NEXT GENERATION SCIENCE STANDARDS AND PHENOMENON-DRIVEN STORYLINING IN HIGH SCHOOL BIOLOGY

by

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ABSTRACT

The purpose of this study was to determine if the use of an NGSS centered, phenomenon-driven storylining curriculum would increase student development of scientific literacy and skills as well as student engagement within the classroom. The treatment group received an NGSS driven, phenomenon-based, student-centered curriculum which was grounded in the Africa storyline. The non-treatment group received a teacher led, direct instruction biology curriculum. The treatment group (*n*=47), had a mean post test score that was 7.5% higher than the control group (*n*=26). Teacher observations, student surveys, as well as pre and post test results were analyzed. The data supported higher levels of content knowledge retainment, skill development, and engagement within the treatment group.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

School Demographics

William Fremd High School. A site of high expectations, rigor, and success. A renowned name in the suburbs of Chicago. William Fremd High School is a building which is looked up to and modeled after. It is a place that is not only an academic dream for many families immigrating to Illinois, but also a proud site that many call home for those residing in Illinois. Many parents of the students who attend Fremd also attended Fremd themselves, proving the high sense of belonging and pride associated with the school. William Fremd High School is located in the northwest suburbs of Chicago in the town of Palatine, IL. According to Illinois Report Card in 2022, the school was home to 2,633 students. Of the community, 49.2% of the population was White, 4.2% Black, 10.6% Hispanic, 32.3% Asian, 0.2% American Indian, 0.1% Pacific Islander, and 3.2% two or more. In 2022, seventeen percent of our Fremd family was low-income students and seven percent of our students have IEPs and access to special education services (Illinois Report Card, 2022). In Illinois, there is a two year science requirement for high school students to graduate. According to Illinois Report Card (2022), 51% of students in the state performed proficient or exemplary on the science assessment. At Fremd, 79% of students were in this group of achieving performance level on the science assessment (Illinois Report Card, 2022). At Fremd, we encourage all of our students to take three or four years of science while in high school which is proving to be significant to student success when looking at the state science assessment.

This year is my third year at William Fremd High School. I teach regular level biology, regular level chemistry, anatomy and physiology, as well as regular level EL biology. My passion lies with building a home for all students at Fremd while encouraging them to grow in their skills that will be essential to their success in life.

Context of the Study

Upon joining the Fremd community as a first-year teacher, my goal was to be a sponge and learn everything I could. I spent my first two years teaching three different courses: regular level chemistry, regular level biology, and regular level EL biology. I spent five periods within my own classroom teaching while spending two additional periods sitting in other teachers' classrooms and learning from them. I was fortunate to be working in a collaborative department where this was an accepted opportunity to be able to learn from more experienced teachers. Throughout these two years, I had a realization. I was reassured that I loved teaching. The relationships I was able to build with my students were truly what I lived for. My passion for the role of an educator has only grown since I began teaching, but over time I noticed I was not enjoying all parts of teaching.

Throughout my second year, I had an issue with the world of education that was starting to pull me away from my love of the profession. I was taken aback when I started waking up in the morning less and less excited about going to work. This brought me back to the reason I became a teacher. All throughout my undergraduate experience, I planned to enter the world of medicine. My premedical path required many late nights and early mornings, but I loved the material I was studying and was truly passionate about science. I had the opportunity to meet many amazing individuals through this program, but I realized I was very different from many of my classmates and I struggled. I struggled with the content. I struggled with the process of studying. I struggled with exams. I also, often times, struggled with connecting with my professors as I usually did not understand quickly. It took me longer and I did not feel “normal.”

Throughout the completion of my degree, I improved with the content. I improved with studying. I improved with my exams. I finally saw success. But, why did this take me so long? There were so many lightbulb moments I had, by myself in the library, when I asked myself “Why didn’t they just explain it this way?” These were the moments that made me realize two things. First that science is hard, but second, that it can be made so much more accessible by a good teacher. And here I am at William Fremd High School working every day to make science more accessible to students who feel like I did, like they are not good enough for science.

The roadblock I hit about a year and a half into working was the curriculum. The curriculum in which I was using was not accessible and I noticed I was putting students of my own in the same seat I was in during my undergraduate experience. I was part of the problem. This was when I decided a change was needed. Therefore, I completed action research to determine if the implementation of NGSS and phenomenon-driven storylining curriculum furthers student learning, not only of the content but also skills. As of January 2014, Illinois is one of 20 states that has fully adopted NGSS as our science standards, but structural norms of secondary education have yet to fully conform to the standards set forth by NGSS (Figure 1). This brings up a major concern that schools claim to be implementing NGSS, but their curriculums do not reflect the updated guidance on curriculum. NGSS is very different than the previous state standards used in Illinois, so curriculums that were not written with NGSS in mind are outdated and not applicable to the NGSS goals and values.

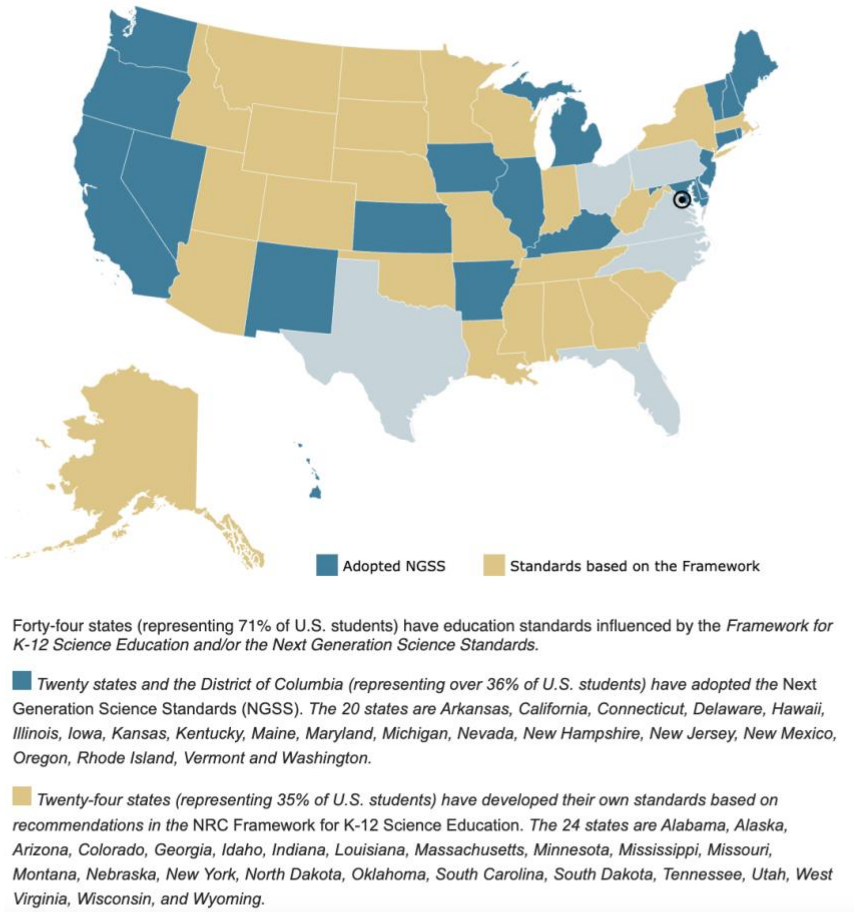

Figure 1. K-12 science standards adoption (NSTA, 2014).

It is also important to mention the difficulty associated with adopting NGSS within the classroom. Being a younger teacher, I learned the way of NGSS from the beginning. I was immersed in the core values and goals throughout all of my teacher training, but this was not the case for many of my colleagues. In the science department at Fremd, only three of 24 science teachers were trained in NGSS, and therefore, most of the teachers are not familiar with the approach. That being said, there is a difference between the state adoption of NGSS and the adoption of NGSS in the classrooms of teachers. These teachers are not to blame as professional development surrounding NGSS has been minimal. The standards are difficult and would truly change many teachers' classrooms if they were to adopt them fully. With this being said, my goal was to follow the NGSS recommendation with an emphasis on methodology and skill-based, student-centered learning within my science classroom. Through this study, I aimed to positively impact student learning, achievement, attitude, and engagement with my students.

Focus Questions

My focus question was, How does NGSS with emphasis on the Science & Engineering Practices and Crosscutting Concepts (skills) improve content knowledge retainment in science?

My sub-question includes the following:

1. How does implementation of phenomenon-driven storylining affect student engagement and attitudes in the science classroom?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Overview of the Next Generation Science Standards

The Nature of Science has been a thought swirling in the world of education for decades. According to McComas, Clough, and Almazroa (1998), the nature of science emphasizes the How of science. This includes how information is collected and how scientists complete their work (p. 67). On the other hand, Espinoza (2012) shared his emphasis on the use of wisdom within the real world as opposed to simply the facts and data. This wisdom which encompasses critical thinking is what Espinoza aims to emphasize as the most important to teach students within the science classroom. From this perspective, the nature of science has more to do with a full understanding that can be applied to many circumstances as opposed to the process of how science is completed (Espinoza, 2012, pp. 11-18). Finally, Flick and Lederman (2006) emphasized understanding the nature of science from a student's perspective as opposed to from a scientist's perspective. They emphasize the importance of inquiry within the nature of science, which is framed through current issues in the world and provides students the ability to solve problems happening right now in their own worlds (Flick & Lederman, 2006, pp. 332-333).

The Next Generation Science Standards strive to fully encompass in the nature of science within the science classroom (McComas & Nouri, 2016, p. 556). Through this approach, students are able to wrap their minds around science at a level that is much deeper than the more traditional approach to science education. As noted above, there have been many differing views concerning the true definition of the nature of science, but according to McComas and Nouri

(2016), the definition is not essential as long as the aspects of the nature of science are incorporated in the curriculum (p. 557) (Figure 2).

Key Aspects of the Nature of Science

1. Scientific knowledge is not entirely objective
2. Scientists use creativity
3. Scientific knowledge is tentative but durable
4. Scientific knowledge is socially and culturally embedded
5. Laws and theories are distinct kinds of knowledge
6. Scientific knowledge is empirically based
7. There is no universal stepwise scientific method
8. There is a distinction between observations and inferences
9. Science cannot answer all questions (and is therefore limited in its scope)
10. Cooperation and collaboration are part of the development of scientific knowledge
11. There is a distinction between science and technology
12. Experiments have a role in science

Figure 2. Elements of NOS recommended in school science programs (McComas & Nouri, 2016).

The Next Generation Science Standards (NGSS) were released in April of 2013 and were adopted by the state of Illinois in January of 2014. Almasi and Hart (2011) described the approach best by sharing that it is important to "teach readers to be strategic versus teaching strategies" (p. 250). This approach encompasses the ideas of the nature of science as well as NGSS which strive to accomplish four items within the classroom: (a) less memorizing, more sense making, (b) making connections to common core, (c) grounding practice in research, (d) applying knowledge in context. NGSS provides a three-dimensional approach that changes the world of science by emphasizing student-centered learning through the use and development of skills (NSTA, 2014). The three dimensions of this approach include: 1) Disciplinary Core Ideas (DCIs), 2) Science and Engineering Practices (SEPs), 3) Crosscutting Concepts (CCCs) (NSTA, 2014). With successful implementation of NGSS, these three dimensions are seamlessly intertwined throughout the entirety of the curriculum offering students the opportunity to grow in scientific literacy, conceptual understanding, as well as skills. This new approach encourages students to think more while changing the overall look and feel of science education all while emphasizing the key aspects of the nature of science (Figure 3).

A New Vision for Science Education

Implications of the Vision of the Framework for K-12 Science Education and the Next Generation Science Standards

SCIENCE EDUCATION WILL INVOLVE LESS:	SCIENCE EDUCATION WILL INVOLVE MORE:
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning.
Learning of ideas disconnected from questions about phenomena	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned
Teachers providing information to the whole class	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance
Teachers posing questions with only one right answer	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims
Students reading textbooks and answering questions at the end of the chapter	Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information.
Pre-planned outcome for "cookbook" laboratories or hands-on activities	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas
Worksheets	Student writing of journals, reports, posters, and media presentations that explain and argue
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Provision of supports so that all students can engage in sophisticated science and engineering practices

Source: National Research Council. (2015). *Guide to Implementing the Next Generation Science Standards* (pp. 8-9). Washington, DC: National Academies Press. http://www.nap.edu/catalog/18802/guide-to-implementing-the-next-generation-science-standards

Figure 3. A new vision for science education (National Research Council, 2015).

In addition to changes within each educator's classroom, NGSS takes science one step further to truly ensure the cohesiveness of the approach to teaching science. The essence of NGSS is to provide students with high-quality science experience "They need to be well informed citizens, to be prepared for college and careers, and to understand and appreciate the scientific enterprise," (NSTA, 2014). This is accomplished through an approach of cohesive education which starts in kindergarten and follows students all the way to twelfth grade. This means grade schools, junior high schools, and high schools must compare curricula and make use of the previously developed and influenced schemas that students are bringing to class every day. The approach allows students to learn concepts in bundles, emphasizing the full understanding of the nature of science within each lesson and module (NGSS Lead States, 2013, p. xxvi). It is also noted that the nature of science is not simply a science and engineering practice, but should also be represented in the crosscutting concepts. Fully grasping science is more than just a practice and is truly something that can be tied with a cocurricular and multi-skill approach to many other areas (NGSS Lead States, 2013). This explains the need for the inclusion of *Connections to Nature of Science* found in many of the NGSS performance expectations. These often fall under science and engineering practices, but the connections can also be seen within the crosscutting concepts of each performance expectation (NGSS Lead States, 2013, pp. 9-324). Throughout the creation of NGSS, the aim was to emphasize the importance of the nature of science aspects and ensure they were integrated into science classrooms around the United States (McComas & Nouri, 2016, p. 557) (Figure 4).

I	Scientific investigations use a variety of methods
II	Scientific knowledge is based on empirical evidence
III	Scientific knowledge is open to revision in light of new evidence
IV	Science models, laws, mechanisms, and theories explain natural phenomena
V	Science is a way of knowing
VI	Scientific knowledge assumes an order and consistency in natural systems
VII	Science is a human endeavor
VIII	Science addresses questions about the natural and material world

Figure 4. Nature of science categories in NGSS (NGSS Lead States, 2013).

Phenomenon-Driven Storylining

One approach for implementing NGSS core values within a curriculum is through the practice of storylining. Storylining is an approach used to emphasize scientific inquiry within studies (All Species Education Consulting, 2023). Schwartz and Crawford (2004) described inquiry as diving deeper than the data and facts. Teachers must provide students a background and the skills necessary allowing them to “educate themselves” (p. 333). Through inquiry instruction, emphasis is placed on student-centered learning as opposed to teacher-disseminated information.

The storyline approach to teaching dates back to the 1960s Scottish teaching approaches. The development of this approach stemmed from the release of a new curriculum that emphasized interdisciplinary studies (Mitchell & McNaughton, 2016). Storylining is widely known and has been a topic of discussion around the world at conferences such as a conference held in Slovenia titled *Storyline- The next generation*. As shared by Karlsen and Haggstrom (2020), “There are many reasons for furthering Storyline as a pedagogical approach that includes… inclusiveness towards different learners, cultivating students’ creativity and imagination, and the recognition and acceptance of feeling as an essential part of the learning process” (p. 12). It has been shown that sense making has been vitally impacted by storytelling (Mitchell & McNaughton, 2016). Through the storylining approach, students work through phenomena which are extremely timely and are intentionally connected to each other with the end goal in mind. This approach allows for maximum student curiosity, learning, and attentiveness (Karlsen & Haggstrom, 2020, p. 14).

All Species Education Consulting (ASEC) created a high school biology curriculum which invites students to learn science by exploring big ideas and concepts, or as we call it in the world of science, naturally occurring phenomena through inquiry. This curriculum allows students to build explanatory models which requires utilization of all 3 dimensions of NGSS. Ultimately, student learning is deeper and the knowledge gained is relevant to phenomena that surround students in their real world (All Species Education Consulting, 2023). Additionally, by inviting students to bring their personal story into the classroom, they are more likely to feel connected to the curriculum as well as to their peers. This aspect of the curriculum plays a large role in allowing for students to feel a true sense of belonging within the classroom (Karlsen & Haggstrom, 2020, p. 12).

The ASEC curriculum was developed by teachers and has been tested and used in many schools around the country and internationally. The focus of the curriculum is placed on student mastery of Science and Engineering Practices (SEPs) and Crosscutting Concepts (CCCs) as opposed to memorization of content. Disciplinary Core Ideas (DCIs) are used to focus how the skills are taught and practiced (All Species Education Consulting, 2023). In the curriculum via NGSS, thinking skills are emphasized through the discovery of content. Students are encouraged to figure things out as opposed to simply learning about topics. This approach combines all areas of biology making phenomenon-driven storylines, each of which seamlessly ties in many content units (Figure 5). This cohesive approach encourages students to use the information they already know to discover and piece together new findings all while proving the interconnectedness and importance of science within our real world (All Species Education Consulting, 2023). Phenomenon-driven storylines are one approach to incorporating anchoring phenomenon and inquiry within the science classroom which has proven to improve student learning, mastery, and retention.

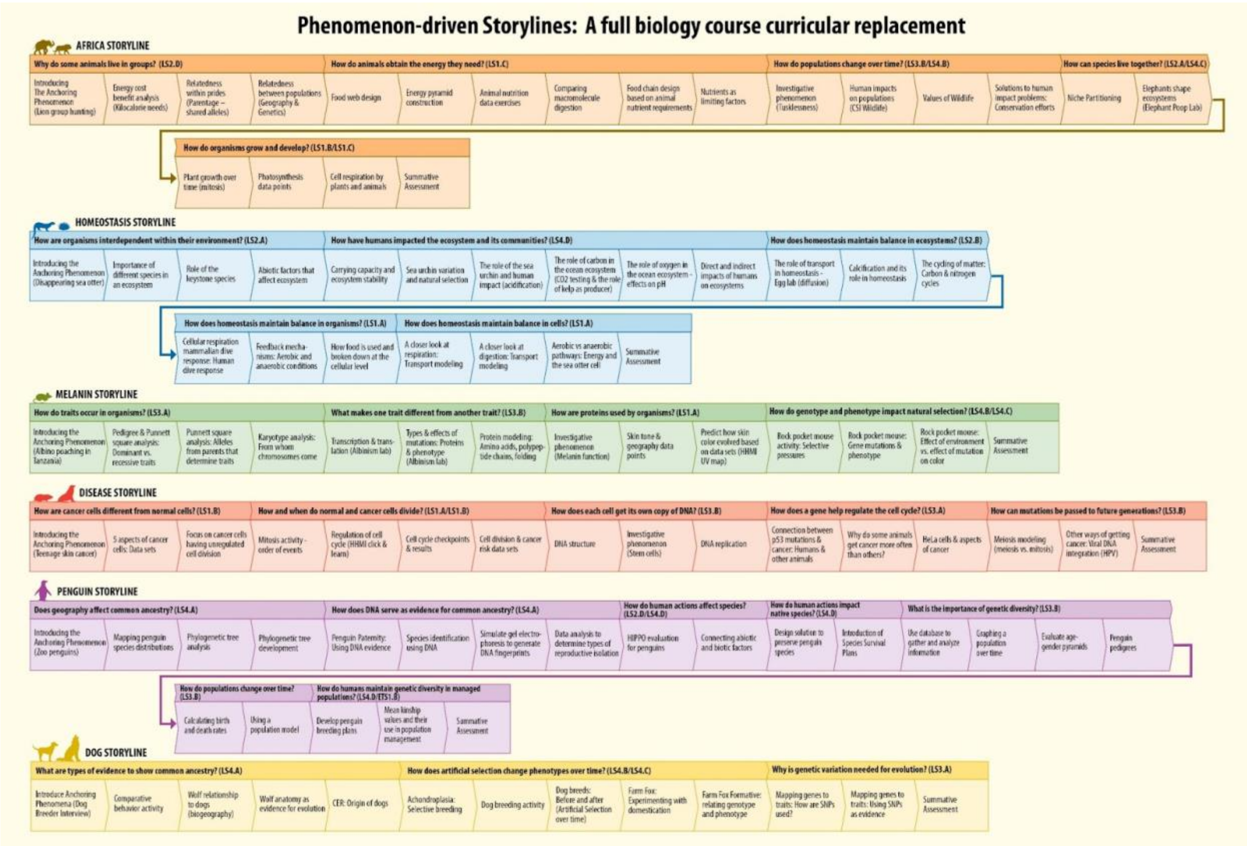

Figure 5. ASEC phenomenon-driven storylines (ASEC, 2023).

The difference seen with storylining is that students play the primary role of thinker and learner. Students are involved in developing the questions and goals to accomplish throughout each class period and module overall (NSTA, 2014). The learning is truly student-centered and student-driven allowing students to be a stakeholder in their learning experience as opposed to simply being along for the ride. Storylines make use of phenomenon and applications to the real world to engage students in topics which are timely, engaging, and relevant (Sherman, 2021).

Student Engagement and Attitude in Science

Through the use of storylines, advanced narratives are implemented within the classroom which not only spark student engagement, but also encourage students to take risks. Through student risk taking, Sherman (2021) argued that this approach encourages stronger student engagement within the classroom. A starting point to encourage risk taking involves sparking curiosity. “Good stories raise our curiosity about what is going to happen,” (Nordine et al., p. 87). When student interests can be incorporated into the curriculum, engagement prospers. Nordine et al. (2019) compared this to a common experience of struggling to stop reading a good book or binge-watching a good tv show. Taking advantage of this fully-human, addictive quality is possible within the classroom through allowing science to “unfold like a great story” (Nordine et al., 2019, p. 87). Through the storylining approach, students drive the development of the content through taking risks and therefore must take ownership of the content (Karlsen & Haggstrom, 2020, pp. 13-14).

Storylines are different in that both the students and teachers are involved in the planning process. Of course, the teacher questions and guides with the end goal in mind, but students are put in the driving seat as to what they would like to investigate next (Sherman, 2021, p. 2). This allows students to have more confidence and control within the classroom eliminating the passiveness often associated with the role of student. Ainley and Ainley (2011) described the most important aspect of engagement and enjoyment within the classroom to be associated with the adoption of the mentality of becoming a lifelong learner (p. 4). The struggle does not come solely from engagement and providing attention-savvy experiences, but instead from developing an attitude “involving ongoing, voluntary, and self-motivated learning activities directed to personal… development" (Ainley & Ainley, 2011, p. 4). This struggle continues as students do not come into a classroom as a clean slate. Instead, they bring with them past experiences, both positive and negative, which may change their outlook on the class or content being presented. This idea has to do with achievement emotions which affect all students in their attitude and approach within the classroom (Ainley & Ainley, 2011, p. 4).

From Fredrickson's positive psychology approach, it is suggested that emotions stem from either a positive or negative place. Some positive emotions suggested, which pair very well together within the classroom, included joy and interest. Although fully separate from each other, when experienced together, joy and interest work together to build up student engagement. The emotion of joy often sparks "the urge to play, push the limits, and be creative" (Fredrickson, 2001, p. 3). Similarly, the emotion of interest sparks "creating the urge to explore, take in new information and experiences, and expand the self in the process" (Fredrickson, 2001, p. 3). When paired together, joy and interest complement each other to create the perfect approach to learning and developing the attitude required to become a lifelong learner. Positive emotions are often associated with building one's self and growing as a person to build the resources one has. When positive emotions are involved, individuals tend to have better attention (Fredrickson, 2001, p. 5). This results in higher levels of "achievement and… task engagement" (Ainley & Ainley, 2011, p. 5). Finding and encouraging these positive emotions within students' needs to be a goal when developing curriculums as this will likely result in a student attitude that wants to continue connecting and building upon ideas being worked with.

In terms of involving these positive emotions within the curriculum, Ainley and Ainley (2011) suggested choosing topics that are "more restricted" (p. 6). The increased focus, or narrowing in on a concept, allowed for student connection and an increased feeling of positive emotions. This is seen throughout the entirety of the ASEC Storylining curriculum. Joy is closely tied to enjoyment. When speaking of science specifically, enjoyment is often related to personal value which can predict one's interest in science. Emphasis of this is seen throughout the entirety of the ASEC Storylining curriculum as many topics are based around ideas and phenomenon which are interesting to students. For example, one of the six storylines which focuses on genetics is centered on dogs. This storyline dives into the genetic relationship between all dog breeds as well as how different breeds were developed. Many students can relate to having a pet dog or a positive experience with dogs which aids in the level of interest throughout this storyline (All Species Education Consulting, 2023). If topics can be chosen which are interesting to students, this will positively impact their personal value as well as enjoyment levels (Ainley & Ainley, 2011, p. 6).

Overall, the main goal of storylining is to increase student engagement. Student engagement is heavily influenced by student joy and interest. Both areas can be targeted through curriculum development and implementation of NGSS, particularly the SEPs and CCCs, within the science classroom.

CHAPTER THREE

METHODOLOGY

Demographics

The purpose of this study was to determine the effectiveness of a phenomenon driven storylining curriculum within regular level freshman biology classes and its impact on students' content knowledge retention, engagement, and attitudes in the science classroom through implementing a mixed-method research approach. The treatment group included 47 students who participated in an NGSS aligned storylining curriculum throughout their freshman year. Quantitative and qualitative data were collected to compare the treatment group (n=47) who engaged in the storyline curriculum developed by All Species Education Consulting Group to the non-treatment group (n=28) who experienced the traditional freshman biology curriculum previously used at Fremd High School. This study was conducted over two school years, 2021-2022 and 2022-2023. The first year of the study focused on the non-treatment group and traditional curriculum while the second year of the study focused on the treatment group and storylining curriculum. My research plan and data collection tools received an exemption by Montana University's Institutional Review Board as well as compliance for work with human subjects.

Treatment

For the purpose of this study, freshman biology class sections were grouped into treatment and non-treatment groups based on the implementation or non-implementation of the

All Species Education Consulting (ASEC) Phenomenon-driven Storylining Curriculum. The non-treatment groups received direct-instruction surrounding the same scientific concepts as the treatment group. The main topics in which quantitative data was collected included the study of macromolecules and biochemistry, but the groups received their assigned curriculum all school year.

For the non-treatment group, the traditional curriculum used at Fremd for biology was implemented all year. The non-treatment group included one section of regular level biology (n=28) during the year of 2021-2022. Of this group, 14 (50%) were female and 14 (50%) were male. Four (14%) students of this group qualify to receive special education services. With the non-treatment group, a typical day included teacher-led notes/lecture, followed by practice, and often followed by a hands-on lab or activity, but did not include phenomenon-driven storylining curriculum. The non-treatment group spent an abundant amount of time memorizing as emphasis was placed on reproducing content-based material with accuracy. Lab skills were emphasized in this curriculum, but other SEPs and CCCs were not prevalent in instruction nor in the planning of curriculum.

For the treatment group, the ASEC Phenomenon-driven Storylining Curriculum for biology was implemented all year. The treatment group included two sections of regular level biology (n=47) during the year of 2022-2023. Of this group, 28 (60%) were female and 19 (40%) were male. Seven (15%) students of this group qualify to receive special education services. The newly developed phenomenon-based storylining curriculum also covered macromolecules and biochemistry, but further emphasized student-centered learning and discovery as suggested by NGSS (All Species Education Consulting, 2023). The treatment group was participating in a curriculum that was much more inquiry driven and followed a phenomenon-based storyline structure created by ASEC.

Quantitative data was collected during the macromolecule & digestive section of the storyline. This included normalized gain data using the Macromolecule Content Assessment with pre and post test scores of the treatment group in which independent t-tests were used to show growth and paired t-tests were used to compare between post test scores of treatment and non-treatment groups. The Final Exam Multiple Choice Content Assessment was also given to both groups and compared using independent t-tests. Additionally, the treatment group completed the Final Exam CER assessment both at the beginning of the semester and the end of the semester. The pre CER at the beginning of the semester was titled Life as a Hunter and the post CER at the end of the semester was titled Final Exam CER where students had a choice of four questions to answer. Paired t-tests were used to compare the scores from the first CER of the semester to the last CER of the semester. Qualitative data was collected throughout the semester and at the end of the semester once the entirety of the Africa storyline concluded. This qualitative data included the Student Engagement and Attitude Survey using a four-point Likert scale of the treatment group and Teacher Observations of both the treatment and non-treatment groups. The focus questions and data collection strategies are organized below (Table 1).

Table 1. Data Triangulation Matrix.

	Focus Question	
Data Collection Instruments	How does NGSS with emphasis on the Science & Engineering Practices and Crosscutting Concepts (skills) improve content knowledge retainment in science?	How does implementation of phenomenon-driven storylining affect student engagement and attitudes in the science classroom?
Macromolecule Content Assessment	X	
Final Exam CER Assessment	X	
Final Exam Multiple Choice Content Assessment	X	
Student Engagement & Attitude Survey		X
Teacher Observations	X	X

Data Collection and Analysis Strategies

Data Collection Methods

Pre and Post Intervention Macromolecule Content Assessment. Most qualitative data was collected throughout the macromolecule and digestive unit. Pre and post tests were developed to represent the NGSS Biology standards and DCIs being addressed. The pre test mirrored the post test and paired t-tests were used to analyze the data. The main focus of this was to ensure the Content Learning Standards (CLSs) which are required by my district were being met through the use of this curriculum and mastered by students. These CLSs are based on the DCIs published by NGSS and adopted by the state of Illinois. I then compared the treatment group's post test results to the non-treatment group's post test results using an independent samples t-test. The post tests administered were identical between the two groups. The tests were given after the test unit (macromolecules) in order to determine student content mastery of CLSs between the two curriculums. Independent t-tests were used to compare the two groups.

Final Exam Multiple Choice. I used the content-based questions from the final exam given to the non-treatment group and gave these same questions to the treatment group at the conclusion of the semester. I compared the two groups' results to determine the retention of content specific knowledge based on the two different curriculums. This data was analyzed using independent t-tests.

Final Exam CER. Claim, Evidence, and Reasoning activities (CERs) played an important role in every summative assessment given to the treatment group. They also served as many formative assessments throughout units. Treatment group results on CERs from the beginning of the semester to the end of the semester were compared using a paired t-test to determine student mastery of SEPs and CCCs. The CERs were assessed using a rubric to correspond with a numerical score. Paired t-tests were used to compare scores from the first CER of the semester to the last CER of the semester. SEPs and CCCs that were focused on this year are listed below (Table 2).

Table 2. Science and engineering practices & crosscutting concepts.

Main SEPs Addressed	Main CCCs Addressed
1. Obtaining, Evaluating, & Communicating Information 2. Engaging in Argument from Evidence 3. Constructing Explanations & Designing Solutions 4. Analyzing & Interpreting Data	1. Patterns 2. Cause & Effect 3. Scale, Proportion, & Quantity 4. Systems & System Models 5. Energy & Matter 6. Structure & Function 7. Stability & Change

Student Engagement and Attitude Survey. The qualitative data collection process began with the student engagement and attitude survey. This survey was administered to all students in the treatment group to gauge the overall temperature of the classroom. Students read statements and answered using a four-point Likert scale ranging from strongly agree to strongly disagree without a neutral answer choice. The questions aimed to better understand student attitude toward science in general and students' past experiences in science as well as student attitude towards the phenomenon-based storylining curriculum experienced during their freshman year. Results were analyzed using frequencies and modes.

Teacher Observations. Unstructured observations of the classroom were conducted throughout the study. Notes were taken after each activity focusing on how the implementation of the new curriculum was going from the teacher's perspective. Notes were used to determine the success of the new curriculum, student engagement, and the ability to build upon SEPs and CCCs found within the anchoring phenomenon of the storyline. Along with this, results helped to influence curriculum pacing, guiding questions, as well as student misconceptions that needed to be addressed.

Data Analysis Strategies

Through the use of both quantitative and qualitative data, I was able to get a full picture of the effects of the use of an NGSS centered storylining approach and how this impacted both student skill development and engagement levels. For my quantitative data, I compared means and medians as well as ran independent and paired t tests. This data allowed for me to gain an understanding of student growth from beginning to end of the phenomenon-based curriculum as well as to compare final results between the phenomenon-based approach and the traditional learning approach. This was made possible through the Macromolecule Content Assessment. These assessments were designed in a multiple-choice format which allowed for one correct answer and objective data (Lasen et al., 2018). To gain quantitative data concerning skill development within my treatment group, I used the same approach mentioned above using the Life as a Hunter CER compared to the Final Exam CER Assessment tool. Lastly, the Final Exam Multiple Choice Assessment was used along with mean and median data as well as t tests to compare results in long term memory of content-based information between the two groups.

In terms of qualitative data, the tools used included the Student Engagement and Attitude Survey, and Teacher Observations. For my Likert survey, I used a scale that included options of *strongly disagree*, *disagree*, *agree,* and *strongly agree*. Through the removal of the middle option, neither agree nor disagree, I hoped to encourage students to think deeper and determine which side of the spectrum they fell on without having the opportunity to simply choose none (Hampson, 2014, p. 3). This forces students to make a choice. All statements in the survey were independent of each other so I analyzed them separately using modes and frequencies to gauge responses. Data collected from student interviews were compared and keywords were used to determine consistencies and trends in the data. This data was used to support other findings (He, 2012). Lastly, Teacher Observations were used to make adjustments throughout treatment as well as ensure the pacing was consistent and appropriate for both groups.

CHAPTER FOUR

DATA ANALYSIS

Impact of NGSS Curriculum with Emphasis on SEP and CCC on Content Knowledge Retainment

Macromolecule Content Assessment

The Macromolecule Content Assessment assessed students' ability to apply course information through a multiple-choice assessment. The topics addressed in this unit include the NGSS standard HS-LS1 From Molecules to Organisms: Structures and Processes. Specifically, HS-LS1-6: Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. The focus was placed on carbohydrates, proteins, and lipids. This outlines the CLS emphasized throughout this unit and study. The treatment group participated in a pre test before the unit as well as a post test after the storylining unit was completed. The results support that students improved in their content understanding between the pre and post test. The average of the pre test was 28.0% which, when compared to the post test, almost quadrupled to an 81.2% average (N=47). The averages were very close to the medians with both pre and post test. The pre test median was 28.6% and the post test median was 78.6% further supporting the growth of student content knowledge. Overall average gains between the pre and post tests were 53.2% while overall median gains between the pre and post test were 50%.

In addition to large gains within the treatment group between pre and post test results, data supports that the treatment group performed stronger overall when compared to the non-treatment group. When comparing post test results between the treatment group and the non-treatment group, the treatment group scored an average of 81.2% and median of 78.6% (*N*=47). The non-treatment group scored an average of 73.7% and a median of 76.4% (*N*=26). This includes an average gain of 7.5% between the two groups. The median gain was 0.2% (Figure 6).

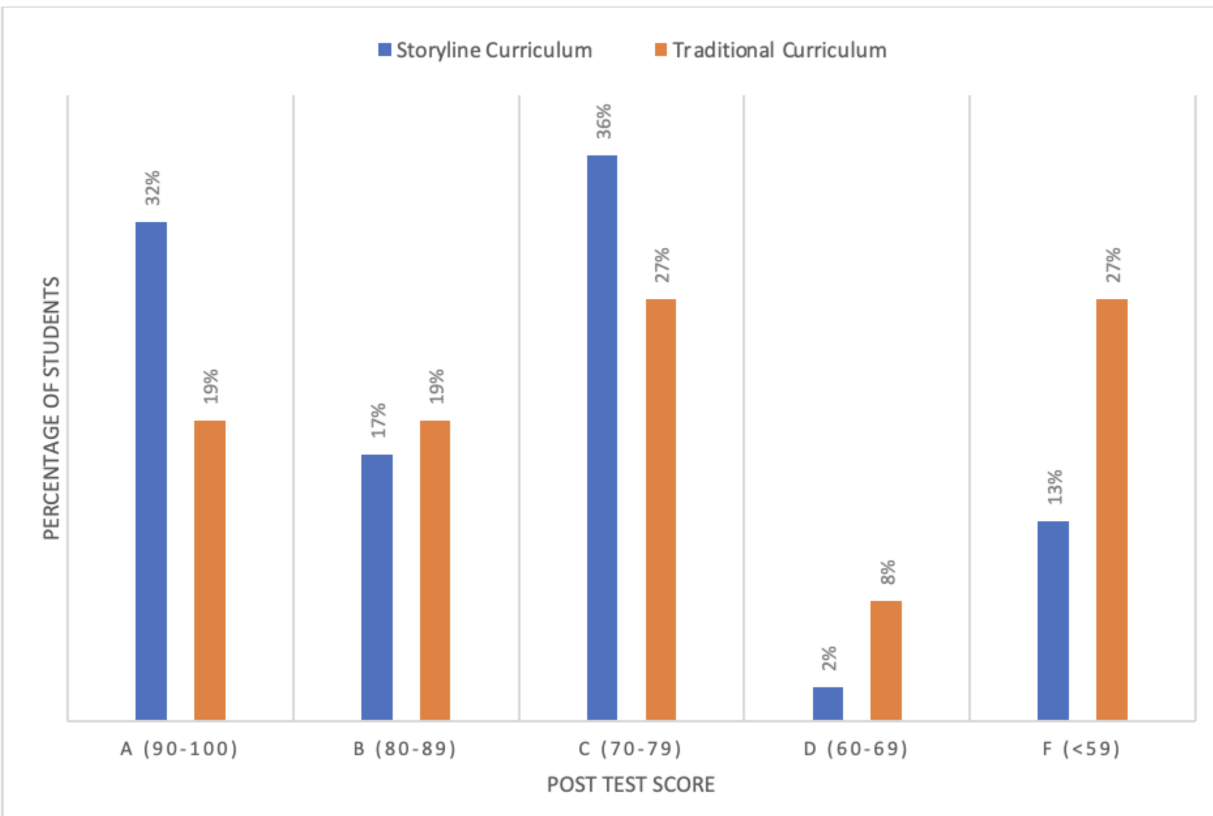

Figure 6. Percentage of students in treatment group versus post test score, (*N*=47).

In addition to large average gains, the standard deviation also showed less variability within scores of the treatment group when compared to the non-treatment group. The treatment group's standard deviation was 13.9% while the non-treatment standard deviation was 14.5%.

These calculations include all student scores, including outliers, which supports the idea that the storylining curriculum encourages growth in the knowledge of all students. When the Grubbs test was run to calculate the outliers with a significance level of 0.05, 2.1% of all student scores were deemed outliers within the treatment group. When the same test was run on the non-treatment group 3.8% of all student scores were deemed outliers. This further supports that the storylining curriculum is more inclusive and a better fit to guide students to success with the material (Figure 7).

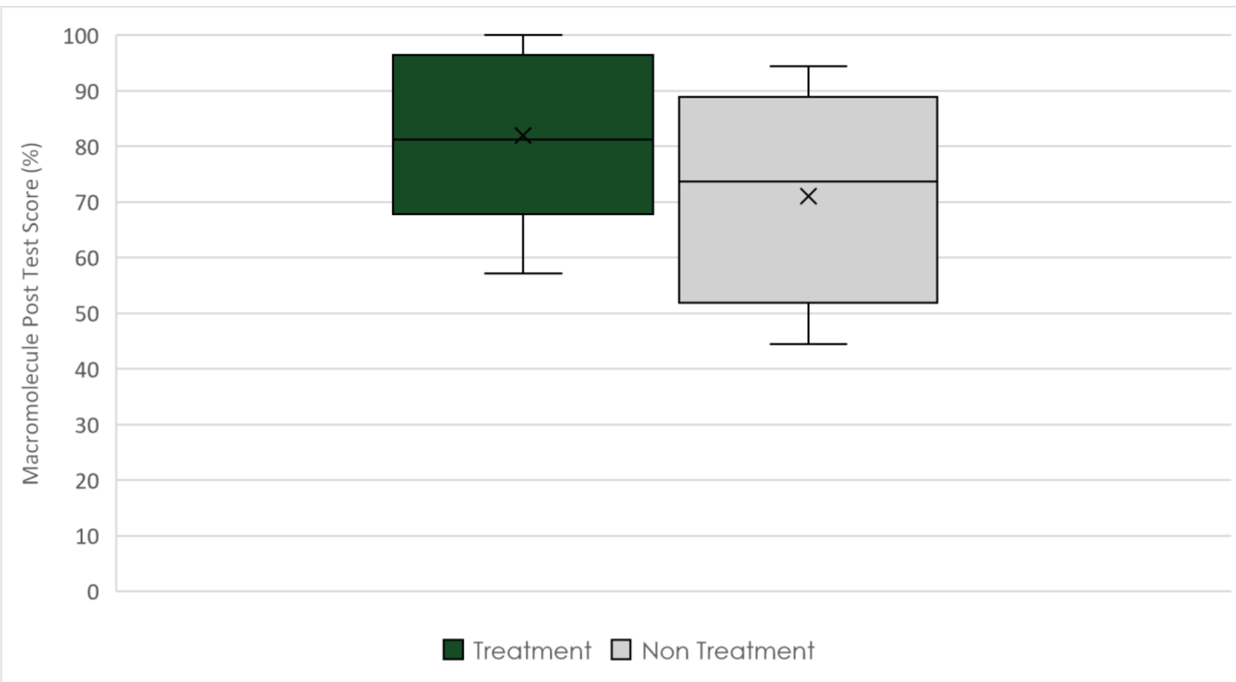

Figure 7. Treatment (*N*=47) vs. non treatment (*N*=26) macromolecule results.

Final Exam Multiple Choice Content Assessment

Another piece of data collected includes the results of the final exam questions pertaining to the macromolecules CLS. On this group of macromolecule questions, the treatment group scored an average of 82% with an 83% median (*N*=47). The non-treatment group scored an average of 74% with a median of 81% (*N*=26). This includes a 15% average gain as well as a 2%

median gain between the two groups. The standard deviation within the treatment group was 16% while the standard deviation within the non-treatment group was 21% (Figure 8). Once again, this supports the idea that the storylining curriculum is a better support for all students to reach mastery with a smaller standard deviation. In addition, students not only learned the material, but also retained the knowledge as this unit took place in October and the final exam was given in December.

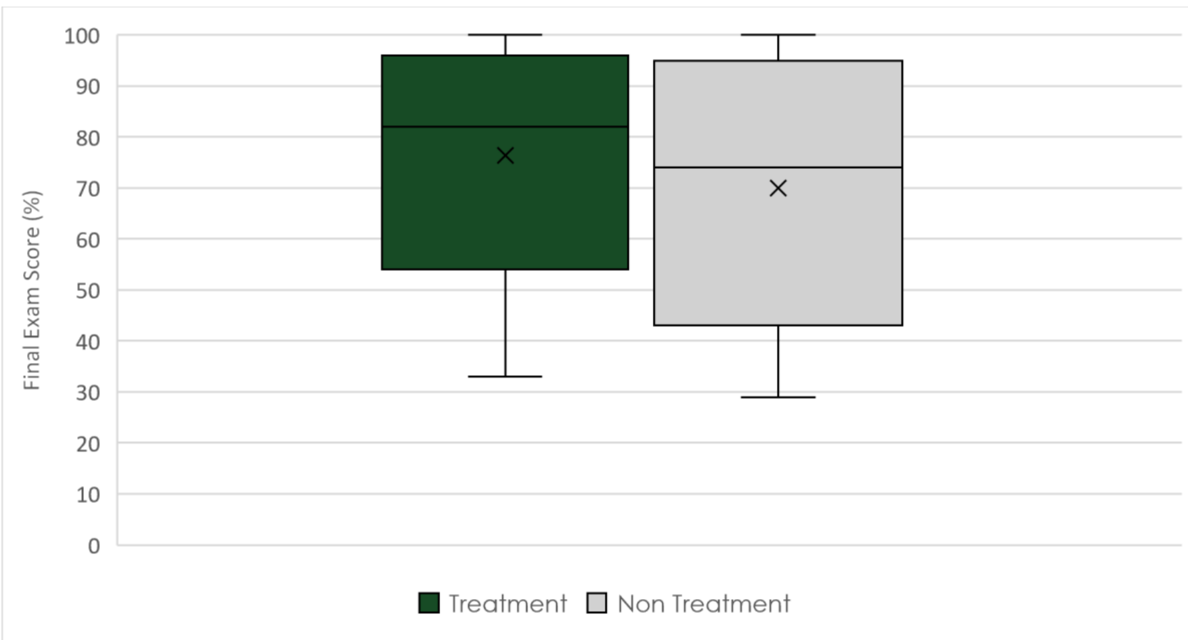

Figure 8. Treatment (*N*=47) vs. non treatment (*N*=26) final exam results.

<u>Final Exam CER Assessment</u>

Lastly, students in the treatment group participated in many Claim, Evidence, Reasoning check-ins throughout the year. The first CER of the year was compared to the last CER, included on the final exam (Final Exam CER Assessment). Scores between the pre and post CER assessments were compared. Scientific argumentation and providing evidence to support an argument are two skills that were emphasized throughout the treatment curriculum. This related to emphasis on the SEPs within NGSS as well as my district's goal of encouraging students to "be able to use these practices to strengthen their science skills and to further develop their understanding of the nature of science and engineering." I used the same CER rubric to grade both the pre and post assessment CERs (Appendix A).

The average score on the pre test CER assessment was 61.5% with a median of 65%. The average score on the post test CER assessment was an 86.5% with a median of 90% (*N*=47). This high median proves that more students were able to be successful and there were fewer that fell short. To further support this, only 4.3% of students scored less than a C on the post test while 72% of students scored less than a C on the pre test. These numbers are incredibly telling in that our main effort was to develop students' skills that will be useful in their futures no matter what they decide to specialize in later in their life. Science and Engineering Practices, specifically writing and argumentation, are two skills which are transferrable to every future job that our students may hold. The standard deviation with the post test assessment was 9.24% while there was a larger spread of scores on the pre test with a standard deviation of 12.26% (Figure 9). In addition to this, the maximum score on the pre test was an 80% which was only achieved by one student. On the post test, 41 out of 47 students scored at this maximum score of 80% or higher. This emphasizes the huge amount of growth which occurred throughout the use of the treatment curriculum in terms of student skill development, particularly argumentation.

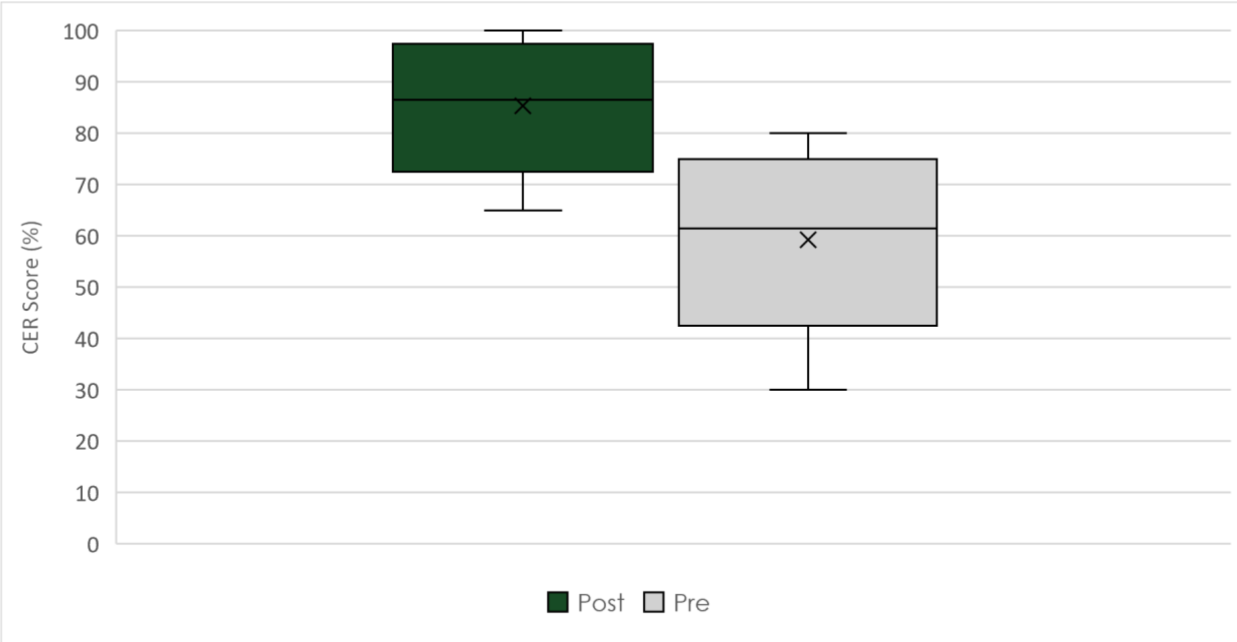

Figure 9. Pre vs. post CER assessment results (*N*=47).

Teacher Observations

Finally, Teacher Observations were collected throughout the semester. A major trend within the observations and notes collected included comments on student discussion. The beginning of the year required a lot of guiding questions from the teacher when students were posed with a problem or question to answer. As the semester went on, it was incredibly noticeable the students' ability to guide their own discussion and synthesize information from class in their thought process and development of solutions. This difference not only emphasizes student skill development, but also supports the fact that students were learning material at a higher level since they were able to synthesize and justify opinions or judgments with strong evidence (Bloom, 1956). Students tended to function at higher levels on Bloom's Taxonomy within the cognitive domain (Figure 10). At the beginning of the year, classroom discussions often operated in the understanding and applying categories of the pyramid. As the semester progressed, many observational notes were collected which emphasized student ability to analyze, evaluate, and a couple of times, even create.

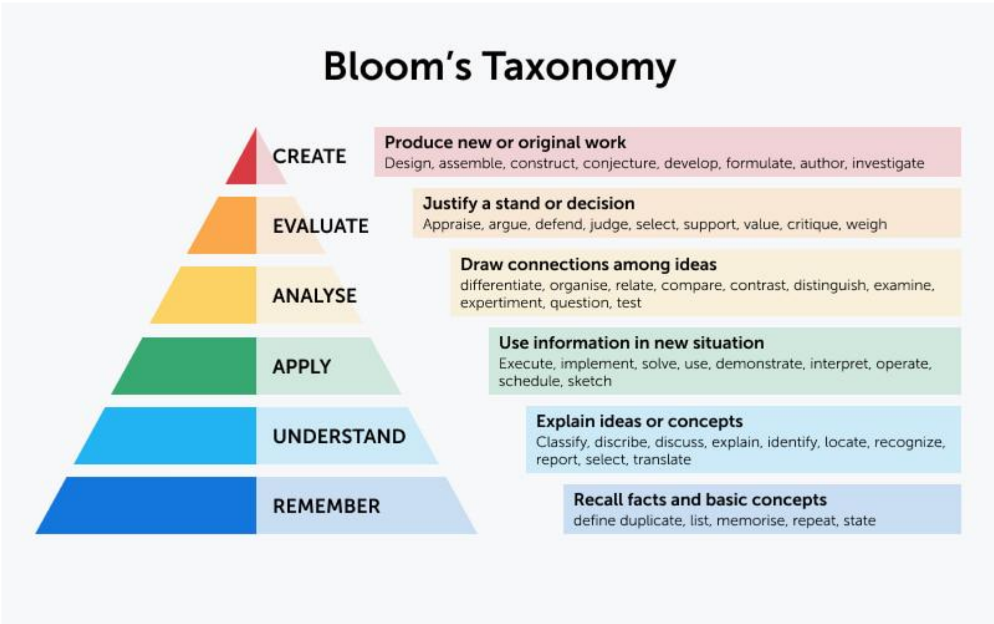

Figure 10. Pyramid with levels of learning suggested by Bloom.

<u>Impact of Phenomenon Driven Storylining Curriculum on Student Engagement and Attitude</u>

<u>Student Engagement and Attitude Survey</u>

In order to determine student engagement and attitude differences through the use of the treatment curriculum, students participated in a Likert survey. The survey was given to all students in the treatment group (*N*=47). Before students began the survey, they were told to answer the survey comparing their previous experience within science classes to their current experience with the new curriculum. This approach was used in order to keep constant the students being surveyed as interest levels could skew the results if different groups of students were used. In order to ensure that this data would accurately reflect the different shifts of the NGSS approach, students responded to questions geared toward their past experiences within science classrooms in middle school as well as questions geared toward their current experience with the NGSS curriculum. In my district, the middle school curriculum has not fully transitioned to NGSS so this was a strong comparison to use.

To first gauge the overall interest level to science in general and set the stage for future questions on the survey, students were asked to respond to the statement, “Science is one of the most interesting school subjects.” The data shows that about half of students agree while about half disagree. This is interesting as our data will provide feedback both from students who have a strong passion for science as well as those who may have interests in other fields (Figure 11).

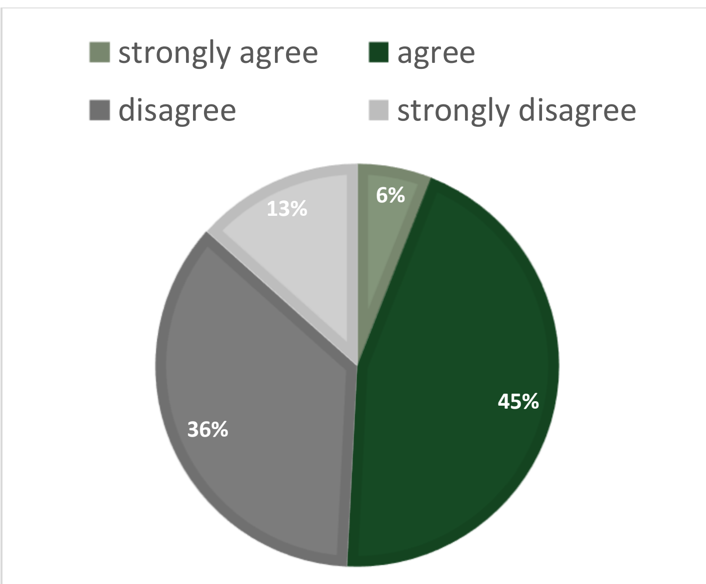

Figure 11. Likert survey responses of interest level in science.

Second, students were asked to respond to the comment, “This class is different than my past science classes.” More than 88% of students responded positively (strongly agree or agree) to this statement. This helps to validate the data in that students are reflecting on both the treatment curriculum as compared to a more traditional approach.

The first set of questions that were helpful in determining a difference in student engagement included, “In middle school, I looked forward to attending science class” versus “I look forward to attending science class in high school” (Figure 12). The number who responded positively to this statement for middle school (strongly agree or agree) was 63% of students while 64% of students responded positively for high school. I was surprised that the numbers were not more different, but attribute some of this to the fact that many students find this course difficult. Often difficulty can turn students off from a course as it requires a significant amount of thinking and work more than just being told information. This is also supported by the statement “I miss the ‘more-typical’ methods of teaching and learning that we did in middle school, which includes textbooks, worksheets, memorization, etc.” Twenty percent of students responded that they agreed to this statement. I assume that this 20% of students may be especially challenged by this course through the high level of thinking and practicing of skills required by the course. This is also supported by the free response section of the survey where students were asked, “If you could change something about this class, what would it be?” Some responses from students included, “I want more memorizing than problem solving.” “Spread out the information we learn more and focus more on one thing at a time rather than giving a bunch of information all at once.” as well as “More memorizing what I know.” Students are not necessarily used to spending time synthesizing information and combining many concepts to be able to support an argument. The storylining curriculum is not organized based on typical units, but instead incorporates many aspects of biology in which students need to make connections to fully understand issues happening in our world.

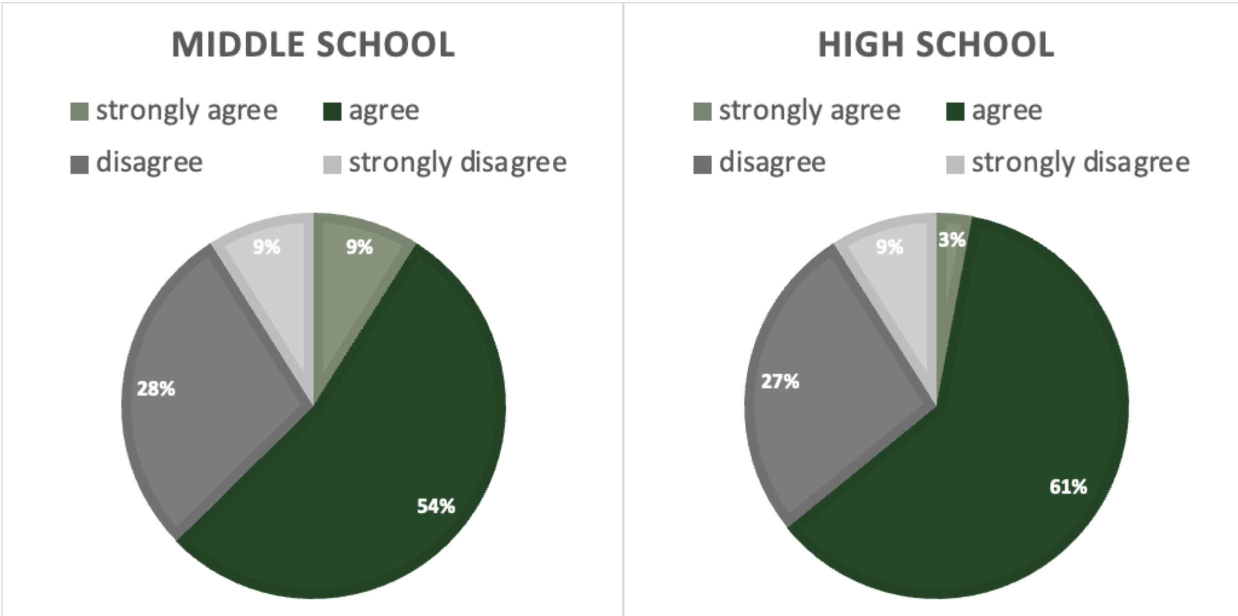

Figure 12. Likert survey responses comparing middle school to high school.

Some of the most telling questions which focused on the treatment curriculum include student attitudes and value seen in the treatment curriculum. Overall, the majority of students see value in the work they are completing and the topics they are learning (Figure 13). If students are able to recognize, value, and find interest in topics presented in class, their engagement benefits.

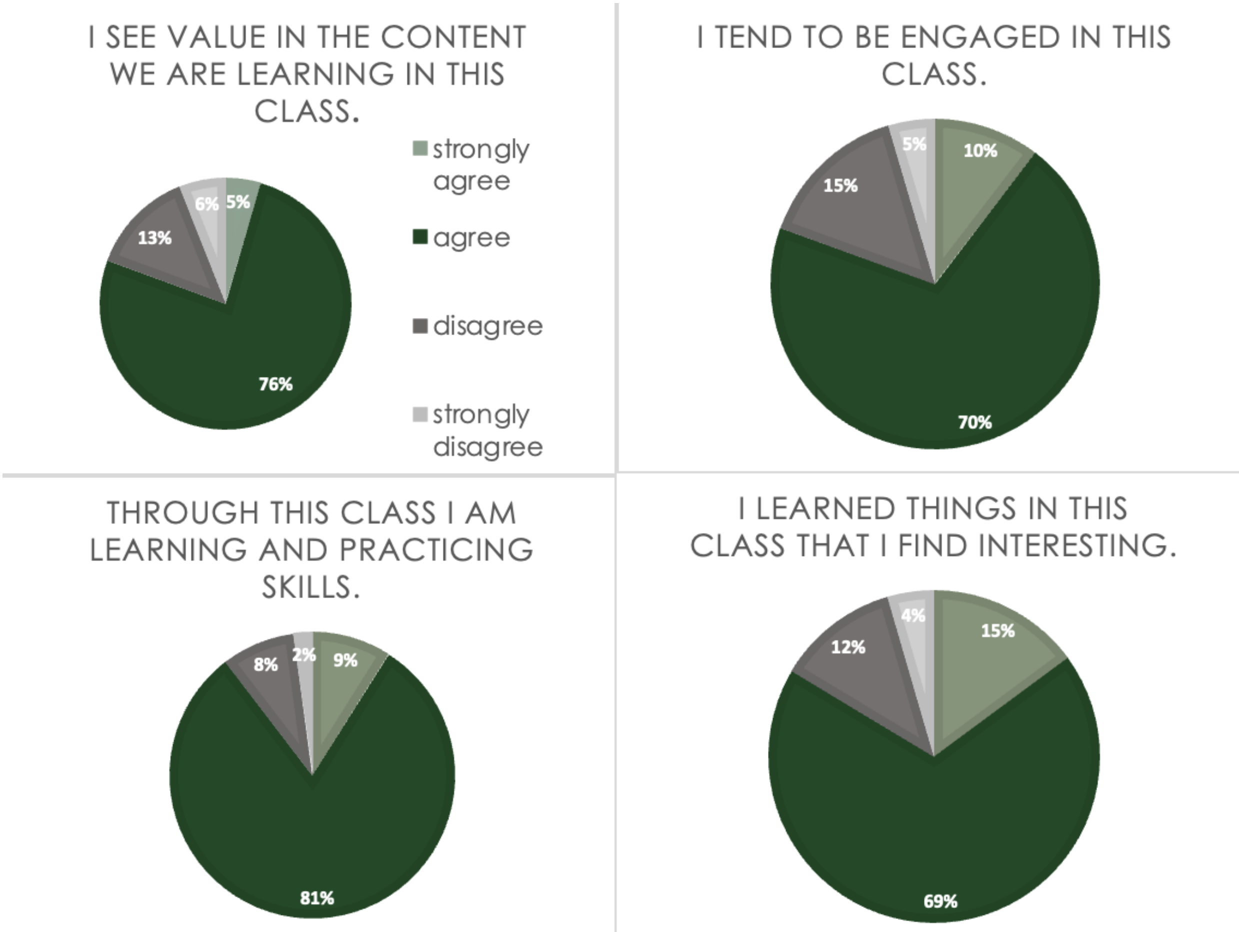

Figure 13. Likert survey responses concerning interest and engagement.

In addition to this, when students are engaged, they are more likely to participate in a larger capacity during class. High levels of participation, especially in group work, is something that was observed throughout the semester. This is also supported by student responses to the question, “What is your favorite part about this class?” Out of all students, over 40% of students responded to this question with positive comments about working with others. While participating in the non-treatment curriculum, it was noted that I was typically doing more than 60% of the speaking during a class period. In addition to this, within the non-treatment group, when given the opportunity to work together many students chose to work alone or with a single partner as opposed to a larger group. When walking around the classroom, it was observed that even when students were working together their conversation was not science based, but instead small talk while they worked on the assignment independently. Throughout the treatment group, it was noted that students took much more responsibility within the classroom when it came to discussing, asking questions, answering questions, etc. Students were responsible for up to 80% of conversation with a small 20% of teacher led instruction within a class period. The classroom had been flipped in terms of the student versus teacher role within the classroom between the non-treatment and treatment groups. It was also noted that students worked in larger groups with most conversation revolving around the activity they were completing as opposed to small talk and personal conversation.

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

There are two main claims made based on the data collected from completing this study. These claims include 1) an NGSS storylining approach with a focus on SEPs and CCCs best allows for content mastery and retention and 2) a storylining approach best encourages student engagement and interest within the classroom. Each of these claims is supported by data collected throughout this action research project, correlates with others' findings in this area of research, and will positively influence the world of teaching and learning in high school biology.

Content Mastery and Retention

The Pre and Post Macromolecule Content Assessment as well as the major gains between the treatment and nontreatment groups with the Post Test Macromolecule Content Assessment comparison of results and Final Exam Multiple Choice Content Assessment results all support the claim that an NGSS storyline, phenomenon-based approach in teaching biology best allows for students to master the content as well as retain content as emphasized in the Nature of Science (McComas et al., 1998). This is also supported by Final Exam CER Assessment which highlighted high levels of student growth within the treatment group. Additionally, the student responses in the Student Engagement and Attitude Survey also supported student growth not only in content, but also in skills that will be applicable later in life (McComas & Nouri, 2016, p. 557). Flick and Lederman (2006) emphasized the importance of understanding the How of science from a student's perspective (pp. 332-333).

Value of the Study and Consideration for Future Research. This action research project supported the idea that students succeed in mastering and retaining content through the use of an NGSS storyline curriculum. I would be interested to collect more data on student skill development through the use of this curriculum as high emphasis is placed on SEPs and CCCs (NSTA, 2014). This could be accomplished by surveying sophomore, junior, and senior science teachers to compare student thinking skills over the course of a non-treatment group with a traditional curriculum compared to a treatment group with the treatment curriculum. This will be possible as the treatment group from this year progresses through their high school career and teachers can compare their experiences with their previous experience teaching the course before implementation of the new curriculum. I would also be curious to complete more research when it comes specifically to writing skills. A lot of time in the treatment classes was spent completing argumentative writing. I would like to see student progress specifically in terms of writing and ability to support a claim with evidence outside of the content (NGSS Lead States, 2013).

In addition to this, the study was completed within a tight time span of one semester. An additional question I have concerning the progress students made includes how permanent the learning truly was. The largest concern I have is whether students developed skills including being able to interpret data, both visually and in writing, as well as being able to communicate strongly in both writing and verbally. As such, I wonder if the final exam was given to students at the end of the second semester or even in another year if students would be able to perform as well as they did the first time around? I am hopeful that the answer to this would be yes as the final exam was written in a way that previous content knowledge was not incredibly prevalent, but instead focused on student interpretation of charts, diagrams, maps, etc.

Student Engagement and Interest

Through analyzing the data collected and analyzed from the Student Engagement and Attitude Survey as well as Teacher Observations, it was clear that students in the treatment group were more engaged and interested in the class. I believe this is in part due to the lack of direct instruction and the higher emphasis placed on the student's role within the classroom (Sherman, 2021). Second, I believe the main pieces of the storyline intrigue students as the curriculum focuses on real life stories which tie in biology content as opposed to placing all emphasis on the biology content and providing minor examples of how it applies to real life (Ainley & Ainley, 2011, p. 4).

Value of the Study and Consideration for Future Research. I would be very curious to further analyze the connection between the student anticipated career path or career interest and the skills necessary for that career. One of my main goals with this curriculum has included making the course applicable to all students so that everyone is growing in a way that will be useful for their lives in the future. I believe this is especially important in a graduation required course, like biology, that all students are required to take. I would find it interesting to partner with the career advisor or counselors at my school to develop a list of skills necessary for success in a range of careers. This would not only be beneficial for me as the teacher to best focus our class on a range of skills necessary for success in the "real world" but would also be a great list to share with students. I noticed throughout the course that if students can be convinced they are completing something that is worthwhile to their growth, not only in course content, but in life, they will be both more engaged and willing to give more effort (Karlsen & Haggstrom, 2020, p. 14). About half of the students answered in the Student Engagement and Attitude Survey that they were not interested in science. If we can respect the fact that different people have different interests while explaining the benefits that each student will gain from the course outside of simply biology content knowledge, I believe students would be more willing to participate at a higher level of engagement (All Species Education Consulting, 2023).

Impact of Action Research on the Author

I began this action research project about 18 months ago with many different ideas in mind. It was not until about 10 months ago that things finally started to fall into place, and I was able to definitely state my goals for the project. The moment that defined my action research project was when I found Jason Crean's Biology Storylining Curriculum and was truly changed as a teacher. Until this moment, I did not realize the disservice I was doing to my students by providing a curriculum that mainly focused on high level biology content and had little to do with real-world examples, life skills, and academic skills. Truly, I believe the only skill that my non-treatment group accomplished through the old curriculum was learning how to study. Although important, this does not even begin to scratch the surface of the huge opportunity available to introductory level, graduation requirement courses offered for freshman students.

The first part of the problem with the non-treatment curriculum was that it was very high level and, to put it lightly, hard. Students were simply memorizing material and if this material was not able to be memorized, students would not perform well on assessments. In addition to this, students would memorize a concept for the assessment and then forget it immediately after. There were seldom connections made between units as once a unit was over, students were essentially allowed to forget that material as the class just moved on to the next topic. Memorization, I agree, is a skill that can be helpful in life, but with our current world shifting to

AI and high-level technology, I would argue that memorization is not necessary to be successful in life. It is easy to google any topic in seconds as just about everyone has a cell phone on them at all times. With this realization, I knew that the storyline I discovered from Jason Crean was going to be my approach to this school year. I had accepted the fact that all my previous work on the old curriculum would need to be scrapped and I would be starting from scratch, but I truly believed this would be to the benefit of all freshman students. I was determined to make a change as opposed to getting stuck in "what has always been done."

First, I am convinced that this storylining, NGSS focused curriculum is truly the best for students. The curriculum not only encourages student thought and development of skills, but students enjoy the curriculum much more than the more traditional, lecture-style approach.

Second, we have been part of many discussions within the school that science enrollment numbers are dropping. I am concerned this is due to the fact that some of our classes can scare kids away from science. For ninth graders who are getting their first high school experience with science, I think one of our main goals should be convincing students to love science and developing their lifelong love of learning. I believe this is possible if the content provided is both interesting to students as well as provides them with skills that will be beneficial in their futures.

Overall, this action research experience has been incredibly rewarding and has truly changed my identity as a teacher. With this new curriculum came a lot of questions from colleagues, my boss, my principal, my students as well as my students' parents. I have fielded these questions and concerns with grace as this curriculum is my true passion, but I will be the first to admit has a lot of edits and growth to come. This project has provided the motivation behind the work that has gone into completely flipping the curriculum of all freshman biology courses at my high school this year. The work done this year is just a start to the new curriculum that will continue to grow year after year.

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APPENDICES

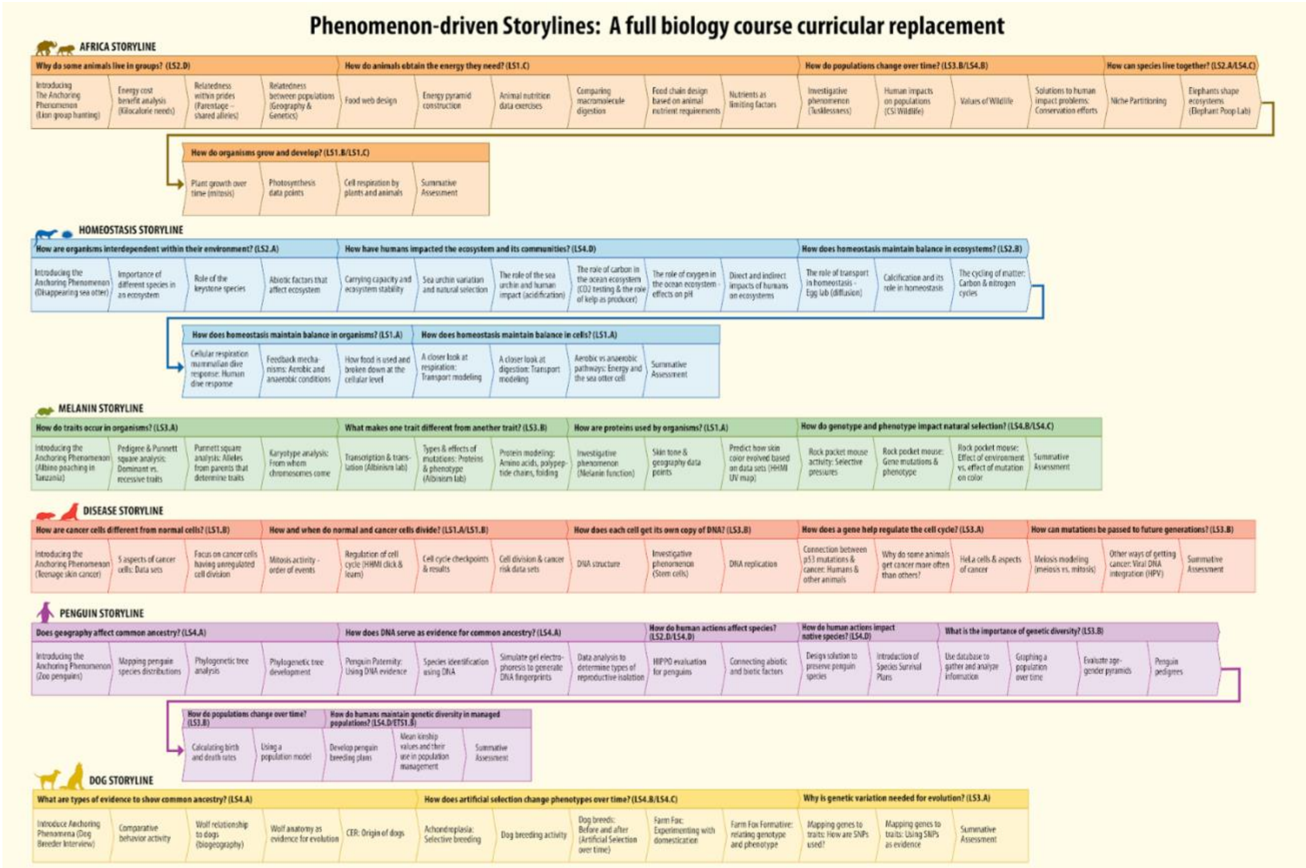
APPENDIX A

CER ASSESSMENT RUBRIC

	1.5 Description	1 Description	0.5 Description	0 Description
Claim Description		Claim is accurate, complete, and concise.	Claim is provided, but not complete or concise.	Claim is not accurate.
Evidence #1 Description	Evidence is specific (includes reference to lab, numbers, video, activity, graph, and/or model). Evidence is relevant to the claim. Evidence is accurate.	Evidence is relevant to the claim. Evidence is accurate.	Evidence is provided, but is not relevant or accurate.	Evidence is not provided.
Evidence #2 Description	Evidence is specific (includes reference to lab, numbers, video, activity, graph, and/or model). Evidence is relevant to the claim. Evidence is accurate.	Evidence is relevant to the claim. Evidence is accurate.	Evidence is provided, but is not relevant or accurate.	Evidence is not provided.
Evidence #3 Description	Evidence is specific (includes reference to lab, numbers, video, activity, graph, and/or model). Evidence is relevant to the claim. Evidence is accurate.	Evidence is relevant to the claim. Evidence is accurate.	Evidence is provided, but is not relevant or accurate.	Evidence is not provided.
Reasoning F Claim		Claim is restated.		Claim is not restated.
Reasoning F Evidence Discussed	All 3 pieces of evidence are discussed.	2 pieces of evidence are discussed.	1 piece of evidence is discussed.	No pieces of evidence are discussed.
Reasoning F Evidence Explained	All 3 pieces of evidence are explained with more information.	2 pieces of evidence are explained with more information.	1 piece of evidence is explained with more information.	All pieces of evidence are simply restated.
Reasoning F Background Information			Background information is provided for a strong reasoning section that "tells a story" and "paints a picture".	Background information is not provided.

APPENDIX B

ASEC STORYLINE CURRICULUM MAP


Phenomenon-driven Storylines: A full biology course curricular replacement
AFRICA STORYLINE
Why do some animals live in groups? (LS2.D)
Introducing The Anchoring Phenomenon (Lion group hunting)
Energy cost benefit analysis (Kilocalorie needs)
Relatedness within prides (Parentage – shared alleles)
Relatedness between populations (Geography & Genetics)
How do animals obtain the energy they need? (LS1.C)
Food web design
Energy pyramid construction
Animal nutrition data exercises
Comparing macromolecule digestion
Food chain design based on animal nutrient requirements
Nutrients as limiting factors
How do populations change over time? (LS3.B/LS4.B)
Investigative phenomenon (Tusklessness)
Human impacts on populations (CSI Wildlife)
Values of Wildlife
Solutions to human impact problems: Conservation efforts
How can species live together? (LS2.A/LS4.C)
Niche Partitioning
Elephants shape ecosystems (Elephant Poop Lab)
How do organisms grow and develop? (LS1.B/LS1.C)
Plant growth over time (mitosis)
Photosynthesis data points
Cell respiration by plants and animals
Summative Assessment
HOMEOSTASIS STORYLINE
How are organisms interdependent within their environment? (LS2.A)
Introducing the Anchoring Phenomenon (Disappearing sea otter)
Importance of different species in an ecosystem
Role of the keystone species
Abiotic factors that affect ecosystem
How have humans impacted the ecosystem and its communities? (LS4.D)
Carrying capacity and ecosystem stability
Sea urchin variation and natural selection
The role of the sea urchin and human impact (acidification)
The role of carbon in the ocean ecosystem (CO2 testing & the role of kelp as producer)
The role of oxygen in the ocean ecosystem - effects on pH
Direct and indirect impacts of humans on ecosystems
How does homeostasis maintain balance in ecosystems? (LS2.B)
The role of transport in homeostasis - Egg lab (diffusion)
Calcification and its role in homeostasis
The cycling of matter: Carbon & nitrogen cycles
How does homeostasis maintain balance in organisms? (LS1.A)
Cellular respiration mammalian dive response: Human dive response
Feedback mechanisms: Aerobic and anaerobic conditions
How food is used and broken down at the cellular level
How does homeostasis maintain balance in cells? (LS1.A)
A closer look at respiration: Transport modeling
A closer look at digestion: Transport modeling
Aerobic vs anaerobic pathways: Energy and the sea otter cell
Summative Assessment
MELANIN STORYLINE
How do traits occur in organisms? (LS3.A)
Introducing the Anchoring Phenomenon (Albino poaching in Tanzania)
Pedigree & Punnett square analysis: Dominant vs. recessive traits
Punnett square analysis: Alleles from parents that determine traits
Karyotype analysis: From whom chromosomes come
What makes one trait different from another trait? (LS3.B)
Transcription & translation (Albinism lab)
Types & effects of mutations: Proteins & phenotype (Albinism lab)
Protein modeling: Amino acids, polypeptide chains, folding
How are proteins used by organisms? (LS1.A)
Investigative phenomenon (Melanin function)
Skin tone & geography data points
Predict how skin color evolved based on data sets (HHMI UV map)
How do genotype and phenotype impact natural selection? (LS4.B/LS4.C)
Rock pocket mouse activity: Selective pressures
Rock pocket mouse: Gene mutations & phenotype
Rock pocket mouse: Effect of environment vs. effect of mutation on color
Summative Assessment
DISEASE STORYLINE
How are cancer cells different from normal cells? (LS1.B)
Introducing the Anchoring Phenomenon (Teenage skin cancer)
5 aspects of cancer cells: Data sets
Focus on cancer cells having unregulated cell division
How and when do normal and cancer cells divide? (LS1.A/LS1.B)
Mitosis activity - order of events
Regulation of cell cycle (HHMI click & learn)
Cell cycle checkpoints & results
Cell division & cancer risk data sets
How does each cell get its own copy of DNA? (LS3.B)
DNA structure
Investigative phenomenon (Stem cells)
DNA replication
How does a gene help regulate the cell cycle? (LS3.A)
Connection between p53 mutations & cancer: Humans & other animals
Why do some animals get cancer more often than others?
HeLa cells & aspects of cancer
How can mutations be passed to future generations? (LS3.B)
Meiosis modeling (meiosis vs. mitosis)
Other ways of getting cancer: Viral DNA integration (HPV)
Summative Assessment
PENGUIN STORYLINE
Does geography affect common ancestry? (LS4.A)
Introducing the Anchoring Phenomenon (Zoo penguins)
Mapping penguin species distributions
Phylogenetic tree analysis
Phylogenetic tree development
How does DNA serve as evidence for common ancestry? (LS4.A)
Penguin Paternity: Using DNA evidence
Species identification using DNA
Simulate gel electrophoresis to generate DNA fingerprints
Data analysis to determine types of reproductive isolation
How do human actions affect species? (LS2.D/LS4.D)
HIPPO evaluation for penguins
Connecting abiotic and biotic factors
How do human actions impact native species? (LS4.D)
Design solution to preserve penguin species
Introduction of Species Survival Plans
What is the importance of genetic diversity? (LS3.B)
Use database to gather and analyze information
Graphing a population over time
Evaluate age-gender pyramids
Penguin pedigrees
How do populations change over time? (LS3.B)
Calculating birth and death rates
Using a population model
How do humans maintain genetic diversity in managed populations? (LS4.D/ETS1.B)
Develop penguin breeding plans
Mean kinship values and their use in population management
Summative Assessment
DOG STORYLINE
What are types of evidence to show common ancestry? (LS4.A)
Introduce Anchoring Phenomena (Dog Breeder Interview)
Comparative behavior activity
Wolf relationship to dogs (biogeography)
Wolf anatomy as evidence for evolution
CER: Origin of dogs
How does artificial selection change phenotypes over time? (LS4.B/LS4.C)
Achondroplasia: Selective breeding
Dog breeding activity
Dog breeds: Before and after (Artificial Selection over time)
Farm Fox: Experimenting with domestication
Farm Fox Formative: relating genotype and phenotype
Why is genetic variation needed for evolution? (LS3.A)
Mapping genes to traits: How are SNPs used?
Mapping genes to traits: Using SNPs as evidence
Summative Assessment

APPENDIX C

IRB APPROVAL

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

PI: Morgan, Julia
Approval Date: 1/20/2023
Title: Next Generation Science Standards and Phenomenon-Driven Storylining in High School Biology

Protocol #: 2023-527-EXEMPT
Review Type: Exempt Review
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