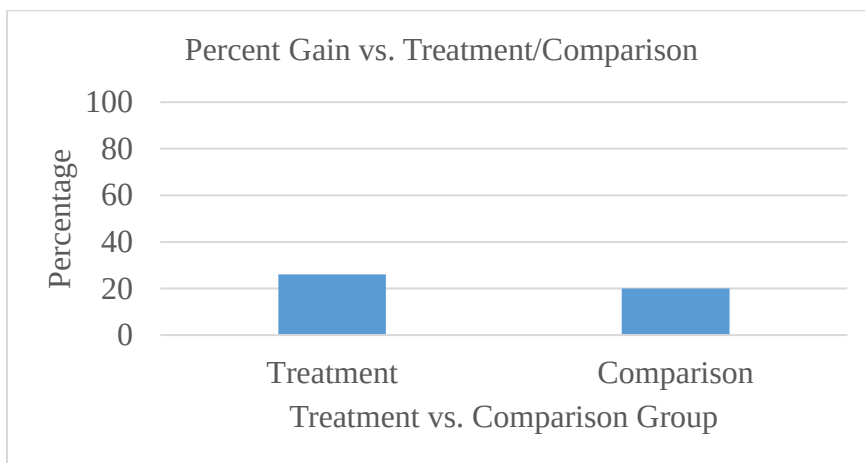


Figure 5. Average percent change for treatment and comparison group.

When looking more holistically at post-assessment data, it can be seen that students in both the treatment and comparison groups struggled the most with the bonding unit portion of the semester final from which the post-assessment data was collected. On this semester final, the treatment group scored on average seven percent lower in the bonding section of the semester final than in any other unit section. While the comparison group, scored on average ten percent lower in the bonding section of the semester final than in any other unit section (Figure 6). Differences in average scores

between the treatment and control groups in each of the semester unit content areas never exceeded one percent, besides in the nuclear chemistry section where a difference of two percent could be seen between average scores.

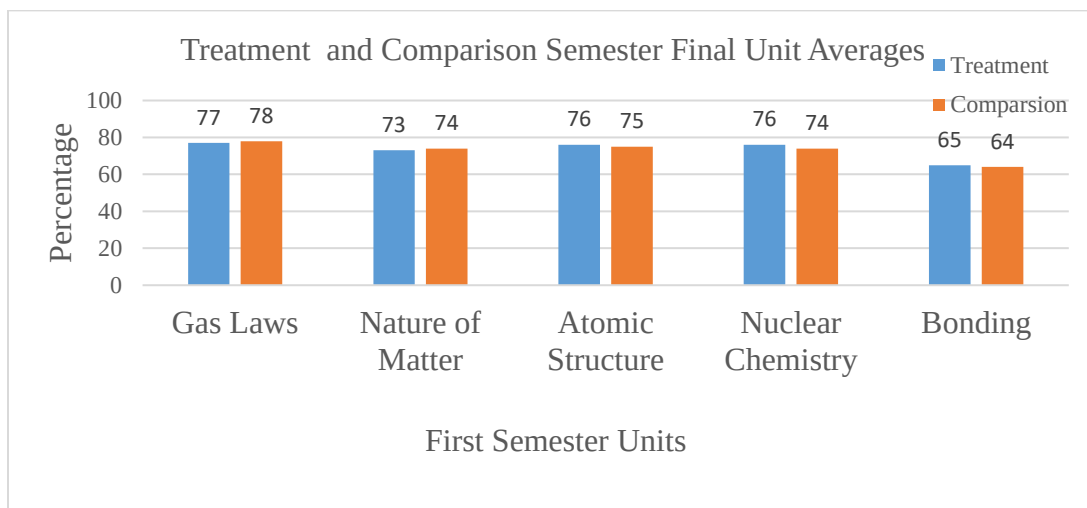


Figure 6. Treatment and comparison group semester final unit averages.

Bonding questions on both the pre- and post-assessment could be separated into three main topics: valence electrons, shapes/polarities, and intermolecular forces. Students in both groups did very well on the valence electron portion of the post-assessment and overall much better than they had on these types of questions on the pre-assessment. There were multiple students from both groups that scored 100% on these questions. On average, students in the treatment group scored an 85% on questions pertaining to valence electrons. While students in the comparison group scored on average an 89% on the same questions (Figure 7).

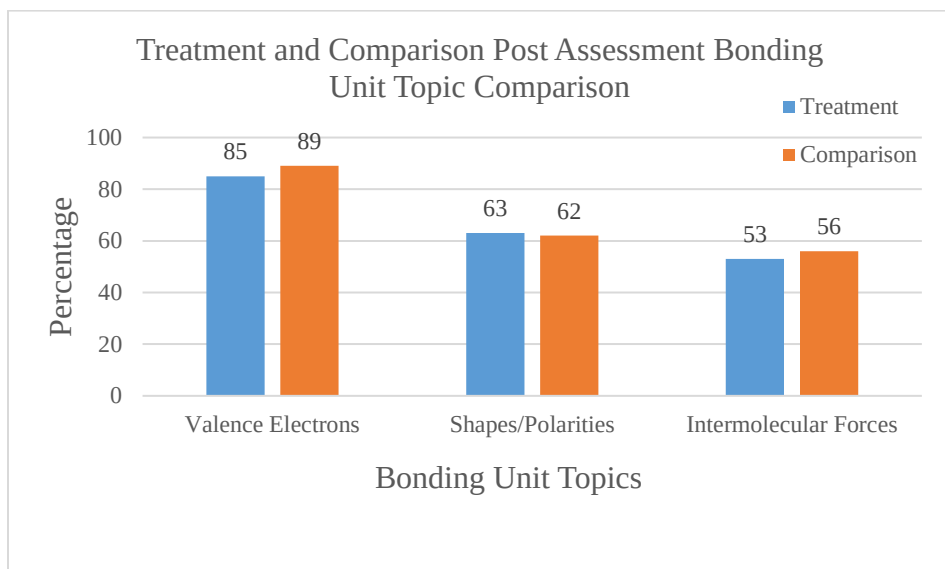


Figure 7. Treatment and comparison group post assessment bonding unit topic.

Students in both groups struggled more so with the other two portions of the bonding unit. On questions regarding shapes and polarities, students in the treatment group scored on average a 63%, while students in the comparison group scored on average a 64%. Additionally, students in the treatment group scored on average a 53% on questions pertaining to intermolecular forces, why they exist, and their relative strengths. While, students in the comparison group scored slightly better with a 56% average. Student success with multiple choice versus short answer portions of the post-assessment was similar between the two groups.

All students from whom assessment data was collected also participated in a unit self-assessment survey after completing the post-assessment. All students filled out the same self-assessment survey regardless of whether they had been exposed to the Maria Storyline or not. In regards to survey statements pertaining to storylines, also known as anchoring events or unit challenges, students in the comparison group are referring to the storylines of previous units as they did not participate in the Maria Storyline used in the

bonding unit. Students in the treatment group when evaluating their level of agreement with these statements are referring to both the Maria Storyline, as well as storylines used in previous units.

On the unit self-assessment survey given after the semester final, students from both groups reported similar levels of perceived preparedness for the bonding unit portion of this assessment regardless of having been exposed to the Maria Storyline (Table 2).

Table 2

Perceived Level of Preparedness for Post-Assessment Among Students in Both the Treatment and Comparison Groups

Statement: I felt prepared for this unit assessment.

Perceived Preparedness (Linkert Score)	4	3	2	1	
Block 1 Treatment Group	5	13	2	1	<i>N</i> =21
Block 7 Treatment Group	2	10	4	1	<i>N</i> =17
Block 2 Comparison Group	4	12	4	2	<i>N</i> =22

Note. 4-Strongly Agree, 3-Agree, 2-Disagree, 1-Strongly Disagree.

Within the treatment group, 79% of students agreed or strongly agreed with the statement: “I felt prepared for this unit assessment.” While 74% of students within the comparison group, agreed with the same statement. This is in contrast with 23% and 28% of students in the treatment and comparison groups indicating that they disagreed or strongly disagreed that they were prepared for the post-assessment (Figure 8).

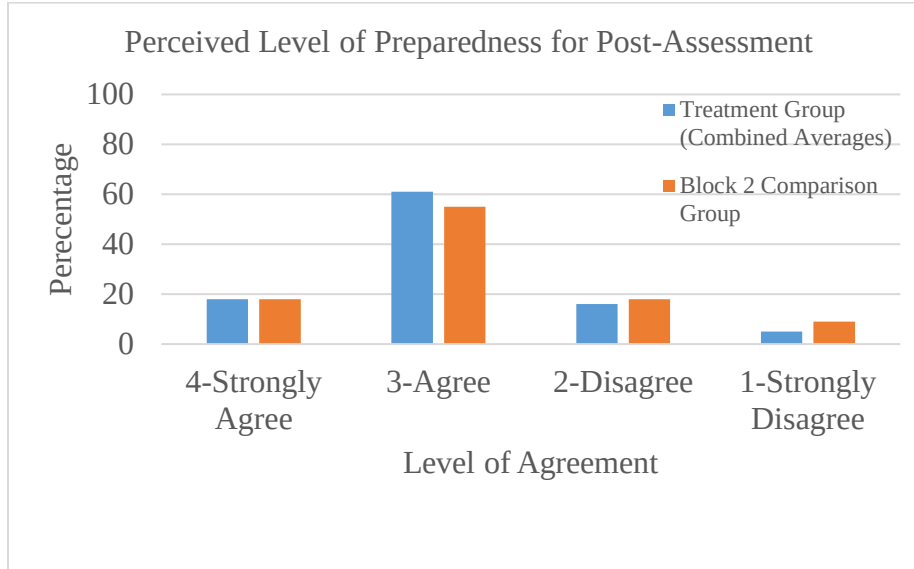


Figure 8. Perceived level of preparedness on post-assessment.

Responses regarding perception of storylines were similar among students in the treatment and control groups, but had some notable differences. Among students in the treatment group, the majority of students responses regarding the use of storylines in the chemistry classroom fell into the strongly agreed and agreed category the majority of the time. Most notable was the highest level of agreement, with 74% of students strongly agreeing or agreeing, with the statement: “Working through anchoring events/unit challenges helped me prepare for the unit assessment” (Figure 9). Comparison group responses followed a similar trend with slightly more students reporting on average that they strongly agreed or agreed with the statements regarding the positive effects of storylines. Eighty-three percent of students in the comparison group felt that past storylines had helped to prepare them for the unit post-assessments. This was almost 10% more than in the treatment group who was exposed to the Maria Storyline (Figure 10).

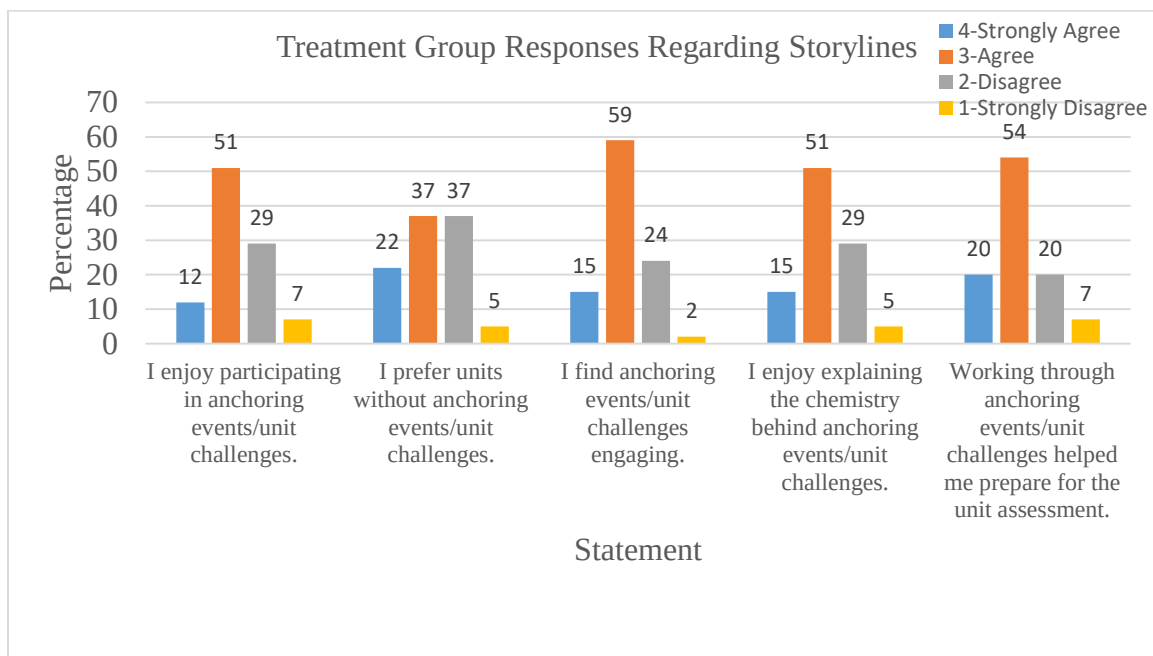


Figure 9. Treatment group responses regarding storylines.

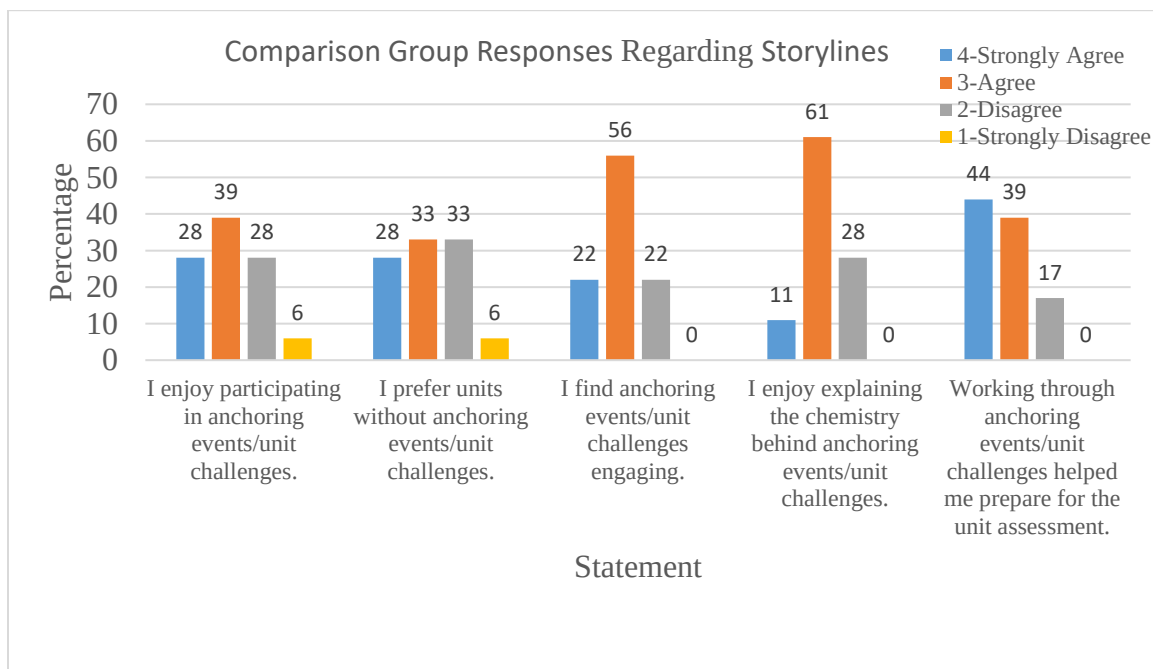


Figure 10. Comparison group responses regarding storylines.

Student end of unit feedback form and interview responses from both the treatment group and comparison were also collected. Feedback form responses were collected anonymously from all students. Student interviews were conducted with

students who were selected based on their post-assessment score with two students from each range, high, middle, and low achieving, being selected for interviews from both the treatment and the comparison groups. On the feedback form, students in the treatment group often wrote statements similar to the following in regards to the question, “What activities or parts of this unit did you like the least?”: “Maybe the Maria stuff. I didn’t understand anything.” Another student wrote, “A lot of the things were very simple and repetitive and just involved going back to previous notes.” One of the top performing students on the post-assessment similarly stated during an interview, “The Maria activity didn’t seem that valuable in helping me to understand the information that we were tested on.” A small number of students in the treatment group seemed to disagree with these statements, writing things like, “I enjoyed making the posters for the Maria Case Study.” Students in the comparison group, who were not exposed to the Maria Storyline, were less specific in their discussion of storylines and more often indicated traditional classroom activities, like notes, worksheets, etc., as either being enjoyable or unenjoyable aspects of the the unit. However, some students did refer back to previous unit storylines when providing feedback. One student when answering, “What parts or activities in this unit did you enjoy the most?” wrote, “The can crushing activity and the water filtration activity were fun.” Another stated during their interview, “The can crushing challenge and the water filtration were very engaging and helped me to understand the content better.” These two storyline activities were present in the Gas Law unit and the Nature of Matter unit respectively. Both of these storylines challenged students in a lab setting to complete a task and were fairly open ended in how students completed the challenge. At

the end of the challenge, students were required to explain their results using chemistry content. This was in contrast the Maria Storyline to which only treatment group students were exposed, which was highly scaffolded and less hands-on with the exception of working at lab stations to complete a summary poster of findings. Students in the comparison group, as well as in the treatment group, who cited these prior activities as engaging or helpful for their learning often indicated that the activities' hands-on and challenging nature were what they found valuable and memorable about these activities. Based on survey, feedback form, and interview responses, it appears that overall students prefer and report a higher level of satisfaction with hands-on, less structured activities to which they can apply their content knowledge. It remains unclear whether these types of experiences will impact student performance on end of unit assessments or their perceived preparedness for these assessments as the Maria Storyline for which data was collected did not provide this type of experience.

INTERPRETATION AND CONCLUSION

In contrast to previous research in which a context-based approach using storylines was used, no significant impact of the Maria Storyline was found on student understanding of bonding unit content. When comparing pre- and post-assessment data along with percent changes for the treatment and comparison groups, it can be seen that both treatment and comparison group students performed similarly on the bonding unit portion of the semester final. Although students in the treatment group did on average experience a higher percentage of growth, 26%, compared to students in the comparison group, 20%. Pre- and post-assessment data shows that the lower pre-assessment scores of

students in the treatment group could account for this difference in growth. Post-assessments scores for both the treatment group and the comparison group were almost identical with averages of 65% and 64% respectively (Figure 5). In addition, both students in the treatment and comparison groups struggled the most with the bonding unit portion of the semester final from which this post-assessment data was taken.

Similarities, however, can be seen between prior research and the results of this classroom research project in regards to students' self-reported responses relating to their attitudes towards chemistry. In prior research, student responses to self-assessment survey questions revealed that the majority of students reported positive attitudes regarding chemistry content when taught with a context-based approach. Similarly, the majority of students in both the treatment and the comparison groups of this classroom research project reported high levels of agreement with statements regarding engagement with and perceived value of storylines. With students in both groups citing storylines, like the Can Crush Challenge and Water Filtration Activity, as being meaningful learning opportunities on their end of unit feedback forms and in student interviews.

Despite the high level of agreement with statements regarding engagement with and the value of storylines, students in the treatment group reported less engagement with the Maria Storyline to which they were exposed. They also reported via the end of unit feedback form and in student interviews that they felt that the Maria Storyline did not play a significant role in their preparation for or in their improvement on bonding unit questions. One student from the treatment group, who scored a 73% on the post-assessment, when asked the following question: “ Do you feel like you always understand

how the course content links to the anchoring event/unit challenge?,” responded with: “I felt like the unit challenges in previous units helped me prepare more than the [Maria Storyline]. I felt they were more hands-on and didn’t just have us repeat the information.” Further responses from students within the treatment group echoed this claim.

VALUE

Despite similar results of students in both the treatment and comparison groups in regards student understanding and perceived level of preparedness, valuable information regarding student attitude towards the Maria Storyline and the incorporation of other storylines into the chemistry classroom was found. It appears that students value storylines that are able to provide a context for their learning, and that many students prefer storylines that require them to work together to solve a problem as opposed to activities that are more guided and require them to simply recall and link together information. Students also feel that these types of hands-on, problem-based challenges are valuable to the learning experience and help them to retain knowledge.

Although a valuable science concept, the significance of protein folding and its relation to bonding did not seem as engaging to students as hoped. For this reason, it may be better to use the Maria example as a warm-up or even an assessment question that could gauge understanding of content and provide students a novel situation to which to apply their newly acquired knowledge. In the future, it would be beneficial to replace the Maria Storyline with a more hands-on storyline that challenges students to solve a problem using bonding unit content.

The information found in this classroom research project is informative to chemistry classroom teachers and curriculum writers as efforts to further align to the NGSS continue. Through the use of context-based challenges that require students to use teamwork, content knowledge, and hands-on practices to approach a problem, students will not only be more engaged with chemistry content, but also likely more successful at acquiring and retaining knowledge. Going forward, it would be beneficial if efforts were made to further improve and implement these types of experiences for students in at least some of their chemistry instruction.

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APPENDICES

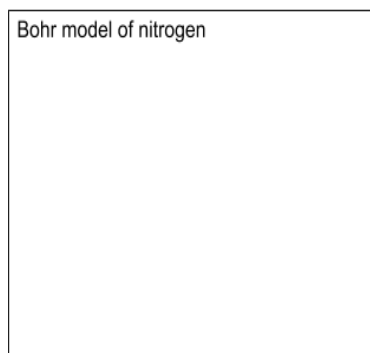
APPENDIX A
UNIT PRE-ASSESSMENT

1. What is the name given to the electrons in the highest occupied energy level of an atom?
 - a.) orbital electrons
 - b.) anions
 - c.) valence electrons
 - d.) cations
2. How does calcium obey the octet rule when reacting to form compounds?
 - a.) It gains electrons.
 - b.) It gives up electrons.
 - c.) It does not change its number of electrons.
 - d.) Calcium does not obey the octet rule.
3. Which of the following occurs in an ionic bond?
 - a.) Oppositely charged ions attract
 - b.) Two atoms share two electrons.
 - c.) Two atoms share more than two electrons.
 - d.) Like-charged ions attract.
4. Which of the following pairs of elements is most likely to form an ionic compound?
 - a.) oxygen and chlorine
 - b.) nitrogen and sulfur
 - c.) sodium and aluminum
5. Which of these elements does not exist as a diatomic molecule?
 - a.) Ne
 - b.) H
 - c.) F
 - d.) I
6. How do atoms achieve noble-gas electron configurations in single covalent bonds?
 - a.) One atom completely loses two electrons to the other atom in the bond.
 - b.) Two atoms share two pairs of electrons.
 - c.) Two atoms share two electrons.
 - d.) Two atoms share one electron.
7. Why do atoms share electrons in covalent bonds?
 - a.) to become ions and attract each other
 - b.) to attain a noble-gas electron configuration
 - c.) to become more polar
 - d.) to increase their atomic numbers
8. Which of the following elements can form diatomic molecules held together by triple covalent bonds?
 - a.) carbon
 - b.) fluorine
 - c.) oxygen
 - d.) nitrogen
9. Which of the following is the name given to the pairs of valence electrons that do not participate in bonding in diatomic oxygen molecules?
 - a.) unvalenced pair
 - b.) inner pair

- c.) outer pair
d.) unshared pair
10. A molecule that contains double covalent bond is ____.
- a.) CO_2 b.) HCN
c.) Cl_2 d.) N_2
11. Which of the following covalent bonds is the most polar?
- a.) $\text{H}-\text{F}$ b.) $\text{H}-\text{H}$
c.) $\text{H}-\text{C}$ d.) $\text{H}-\text{N}$
12. What causes hydrogen bonding?
- a.) attraction between ions
b.) attraction of two non-polar molecules
c.) sharing of electron pairs
d.) attraction of a covalently bonded hydrogen atom with an unshared electron pair

Draw the Bohr model for nitrogen and answer the questions to the right.

Bohr model of nitrogen



1. How many valence electrons does nitrogen have? (1 pt.)

2. How many bonds would you expect nitrogen to form? (1 pt.)

3. Explain your answer to #2 in two sentences or less. (2 pt.)

Compare the diatomic molecules CO and NO . Be sure to include all of the items listed. (4 pt.)

For each molecule, please include: • Dipole arrow • Electronegativity difference • Ionic or covalent • Strength of intermolecular forces • Boiling point comparison	dipole arrow $\text{C}=\text{O}$ Electronegativity difference = _____ Ionic or Covalent IM forces = stronger or weaker than NO	dipole arrow $\text{N}=\text{O}$ Electronegativity difference = _____ Ionic or Covalent
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	B.P. = higher or lower than NO	IM forces = stronger or weaker than CO B.P. = higher or lower than CO
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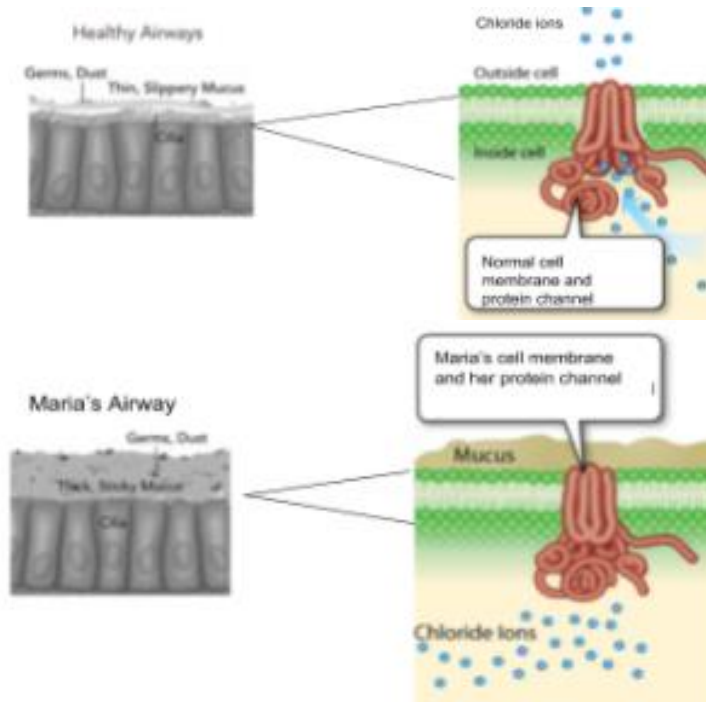
APPENDIX B

MARIA STORYLINE TEACHER GUIDE

Background Information

Story that Biology students were introduced to freshman year:

During routine newborn screening, Maria was diagnosed with cystic fibrosis. Maria is now 3 and she is suffering from a chronic cough and has had many bouts of shortness of breath. Maria is having difficulty enjoying activities other small children her age enjoy. Medical examination revealed that Maria's lungs are filled with mucus and are not clearing the mucus out like a pair of normal lungs. Maria's mom, Marta, has brought her to see you because you are part of a research group that studies cystic fibrosis. Her mother wants to better understand the type of cystic fibrosis she has, what is causing her cystic fibrosis and why this leads to her symptoms.



What students should recall from freshman year?

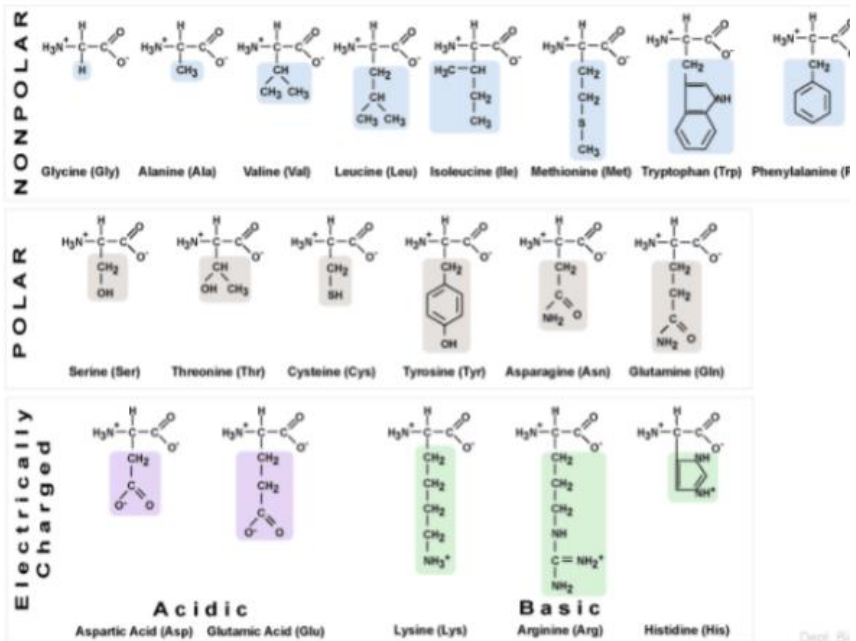
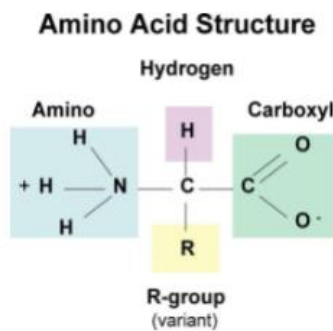
- **DNA** is a sequence of four nitrogenous bases: adenine (A), thymine (T), Guanine (G), and Cytosine (C)
- This sequence of bases holds the instructions for life.
- During **protein synthesis...DNA-->mRNA-->amino acid sequence-->protein**
 - Transcription: The sequence of DNA is copied into mRNA in the nucleus.
 - Translation: The mRNA then leaves the nucleus and is used to create a protein at ribosomes in the cytoplasm.

- During this process, the mRNA is read in codons (groups of three nitrogenous bases).
- Each codon codes for one of the twenty amino acids.
 - Students used codon wheels to determine amino acid sequence of sample mRNA strands.
- Once a sequence of amino acids has been made, it still needs to take its correct shape.
 - After Translation: Proteins go to the Rough Endoplasmic Reticulum (Rough ER) to be folded into their correct shape.
 - **Proteins with the correct shape are able to do their job/function correctly.**
- The DNA sequence is ultimately, what determines the structure of a protein.
- **Mutations are errors in the appropriate DNA sequence and through the process of protein, synthesis can lead to non-functioning proteins.**
 - Errors in DNA sequence lead to an incorrect mRNA sequence.
 - An incorrect mRNA sequence can create an incorrect amino acid sequence.
 - An incorrect amino acid sequence can prevent a protein from folding correctly.

Where are we going?

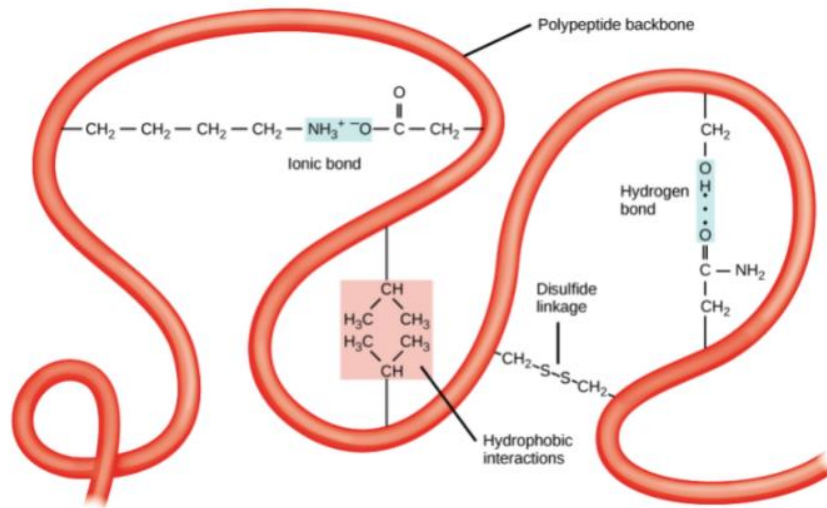
What students should know?	What students should be able to do?
• Proteins are large molecules called macromolecules. ○ Macromolecules are made when smaller molecules/building blocks combine. • The building blocks of proteins are amino acids. • There are twenty different amino acids. ○ Similarities ▪ All have a central carbon ▪ Attached to the central carbon is a hydrogen, an amino group, and a carboxyl group ○ Difference (See below for reference documents) ▪ Amino acids differ in their R group. ▪ R group are classified in different ways based on their chemical structure.	• Explain how mutations in DNA can lead to an incorrect amino acid sequence (from biology) • Explain why changes in amino acid sequence may affect the structure of a protein • Model the types of interactions/bonding that occur between amino acid side chains • Model how changes in amino acid sequence can affect protein shape/structure • Explain how incorrect protein shape/structure leads to incorrect function

- These differences in chemical structure determine the types of interactions/bonding they will take part in.
 - Protein folding/structure depends on the interactions between its R-groups.
- Incorrect DNA sequences can affect the amino acid sequence and change the types of bonding/interactions that occur within a protein--thus affecting the shape.



Potential resources for students to use.

Version of what student model might look like for final protein structure



How to get there?

Day	Idea(s) for getting them “there”:
1	<i>How do changes (mutations) in a DNA sequence affect the protein that is made during transcription?</i> - Students at this point should recall that an incorrect DNA sequence would ultimately cause a misfolded protein. <i>How does the structure of an atom determine how it will bond with other atoms?</i> - Can relate to electronegativity/ionization energy and back to coulombic attraction - Can relate coulombic attraction to why a spectrum of bonding exists between atoms Agenda Protein Structure Student Intro Document - Fill out the first two boxes on back individually - Show video as refresher and have students add info to their sheets - Cracking the code of life section on CF: Cystic Fibrosis Video (cracking the code of life) - 7 minutes -- start at 58:25 - Share individual models in groups in back using stems...

	▪ “I think _____ happened because of _____.” ▪ “Mine is similar because _____.” ▪ “Mine is different because _____.” ○ Create initial model on butcher paper in pods ▪ Using Model Guidelines ▪ Likely shows DNA --->Protein, may show mutation leading to misfolding ▪ Each groups initial models may be different depending where they are at.this is ok ○ Each student should contribute a question that they would like to answer before completing a revised model (last box on handout) ▪ Could be placed on butcher paper via a sticky note • Lewis Dot Lab pre-lab questions front and back • Exit: What did we learn today that might help us to further explain what is going on in Maria’s body?
2	<i>How does the structure of an atom determine how it will bond with other atoms?</i> • Predicting number of valence electrons • Drawing dot diagrams • Using octet rule to predict ratios of atoms in covalent compounds • Drawing structural formulas <i>How do changes in a DNA sequence affect the sequence of amino acids?</i> • DNA holds the instructions for life. • DNA is turned into mRNA during transcription and mRNA into an amino acid sequence during translation. • Each set of three nitrogen bases (a codon) on mRNA codes for a specific amino acid. • There are twenty different amino acids. Agenda: • Warm-Up → ionic vs. covalent compound modeling • Force Notes (first two rows) • Lewis Dot Lab (all) • Protein Primary Structure Document (Part 2) ○ Show DNA to proteins video (2:41) ○ Classroom Set
3	<i>What are the common shapes that molecules will take?</i> • More practice with structural formulas • Identify shared and unshared pairs

	- Identify number of electron domains and link to shape <i>How are the chemical structures of amino acids similar? How are they different?</i> <i>How do amino acids come together to form a polypeptide chain?-- primary structure</i> - Amino acids (small molecules) are the building blocks of proteins (macromolecules) - Peptide bonds (a type of covalent bond) link amino acids together - Amino acids all have a similar structure (amino group, carboxyl group, R group) Agenda: - Warm-Up: Shapes and Polarities Table (Rows 1 and 2) - Molecular Geometry POGIL (as individuals) - Shapes and Polarities Table (Rows 3-7) (as class) Protein Primary Structure Document (Part 3) Shapes and Polarities Practice Packet (up to last column) - Exit: How might the polarity of different amino acid side chains affect protein structure?
4	<i>How does the polarity of different parts of the protein structure affect its folding?</i> <i>Why is the sequence of amino acids important?</i> - Hydrophilic=polar (often face outward in protein structure) vs. Hydrophobic = non-polar (often face inward in protein structure)--secondary structure - Collect information on amino acid structure on R groups--tertiary structure <i>How do electronegativity differences between atoms affect the polarity of molecules?</i> - Polar vs. non-polar molecules <i>How does the polarity of a molecule affect how it will interact with other molecules?</i> - Intermolecular Forces--hydrogen bonding, dipole-dipole, induced dipole Agenda: - Warm-Up: Intermolecular vs. Intramolecular Forces - Force Notes (last three rows) - Shapes and Polarities Table (last row) Protein Primary Structure Document (Part 4) Student Resource Sheet - Shapes and Polarities Packet (finish) - Exit: In your own words, what is going on at the level of atoms and molecules in Maria's cells?

5	<i>How does the type of bonding a molecule experiences affect its physical/chemical properties?</i> <i>Properties of ionic and covalent compounds--appearance, solubility in water and in ethanol, conductivity, and melting point</i> <i>Ionic bonds that result from the transferring of electrons due to large differences in electronegativity are stronger than covalent bonds</i> <i>Ionic bonds also result in the formation of ions...these ions play a role in both conductivity and solubility</i> Agenda: Bonding Lab - Students should complete the bonding lab - Could shorten the lab by assigning each group one test to collect data for - Appearance and Solubility in Ethanol (2 groups) - Melting Point (2 groups) - Solubility in Water/Conductivity (2 groups) - All students complete post lab questions - Could fill in the characteristics and properties portion of ionic/covalent compounds chart
6	<i>Review Day</i>

APPENDIX C
UNIT POST-ASSESSMENT

(taken from end of semester final)

Bonding

44. Which of the following occurs in an ionic bond?
- Oppositely, charged ions resulting from the transfer of electrons attract.
 - Two atoms share two electrons.
 - Two atoms share more than two electrons.
 - Like-charged ions resulting from the transfer of electrons attract.
45. Which of the following compounds is expected to have the strongest ionic bonds?
- RbF
 - NaF
 - NaI
 - CsBr
46. How many valence electrons does oxygen have?
- 2
 - 4
 - 6
 - 8
47. How do atoms achieve noble-gas electron configurations in single covalent bonds?
- One atom completely loses two electrons to the other atom in the bond.
 - Two atoms share two pairs of electrons.
 - Two atoms share two electrons.
 - Two atoms share one electron.
48. What shape will BCl_3 take?
- Linear
 - Trigonal planar
 - Trigonal pyramidal
 - Tetrahedral
49. Draw the structural formula of the molecule above (from problem 48) on your answer sheet.
50. Which molecule is polar?
- BF_3
 - H_2Se
 - N_2
 - GeF_4
51. Which of the following is the name given to the pairs of valence electrons that do not participate in bonding?
- unvalenced pair
 - inner pair

- c. outer pair
 - d. unshared/lone pair
52. A molecule that contains double covalent bonds is ____.
- a. CO_2
 - b. HCN
 - c. Cl_2
 - d. N_2
53. Draw the structural formula of the molecule above (from problem 52) on your answer sheet.
54. Which of the following will have the strongest intermolecular forces?
- a. NCl_3
 - b. H_2O
 - c. O_2
 - d. SeF_2
55. NaCl will have _____ melting point in comparison to NH_3 .
- a. A higher
 - b. A lower
 - c. The same
 - d. Not enough information
56. Explain your answer to question #56 on your answer sheet.
57. There are _____ paired and _____ unpaired electrons in the Lewis symbol for a Nitrogen atom.
- a. 4, 2
 - b. 2, 4
 - c. 2, 3
 - d. 4, 3

APPENDIX D
STUDENT SELF-ASSESSMENT SURVEY

Background Information: The following survey will ask you to assess aspects of the last unit regarding your level of preparedness, your feedback on how you thought the unit went, and how certain activities in the unit aided your understanding of unit content.

Your survey is anonymous. It will not be linked to your grade in any way, but it will help in planning future units and classes.

Directions: For the following statements, indicate your level of agreement by circling the number that corresponds to your level of agreement with each statement.

Statement	Strongly Agree	Agree	Disagree	Strongly Disagree
I liked this unit.	4	3	2	1
I felt prepared for this unit assessment.	4	3	2	1
I enjoy participating in anchoring events/unit challenges.	4	3	2	1
I prefer units without anchoring events/unit challenges.	4	3	2	1
Labs are my favorite chemistry class activity.	4	3	2	1
I always understand how unit content applies to our chemistry labs.	4	3	2	1
I find anchoring events/unit challenges engaging.	4	3	2	1
I enjoy direct instruction in class.	4	3	2	1
I always understand how unit content links with the anchoring event/unit challenge.	4	3	2	1
I enjoy explaining the chemistry behind unit challenges.	4	3	2	1
Working through anchoring events/unit challenges help me prepare for the unit assessment.	4	3	2	1
I work hard to prepare for chemistry assessments.	4	3	2	1
I enjoy coming to chemistry class.	4	3	2	1

APPENDIX E
STUDENT INTERVIEW QUESTIONS

Student Interview Questions

1. Did you feel prepared for this unit assessment?
2. How did you prepare for this unit assessment? What tools or resources did you use?
3. What activities in the classroom aid in your understanding of course content? Why are these activities useful to you?
4. What role do you see anchoring events/unit challenges playing in your understanding of chemistry content?
5. Do you enjoy anchoring events/unit challenges? Why or why not?
6. Do you feel like you always understand how the course content links to the anchoring event/unit challenge?

APPENDIX F

END OF UNIT FEEDBACK FORM

1. What activities or parts of this unit did you enjoy the most?

2. What was it about these parts/activities that you enjoyed? Be specific.

3. What activities or parts of this unit did you enjoy the least?

4. What was it about these parts/activities that you disliked? Be specific.

5. What parts or activities in this unit aided your understanding of course content the most?

6. Do you have any suggestions for future units?

APPENDIX G

IRB FORM



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Bldg. Room 127
 c/o Microbiology & Immunology
 Montana State University
 Bozeman, MT 59718
 Telephone: 406-994-6783
 FAX: 406-994-4303
 E-mail: cherylj@montana.edu

Chair: Mark Quinn
 406-994-4787
 mquinn@montana.edu
Administrator:
 Cheryl Johnson
 406-994-4786
 cherylj@montana.edu

MEMORANDUM

TO: Jacquelyn Curran and Eric Brunzell

FROM: Mark Quinn *Mark Quinn CM*
 Chair, Institutional Review Board for the Protection of Human Subjects

DATE: November 28, 2017

RE: "Using Storylines to Increase Student Performance in the Science Classroom" [JC112817-EX]

The above research, described in your submission of November 28, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it, if you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.