THE EFFICACY OF A HIGH SCHOOL BIOLOGY STORYLINE CURRICULUM

by

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DEDICATION

To my students, I am grateful for the opportunity to work with you, learn from you, and witness your growth as individuals and learners. You have inspired me to be a better teacher. You will do great things, and I am honored to have been a part of your journey. And remember, stay curious.

To my parents who instilled a love of learning and have been my most faithful cheerleaders from the beginning.

To Nolan, Logan, and Soren who might finally see what I was up doing most nights on the computer. Thanks for putting up with the clicking keys and for always supporting me, even when you now know the less glamorous reality behind my screen time.

And to Seth, who quietly took care of the boys and got them to bed while I was too distracted to notice what time it was. Thanks for everything, in this and well, everything.

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ABSTRACT

This project aimed to determine if biology storylines could help students increase engagement and comprehension of the Next Generation Science Standard concepts when compared to a traditional linear-unit curriculum. Storylining is a curriculum replacement that engages students with a phenomenon and continues to be driven by student-generated questions. Concepts are spiraling in nature and are revisited in ever-increasing depth as the curriculum unfolds. Data was collected for two years. The first year of biology was taught using a traditional linear-unit curriculum where individual units were taught in isolation. In the subsequent year, a storyline curriculum was introduced. At the end of each year, students took a computerized test in biology to assess comprehension. Students also provided feedback through both a written and verbal survey. Not only were test scores higher in the group using storylines, but students also reported overwhelming support for storylines. Comprehension, engagement, and coherence all improved with storylines while providing students with an authentic learning experience connected to real-world data.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

Billings Central Catholic High School is a four-year private Catholic school in downtown Billings, Montana. With a little over 300 students, there is a small school culture with many of the same opportunities that are available at large schools. The average class size is 18 and because Billings Catholic Schools is a district ranging from preschool through 12th grade, many students have been together since elementary school. Students at Billings Central are required to complete at least ten hours of community service per semester. In 2022, students donated over 6,500 collective hours (Billings Central Catholic High School, 2023).

There are over 50 clubs, sports, and extracurricular activities offered at Billings Central Catholic High School, and over 85% of students participate in one or more activities. Technology is a priority, and every student is issued an iPad and has the option of taking film and editing, advanced business solutions, AP Computer Science JAVA, and coding classes. Students also have the opportunity to take any of the 20 Honors, AP, and Dual Credit classes that are offered. Billings Central does not assign letter grades, but instead uses a percentage system and 89% of the last graduating class had an 80% or higher (Figure 1). The graduating class of 2023 had a 98.7% graduation rate, which is not an unusual number for Billings Central (Billings Central Catholic High School, 2023).

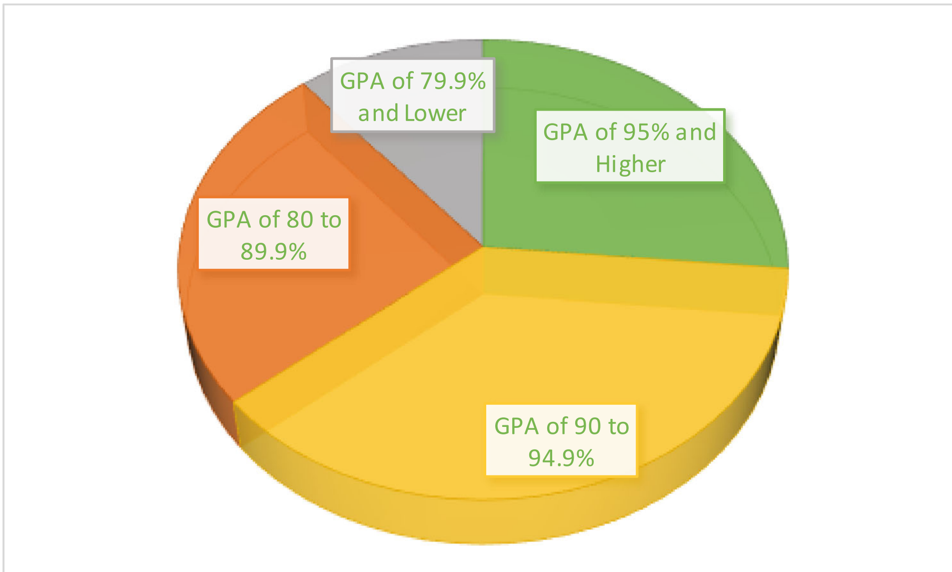

Figure 1. Cumulative academic grade point average distribution at Billings Central Catholic High School for the class of 2023 (Billings Central Catholic High School, 2023), (*N*=68).

Incoming freshmen take biology as their first science class, followed by chemistry, and can then take either one or two upper-division science electives as juniors or seniors. Biology, the first science course that students take, is an important class because it lays the foundation for the skills needed to succeed in future science courses. Students need to be able to think critically and become proficient in more than just scientific content, but also in the practices of scientists. As a freshman biology teacher, I have noticed that incoming biology students struggle with applying what they have learned to real-world scenarios and seem to lack the ability to connect concepts in their mental schema. Due to this, they then struggle with retention of concepts. They only seem to memorize answers for a test, but when asked only weeks later about the same concept, they cannot answer basic questions or connect it to other concepts. For example, I typically teach biological macromolecules early in the year, but when we then need to apply that to various cellular structures, they cannot recall or even see how it might apply. Later in the year, the course covers the nitrogen cycle, but again, students struggle to connect why nitrogen is important or even which macromolecules might require nitrogen. Later in the year we often learn about producers and consumers and food webs, and yet again, when asked why consumers need to eat and what happens to macromolecules during digestion, they fail to see the real-world application and connection to past concepts.

Students' ability to retain and truly comprehend scientific ideas and see how these concepts fit together depends partly on their level of engagement. One aspect of student engagement hinges on how relevant students think concepts are. If students feel that what they are learning is relevant and applicable to the real world, they interact with the material and remember it when asked about it later. It is easier for students to find connections to other concepts and the real world when they feel there is a reason to learn the concepts. When students do not feel that what they are learning has any meaning, it is easily forgotten. Biology, with a lot of the material being on a cellular level and somewhat abstract, is a subject that students can struggle to find connections to and retain long-term recall ability. My students struggle with this issue every year. They often do not see the relevance of what they are learning and easily forget concepts.

Another source of student engagement is an application of the Science and Engineering Practices outlined in the Next Generation Science Standards (NGSS). The Science and Engineering Practices stress the ability to ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information (Figure 2).

PRACTICES FOR K-12 SCIENCE CLASSROOMS

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Figure 2. The Next Generation Science Standards (NGSS) Science and Engineering Practices (National Research Council, 2012).

The Next Generation Science Standards (NGSS) Science and Engineering Practices engage students in skills that go beyond the content. They require students to think critically and solve problems logically. If students are engaged with these practices as well as actively seeking relevance in what they are learning, not only will overall comprehension and coherence of concepts increase, but students will also develop the skills needed to be successful in future high school and college science courses and eventually, become scientifically literate citizens (NGSS Lead States, 2013). In my classroom, I am always looking for ways to help students comprehend the content as well as become critical thinkers, actively engaged with the NGSS Science and Engineering Practices, and able to see the coherence and connections in what they are learning.

Storylining is a concept that has recently garnered momentum in education. It is a curriculum replacement strategy that uses storylines instead of the traditionally used intensive units. These storylines focus on a central idea and then pull from multiple concepts to solve problems. Storylines are often based on real-world applications and use active data from real research. Each storyline spirals from previous storylines and continues to build concepts. Traditional units tend to be linear and rarely circle back, whereas storylines are intended to be much more circular, and concepts are often revisited in increasing complexity.

Focus Question

I have been seeking a way to foster better engagement and comprehension in my biology classes. I see a need to shift instructional methods in science education to increase comprehension by focusing more on engagement with relevant real-world application of concepts and to help develop in students the skills and mindsets needed to solve problems and think critically.

My focus question was, Does a biology storyline curriculum increase student engagement and comprehension of NGSS concepts when compared to a traditional linear-unit curriculum?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Need for Reform

There has been a call for reform in science education that emphasizes meaningful learning. Students need to be given a science education that stresses the application of concepts to the current world. Teachers trained in the early to mid-1900s primarily modeled the way they were taught, which relied on lectures to teach a series of disconnected topics and used cookbook-style laboratory activities (DeBour, 1991). The traditional and long-used method of lecturing, requiring reading from a textbook, and assigning end-of-chapter questions is long outdated. With the speed of current technology and instant access to information, there is less need for rote memorization and more need for the ability to investigate meaningful questions. Isolated facts are useless without the ability to apply that knowledge to real-world issues (Penuel et al., 2022).

Abdi (2014) notes that a big push in this drive for reform has been a renewed emphasis on inquiry-based learning experiences. Inquiry-based instruction engages student interest in science, provides opportunities for data collection, requires students to use critical thinking to solve problems, allows students to elaborate on what they have discovered, and stresses communication of evidence. Inquiry-based instruction replaces teacher-centered models with students as drivers of their own learning. One of the biggest shifts to an inquiry-based mindset is moving away from the idea that the teacher is a disseminator of knowledge and instead seeing the teacher as a facilitator of activities that will foster critical thinking (Abdi, 2014).

Another aspect of science education reform is the application of newfound skills and content to real-world scenarios. Science curricular reforms have focused on teaching students how to make informed decisions and to use scientific understandings to solve problems. According to Gormally et al. (2009), while it is the trend in many universities and secondary schools to move to more inquiry-based investigations, there is still a lack of full curriculum replacements that focus on application. Application is the final piece of the puzzle for students to find relevance and meaning in what they are learning. When students can apply what is learned, they are putting scientific knowledge into context and are further encouraged to the next step in the learning cycle.

Coherence in the science curriculum is one of the larger reform issues. Too often, students see concepts as a series of disconnected and random facts, not as a sequential series of steps to a greater whole. To foster a comprehensive understanding of concepts, students should be able to recognize the interrelated nature of ideas. This necessitates a thoughtfully structured curriculum that effectively highlights these connections (Sikorski, 2017). Students need to play an active role in sense-making and coherence. What seems coherent to teachers might differ from what students perceive to be coherent. To build students' sense of coherence and continuity, science concepts should be built around a natural phenomenon, and each question about that phenomenon should drive the next question. Ideally, students should identify the questions being examined. Students ought to perceive their tasks as tackling questions and issues they have pinpointed, rather than tasks dictated by a textbook or worksheets crafted by a teacher. Students need the ability to connect elements within a topic as well as make connections between scientific topics. When meaningful connections are made, students will be able to make a solid mental framework to understand more complex topics later. This framework serves as a scaffold upon which new information can be organized. A student with a high sense of concept coherence will be able to integrate and apply knowledge to new situations (Reiser et al., 2021).

History

The call for reform in science education to include more inquiry, application, and student coherence has been voiced for a long time. Even as early as 1893, J.M. Rice wrote a series of articles that were published in *The Public-School System in the United States*. In it, he describes the mechanical use of rote memorization, harsh discipline, and lack of active thinking by students. Rice was greatly disturbed by the mindlessness and excessive use of science textbook recitations in place of real-world authentic experiences. Soon after this, great names in education such as John Dewey and William James championed a child-centered approach to science education that stressed observational and critical-thinking skills (DeBoer, 1991).

The push for science reform has steadily progressed since the nineteenth century into the twentieth and twenty-first. In 1986, Kieran Egan, a Canadian educator and philosopher, first proposed a storyline approach. With this strategy, Egan argued that a story structure could be used as a framework for inquiry-based instruction and for the formation of concepts. The aim was to use the stories of past scientists and discoveries as the basis for students to model and discover concepts for themselves (Isabelle, 2007). This idea, while not fully developed at the time, laid the foundation for stories being used in education.

The late 1980s saw the creation of another reform initiative called Project 2061. This was launched by the American Association for the Advancement of Science (AAAS) with an aim to ensure that all students would become literate in science, math, and technology by the year 2061. Project 2061 not only addressed science literacy, but also how the coherence and layout of concepts were presented in current textbooks. AAAS concluded that science textbooks had too many irrelevant activities, too many topics, and too few connections between topics (Sikorski, 2017). These are some of the same issues that Rice was concerned about in the 1890s. The overuse of memorization of detached facts from a textbook was replacing active thinking and learning. Students were struggling with finding meaning and connections between facts.

In 1998, Margaret Bardeen and Leon Lederman proposed the Physics First movement intending to enhance coherence from a student's standpoint. This initiative advocated for a reorganization of the high school course sequence. At the time, as it still is in many parts of the country, the standard approach was for students to take biology, then chemistry, and finally physics. Physics First proposed that physics be the first course that freshmen take, claiming that it is the most foundational, followed by chemistry, and finishing high school with the intricate details of biology (Sikorski, 2017).

Like with Project 2061 and Physics First, coherence is a key element of the Trends in International Mathematics and Science Study (TIMSS). This study, first started in 1995, has continued every four years since. TIMSS collects data on fourth and eighth-grade students internationally to compare scores in both science and math. It also compiles data on students' attitudes towards these subjects as well as current teaching practices (TIMSS, 2015). In 1999, TIMSS focused on curriculum coherence and found that while eighth-grade teachers in the United States were good at creating engaging lessons and activities, they did not use those activities to support the development of these ideas in a way that was coherent for students (Sikorski, 2017).

The Next Generation Science Standards

In 2013, the Next Generation Science Standards (NGSS), based on the National Research Council's *Framework for K-12 Science Education*, set out to pull together inquiry skills, application and sense-making, and coherence into a set of standards for students in kindergarten through twelfth grade using a three-dimensional approach. Every NGSS standard weaves together the three dimensions of Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices. The Disciplinary Core Ideas outline the major content that should be taught, the crosscutting Concepts represent patterns that are seen throughout all sciences and are fundamental to the understanding of major phenomena, and the Science and Engineering Practices describe skills that students should have to be scientifically literate. The Crosscutting Concepts and Science and Engineering Practices are designed to be taught in context and integrated within multiple concepts throughout a student's education. The Disciplinary Core Ideas are designed to build coherently through the grades and concepts progressively develop and spiral (NGSS Lead States, 2013).

One of the largest visions of the NGSS is that of coherence, both within concepts and between concepts. According to the NGSS, instruction should not progress linearly from one performance expectation to another. Instead, it should be presented in bundles where students can perceive the interconnectedness of Disciplinary Core Ideas and Science and Engineering Practices (NGSS Lead States, 2013). Coherence is encouraged by organizing instruction around a phenomenon, which is used as an anchor. This anchoring phenomenon provides a central point around which concepts can be built (Penuel et al., 2022).

Storylines

Storylining is a pedagogical method of instruction based in the Next Generation Science Standards (NGSS) that focuses on coherence from students' perspectives by building from authentic, real-world phenomena and student-generated driving questions. Storylining is cyclical and spiraling, always building upon previously learned concepts and revisiting overarching concepts in different contexts (Illinois Science Teaching Association - Storylining Working Group, 2016). Storylining is not meant to be a way to adjust previously taught material, but instead, it is a full curriculum replacement that builds upon itself throughout the entire academic year. Storylines are driven by the NGSS performance expectations and must be carefully laid out and planned to anticipate and prompt student questioning about phenomena (Next Generation Science Storylines, 2023).

Storylines are generally introduced with a relevant anchoring phenomenon. Students attempt to make sense of what they see both individually and within groups and then ask questions which they want to pursue. These questions get ranked and become part of a Driving Question Board that is used throughout the storyline (Penuel et al., 2022). As the storyline unfolds, students continue to investigate related phenomena and do activities to develop comprehension in order to ask more questions to further propel the storyline forward. All the while, students are engaged in learning the NGSS Disciplinary Core Ideas and Crosscutting Concepts while using Science and Engineering Practices (Figure 3).

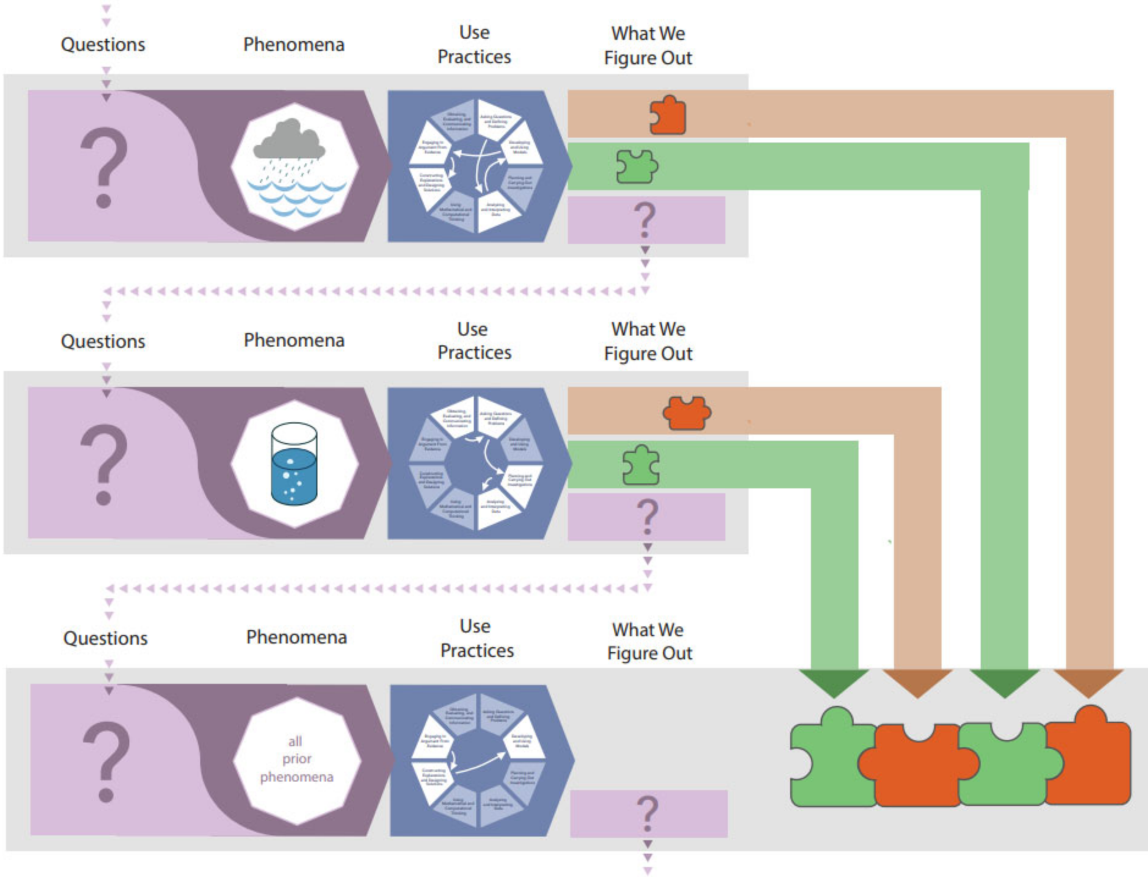

Figure 3. A schematic of the flow of a storyline showing the driving question, the integration of supporting phenomenon, and the use of the Science and Engineering Practices (shown in blue) with the Disciplinary Core Ideas (shown in orange) and the Crosscutting Concepts (shown in green) and how they fit together into a cohesive storyline (Next Generation Science Storylines, 2023).

Storylines strive to predict the questions that students may have regarding phenomena. Consequently, each subsequent activity is designed to address these questions, enabling students to construct their own framework of understanding. The content that students learn is seen by students as a tool to help them answer these questions, rather than a prescribed sequence of units set forth by a teacher or textbook (Penuel et al., 2022). The ultimate goal of storylines is to support the three dimensions of the NGSS by helping students grow in their inquiry skills, fostering critical thinking abilities, enabling the application of knowledge to real-world situations, and cultivating a sense of coherence (Illinois Science Teaching Association - Storylining Working Group, 2016).

CHAPTER THREE

METHODOLOGY

Demographics

This study was conducted over two school years from 2021-2022 and 2022-2023. The first year served as a nontreatment baseline and was used for comparison and followed a traditional linear-unit biology curriculum. A storyline curriculum was implemented in the second year and served as the treatment. The goal was to compare the two years to see if content comprehension and engagement in the Next Generation Science Standards (NGSS) practices would increase with the use of storylines.

Out of 88 students in the first year, 59% (*n*=52) were female and 41% (*n*=36) were male. During the year when storylines were implemented, I taught 66 students with 48% female (*n*=32) and 52% male (*n*=34). I gained a second upper-division anatomy course between school years, and to accommodate my new schedule, I had to drop one section of biology between the nontreatment and treatment years. This means that I lost 18 students between the two years (Figure 4).

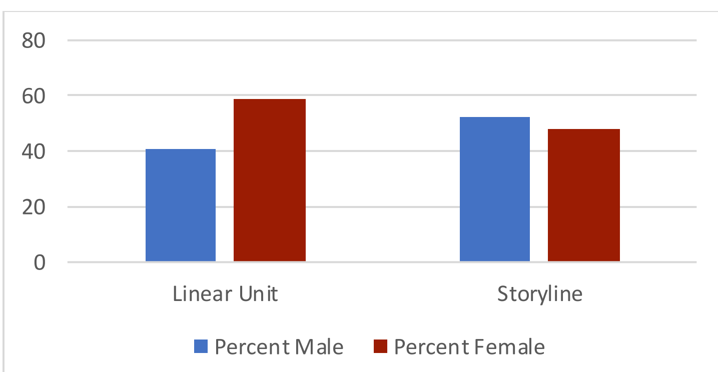

Figure 4. Gender comparison between a year teaching a linear unit curriculum and a year teaching a storyline curriculum, (*N*=154).

I had a mix of honors and general biology students in both years of this study. During the year teaching linear units, I had 39% (*n*=34) in general biology and 61% (*n*=54) in honors biology (*N*=88). During the year teaching storylines, there were 26% (*n*=17) in general biology and 74% (*n*=49) in honors biology (*N*=66). There was a difference of 13% in student class placement between the two years (Figure 5).

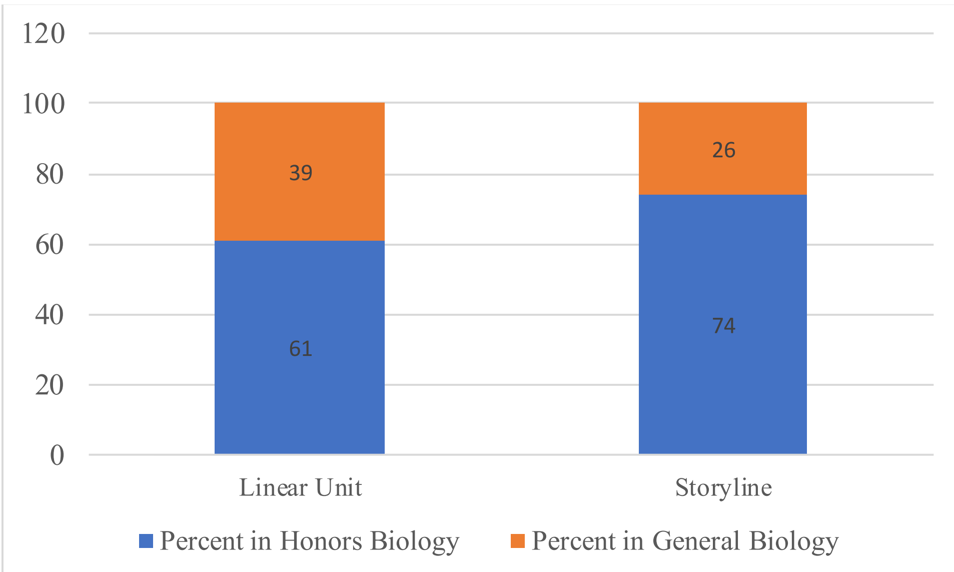

Figure 5. Comparison of the percent of students in general and honors biology between a year teaching a linear unit curriculum and a year teaching a storyline curriculum, (*N*=154).

Treatment

The specific storylines used as the treatment were developed by the Illinois Science Teacher Association under the direction of Dr. Jason Crean (Phenomenon-Driven Storylines, 2015). Each of the storylines used an anchoring phenomenon, and each lesson in the storyline drove the next question. This progression is mapped out in the course outline and it spells out the driving questions, the specific Next Generation Science Standard (NGSS) performance expectations, and the associated activities (Appendix A).

Students opened each storyline by watching an anchoring phenomenon video and then asked questions about what they saw. Questions were compiled collaboratively by teams and then ranked. Students then assembled these onto a driving question board and grouped them according to the NGSS Crosscutting Concepts. This helped students become familiar with the Crosscutting Concepts and create a framework for some of the major driving questions that the storyline might answer (Figure 6).

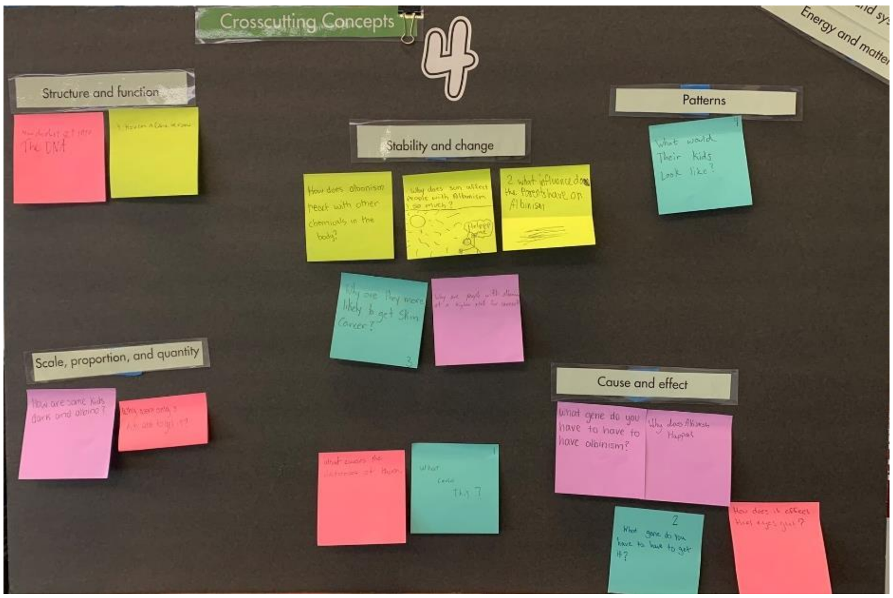

Figure 6. Student-generated driving question board after watching the anchoring phenomena.

As the storyline unfolded, concepts connected from one lesson to the next as well as spiraled between each storyline. The NGSS storyline alignment document lays out the specific storylines that address each performance expectation. The performance expectations that are touched upon in the first storylines are revisited in subsequent storylines and concepts continue to build. No concept is taught in isolation. For example, students learned early in the Africa storyline about DNA, chromosomes, and karyotypes while learning about lion pride relatedness. That idea led to lessons about the different ways animals obtain energy and students compared the macromolecules ingested by carnivorous lions and herbivorous elephants. This then played into the elephant tuskless phenomenon seen after the civil wars in Africa in the 1970s to 1990s due to heavy poaching. From this, students learned about natural selection and selective pressures. Students spiraled back to DNA by doing an interactive to trace poaching hot spots in Africa by running simulated gel electrophoresis to create a DNA fingerprint of ivory and elephants to determine where poaching syndicates are operating. The data used and the poaching areas that students discovered were from real-world sources (Appendix B).

There was particular emphasis on using a claim, evidence, and reasoning approach to communicating information, and multiple lessons within each storyline finished with some variation on this method of sense-making. There was also a heavy emphasis on having students reflect upon each component of the storyline to see where the use of the NGSS Crosscutting Concepts and Science and Engineering Practices were used. Each storyline used a storyline progress tracker to help students see coherence. These had students formulate the next driving question and then at the end of the concept, students would revisit the document to fill in any activities that were done to help answer the question, which the NGSS Crosscutting Concepts and Science and Engineering Practices were used, and then list vocabulary and other terms connected to the concept. Students then answered the driving question before generating the next question (Figure 7).

Storyline: Melanin

Question	Activities to help answer	NGSS Cross-cutting concepts (CCCs) and Science and Engineering Practices (SEPs) that were emphasized	What we figured out (vocab, diagrams, concepts) DNA Chromosomes
What causes albanism? It's Genetic	- Intro Video - Genetics Notes - Amoeba Sisters - Alleles + Genes - Bikini Bottom ws - Monohybrid Crosses - Pipe Cleaner Babies	Cause + effect Patterns develop & use models Analyze data using math	Punnett Square Dominant (D) Recessive (d) Homozygous (DD) Heterozygous (Dd) Gregor Mendel Homologous Chromosomes Karyotype Allele Gene Genotype (Bb) Phenotype (Brown)
What type of inheritance pattern causes albinism? autosomal recessive	-Amoeba Sisters "pedigrees" -Pedigree ws -Albinism pedigree - Helena's Story	Patterns develop + use models constructing explanations	Incomplete dominance Codominance Sex-linked traits Polygenic traits Pedigrees Carriers autosomal and sex-linked
What determines traits? DNA → Protein	- Protein Synthesis Foldable - " " Model - AS "DNA/RNA + PS" ws - Codon Practice - Alien Arthropods	System models Structure + function developing + using models	DNA RNA Uracil RNA Polymerase Transcription Translation Ribosome tRNA & mRNA amino acids codon anti-codon

Figure 7. An example of a portion of a Storyline Progress Tracker.

Assessments were provided by request from the Illinois Storylining website (Phenomenon-Driven Storylines, 2015). These were mostly summative, but a few mid-storyline formative assessments were suggested. Assessments were less focused on detailed memorization and more emphasis was put on the application of the concepts. Most assessments utilized the upcoming storyline's phenomenon as the subject for students to apply their knowledge. For example, the first storyline dealt with genetic similarities to establish relationships among lion prides in Africa. The assessment for this storyline used the same concept but used sea otters in the questions instead of lions. The second storyline opened with an anchoring phenomenon about sea otters. This created a fun segue and showed that the knowledge was transferable to different situations. The research methodology used for this project received an exemption from Montana

State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix C).

Data Collection and Analysis Strategies

The Northwest Evaluation Association Measures of Academic Progress (NWEA MAP) 9-12th Grade Next Generation Science Standards (NGSS) Life Science computerized test was given to biology students at the end of both a full year of a traditional linear-unit curriculum as well as at the end of a full year implementing a storyline curriculum to look at statistical data for comprehension of the NGSS performance expectations. The NWEA MAP 9-12th Grade NGSS Life Science Test is a subject-specific test that is adaptive and looks at proficiency across all three dimensions of the NGSS, including Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices (Appendix D).

This test was analyzed using an independent samples (also called a two-sample) t-test that compared means in both groups to look for a statistically significant difference. Like all standardized tests at my school, this test required special permission from my district's administration. While this test could have been given at both the beginning and end of the school year to look for growth, permission was only obtained to administer it once each school year. The data obtained is still reasonably reliable because the majority of students have very similar baseline knowledge. The Billings Catholic Schools District is made up of one K-8 school and one high school. Most students have the same middle school experience with the same middle school science teacher.

In addition to looking at student comprehension of concepts, I was also interested to see if storylines can increase student engagement as compared to a traditional linear-unit curriculum.

A Likert rating scale was used in a Biology End of Course Student Survey using Google Forms. This was given at the end of each year to look for trends in student engagement with both the NGSS Science and Engineering Practices as well as student thoughts on their level of engagement in the course. The first question asks students for feedback on important ideas that they took away from biology. This question was intentionally phrased to be vague and open-ended to allow students to respond with either specific biology concepts or with larger holistic scientific ways of thinking, such as being open-minded, making detailed observations, asking questions, or the importance of being curious. Other questions ask students to rate their perception of their ability to do each of the NGSS Science and Engineering Practices as well as questions pertaining to curriculum engagement, which included working in a team, the relevance of information learned, and retention of material (Appendix E).

Students in the storyline group were also asked questions through an End of Course Verbal Student Interview. Students were chosen on a volunteer basis from all classes and asked the same set of questions. Students could either answer alone or in small groups. Not every student answered every question, especially if any answers were redundant. I wanted to allow students to share anything relevant to the course and any final impressions that they may have had regarding the curriculum. Because the questions focused on comparing a storyline curriculum to a more traditional curriculum, only students in the treatment group were asked the verbal interview questions (Appendix F). These data were analyzed for themes and used as evidence to support other findings (Table 1).

Table 1. Data Triangulation Matrix.

Question	Does a biology storyline curriculum increase student engagement and comprehension of NGSS concepts when compared to a traditional linear-unit curriculum?
Data Source	1. Northwest Evaluation Association Measures of Academic Progress (NWEA MAP) 9-12th Next Generation Science Standards (NGSS) Life Science Test
	2. Biology End of Course Student Survey
	3. End of Course Verbal Student Interview

CHAPTER FOUR

DATA ANALYSIS

Results

The results of the Northwest Evaluation Association Measures of Academic Progress (NWEA MAP) 9-12th Next Generation Science Standards (NGSS) Life Science Test show that students in the treatment group experiencing storylines scored an average of 7.57 points higher than the students in the nontreatment group experiencing traditional linear curriculum (N=154). An independent samples t-test was used to look for statistical significance in the NWEA MAP 9-12th NGSS Life Science data. An independent samples t-test, also known as a two-sample t-test, is a statistical test used to determine if there is a significant difference between the means of two independent groups. The observations of one group should not be related to or be influenced by the observations of the other group. In the case of this project, there were two different groups of students, each from a different school year, which makes the independent samples t-test the most relevant statistical tool to use.

There is evidence that there is a difference in the test scores between students in the nontreatment group who learned with the traditional linear curriculum (n=88) and those in the treatment group who learned with the storyline curriculum (n=66). In this dataset, students in the nontreatment group had a mean score of 225.34 points while those in the treatment group scored 232.91. Students who used storylines scored 7.57 points higher than those using the linear curriculum on average. With a two-tailed p-value of 0.0001, which is significantly smaller than the standard threshold of 0.01, we can confidently reject the null hypothesis that there is no significant difference between the means of the two groups. Instead, we can assert with 99%

confidence that the data supports the alternative hypothesis, indicating a significant statistical difference between the two groups (Figure 8).

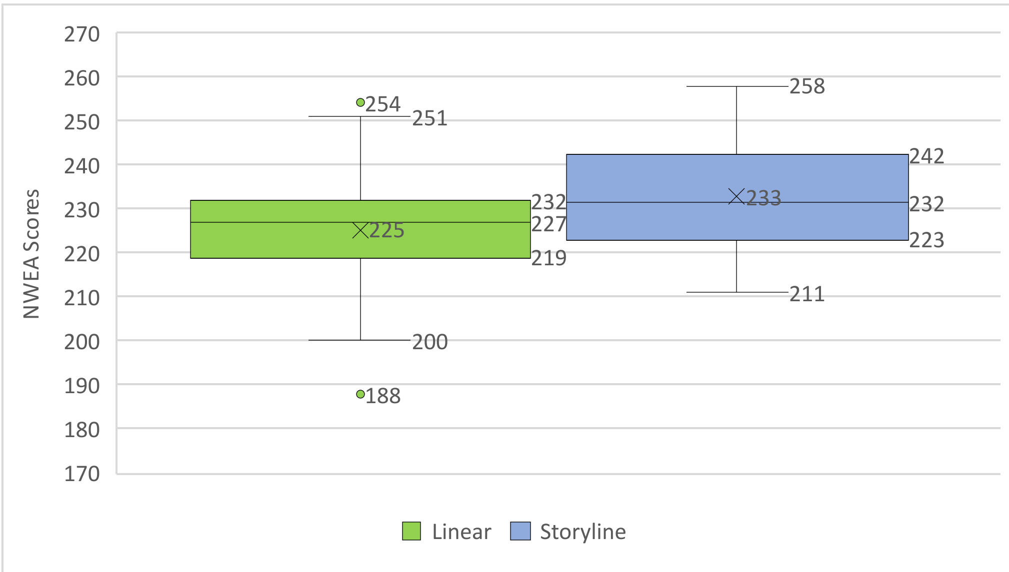

Figure 8. Student NWEA MAP 9-12th Grade NGSS Life Science test scores, (*N*=154).

Honors and non-honors or general students can be separated and compared using the same statistical test to see if there is a difference in the means between these subgroups. Honors students in the treatment group using the storyline curriculum (*n*=49) averaged 235.9 points while honors students in the nontreatment linear-unit curriculum (*n*=54) scored an average of 229.7 points. In comparison, general students in the storyline treatment group (*n*=17) averaged a score of 224.2 points, while general students in the nontreatment linear-unit group (*n*=34) scored an average of 218.4 points. Overall, general students in the treatment storyline group averaged 5.8 points above the general nontreatment linear-unit students, and honors students in the treatment storyline group averaged 6.2 points above the honors nontreatment linear-unit students (Figure 9).

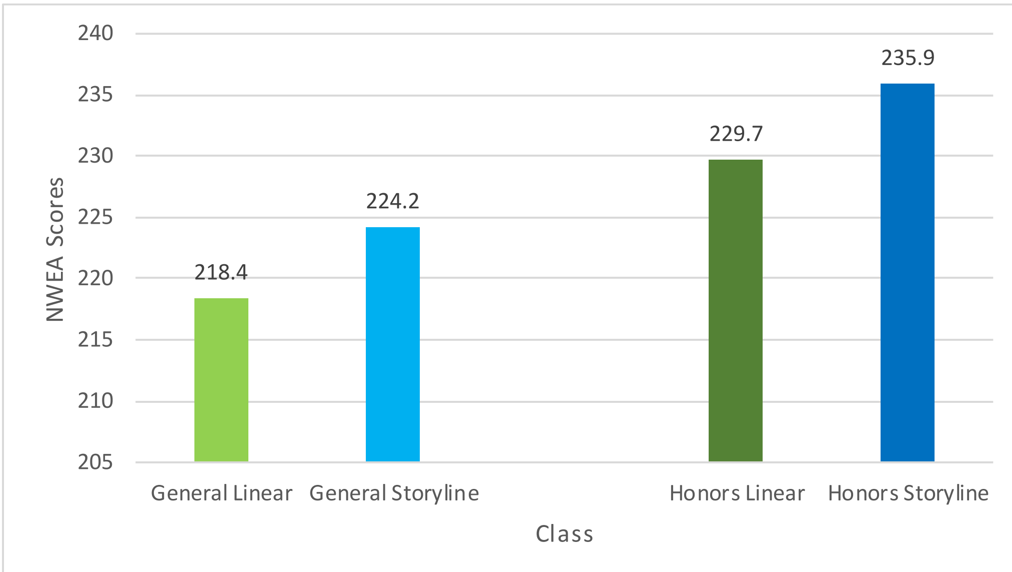

Figure 9. A comparison of honors and general student averages for both a nontreatment linear-unit curriculum and a treatment storyline curriculum, (*N*=154).

After evaluating the Biology End of Course Student Survey for student perceptions of the most important ideas that they took away from biology, a very dramatic trend appeared. In the nontreatment traditional linear-unit curriculum group, every student listed specific topics and there were no comments related to larger ways of thinking. Students simply wrote things like "I learned a lot about plants" or "the characteristics of life and macromolecules." In the treatment storyline group, multiple students showed an understanding of the importance of science and engineering practices and a greater comprehension of critical thinking skills. Students wrote about learning to analyze data, how to research ideas, how to remember concepts and apply them to life, the importance of revising work, how to ask questions, how to work in a team, and how to use lab equipment. One student wrote, "The most important thing I'll take away from biology this year is to take what I've learned and apply it to my everyday life." In response to the same question, another wrote, "I learned more about problem-solving and thinking stuff through."

The discrepancy in higher-order scientific thinking skills between the two groups can also be seen in the results from the NGSS Science and Engineering Practices survey question. Students were asked to rank their ability in each of the eight practices on a scale from one to ten. Adding together the percentage of students who ranked each as a nine or higher, every single practice saw a higher score in the treatment group as compared to the nontreatment group. The largest difference was seen in the ability to analyze and interpret data. Students in the treatment storyline group reported a 14.2% higher score than their peers in the nontreatment linear-unit group. The second largest score difference, at 13.1%, was in students' ability to develop and use models. There was only a 1.1% difference in student perception of their ability to use mathematics and computational thinking (Figure 10).

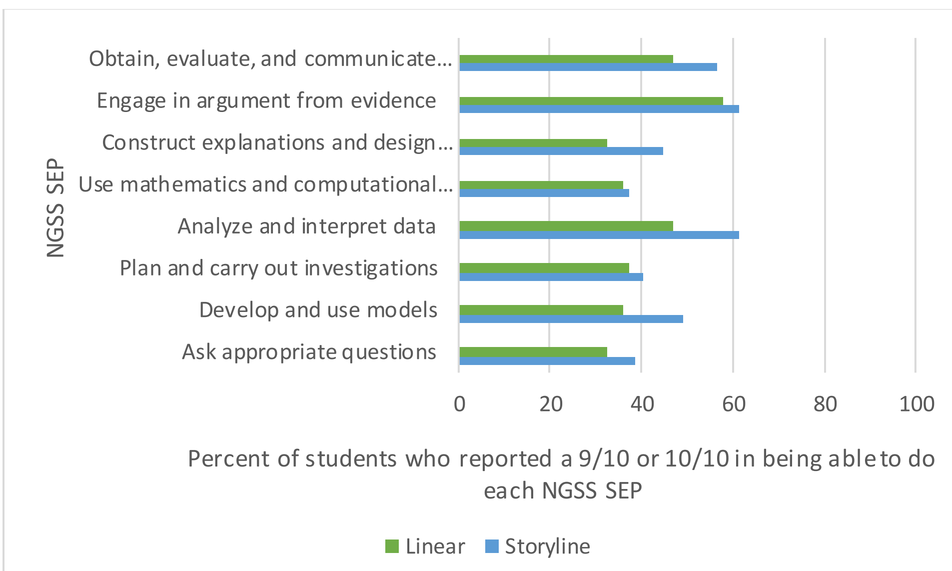

Figure 10. Results from the Biology End of Course Student Survey question regarding student ability in each of the NGSS Science and Engineering Practices, (*N*=154).

When students were asked general engagement questions, three out of four areas showed a higher score in the treatment storyline curriculum as compared to the nontreatment linear-unit curriculum. When asked about the relevance of what was learned to the real world, 64% of students in the storyline group reported a nine or ten on a ten-point scale. Only 59% of students reported the same in the linear-unit curriculum group. The storyline group reported a higher percentage than the treatment group for both retention (5.7% higher) and overall engagement (9.7% higher). When asked if skills to work effectively in a team were gained, both groups reported a high percentage with 98.8% in the linear unit and 95.5% in the storyline group replying positively (Figure 11).

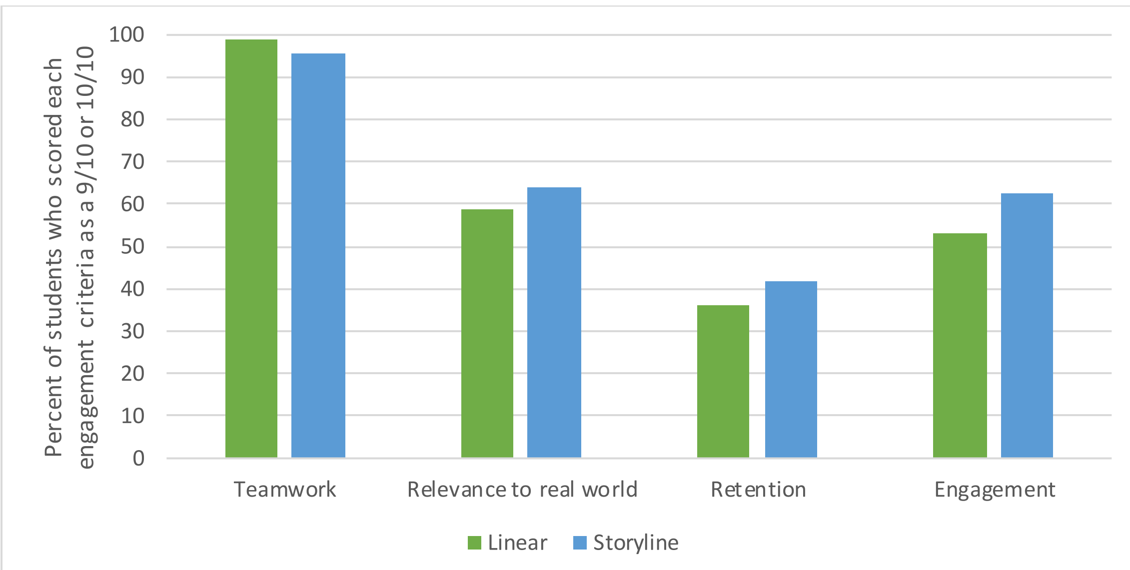

Figure 11. Results from the Biology End of Course Student Survey question regarding student engagement, (*N*=154).

Some of the most persuasive data came directly from student answers to the End of Course Verbal Student Interview. When asked if using storylines was an effective way to learn biology, students overwhelmingly had positive comments. Students talked a lot about coherence. One student said that it was easier to see connections, while another said that it was not random and that it brought up subjects that we learned all year. Another student mentioned that they learned in a way that felt more connected. Multiple comments were made about how the concepts connected and intertwined. When asked if storylines were an effective way to learn biology, one student said, “It was more intriguing, and you could see the connections easier.”

An additional theme that became apparent was that of authenticity and real-world application. One student commented that storylines were more relatable to actual biology. Another said that they got a sense of what real-world science entailed rather than just learning from a textbook and forgetting about it later. One student said, “Storylines used things that we could see in the world right now.” Two students who were interviewed discussed science careers and how using storylines helped them to see actual jobs that they could do in the future with what they learned.

Students also talked a lot about engagement. When asked if they thought storylines could help with remembering concepts, one student said that even months later, if an activity was mentioned, she could still recall details about it. Another student said, “I liked being able to argue different points while working in groups and that by looking at evidence and discussing it in teams, I was better able to understand and remember the information.” One student said, “Science has never been more engaging and everything we learned had meaning.”

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims from the Study

The goal of this capstone project was to see if storylines could increase both content comprehension and engagement in Next Generation Science Standards (NGSS) practices when compared to a traditional linear-unit curriculum. After analyzing the data, it can be claimed that there is a strong relationship between the use of storylines and increased student comprehension and engagement in biology for my students. Not only were test scores higher for the storyline treatment group, but students also reported higher scores in engagement, especially with the NGSS Science and Engineering Practices. It can also be claimed that student coherence improved with the use of storylines.

The quantitative Northwest Evaluation Association Measures of Academic Progress (NWEA MAP) 9-12th NGSS Life Science Test data collected provides evidence that students' comprehension of concepts was higher with storylines. The qualitative data from the End of Course Student Survey and End of Course Verbal Student Interview suggest that engagement was higher with storylines. These two ideas are strongly connected. Engaged students are more likely to be actively involved in classroom activities, show enthusiasm towards the subject matter, and demonstrate a deeper level of interest. When students are engaged with the material, they are more likely to grasp and retain key concepts effectively. Higher engagement leads to better comprehension, which in turn translates into higher test scores. The use of storylines not only enhanced engagement but also contributed to an improved understanding of content, resulting in higher test performance.

Using storylines, students were also able to connect the dots, as one student said, between concepts. One of the long-term struggles with science curriculum is establishing student sense-making and coherence (Sikorski, 2017). Storylines helped students with this challenge. Students could see how each phenomenon was related to other concepts in biology and then apply that to future scenarios. Each storyline hooked students with a relevant phenomenon, clearly connected previously learned concepts to new material, and unfolded in a way that allowed students to create coherence in their mental framework. The spiraling nature of storylines helped students see connections both within the storyline and between the storylines. Students continually built upon former knowledge, which forced them to recall and then apply that knowledge. This method helped to build the mental scaffolding to recall information later.

Reform in science education stresses that learning experiences should engage student interest in science, provide opportunities for data collection, require students to use critical thinking to solve problems, allow students to elaborate on what they have discovered, and stress communication of evidence (Abdi, 2014). Storylines provide a route to achieve all of these effectively. Storylines incorporate the use of the NGSS science and engineering practices in a way that encourages students to work with real-world data and protocols. Punuel et al. (2002) shared that isolated facts are useless without the ability to apply that knowledge to the real world. The intentional design of storylines engages students in real-world data so that science is meaningful, and thus, more memorable.

There is discussion about the effectiveness of storylines for honors students versus general, or non-honors, students. Storylines require a higher level of critical thinking and application than a more traditional linear curriculum. While some argue that storylines are a better fit for honors students than general students, I found that by engaging students with a phenomenon and then using activities that are relevant and build coherence, even students who struggle can rise to the challenge and find success with storylines. After analyzing the NWEA MAPS test scores of both my honors and general students separately, both groups achieved higher scores when utilizing storylines. This highlights the effectiveness of storylines for all students, regardless of their academic track, suggesting their potential to improve learning outcomes across diverse student populations.

While my general linear students and general storyline students did show equal variance, the number of students was not equal. I had 34 students in my general linear classes, but only 17 students in my general storyline class. I had twice as many students in the linear group. This may have affected the data. Having larger and more balanced sample sizes would help increase the strength and reliability of the results.

Value of the Study and Consideration for Future Research

The use of storylines increased student comprehension, engagement, sense of coherence, and provided authentic learning experiences. Transitioning to storylines was a major pedagogical switch for my classroom, but the data gained from this capstone project clearly shows the positive impact that storylines have on student learning, for both my honors and general students. As with any new curriculum, there is a learning curve for the instructor as much as there is for the students. Even after only implementing storylines for one year, I already felt like a better teacher. I found that my role shifted to guiding from the rear instead of leading from the front. There were definite times that I needed to give direct instruction for students to fully understand a concept, but as a whole, there was much more student-led problem-solving and sense-making with storylines. I plan to continue collecting data over the next few years to see if, as I grow in competence in implementing storylines, the data continues to support storylines as an effective curriculum choice for me and my students.

I was only able to get through four of the six storylines during this study. I hope to become more efficient in lesson delivery so that more storylines can be covered in a school year. Covering more storylines may influence the data. I also hope to look into other storyline models in the future. Illinois was one of the first states to develop storylines, but since its inception, more groups have emerged, most notably OpenSciEd (NextGen Science Storylines, 2023) and InquiryHub Biology (InquiryHub Biology, 2019). Different storylines might have different phenomena that could be more effective.

Impact of the Capstone Project on the Author

Classroom research based on an action research model is something that I have done intuitively as a teacher, but never to this magnitude, nor have I ever collected evidence to support a curriculum decision. I first heard about storylines around the same time that I learned about collecting data based on an action research model. When I could not find any actual evidence or data to drive the decision to switch to storylines, it seemed like a natural fit to create my own data.

It was genuinely fun to implement storylines for the first time. I was watching the storylines unfold right along with my students. While it was a bit daunting to do something completely new, it was also refreshing to take a new approach. Storylines pushed me to step out of my comfort zone and allow students more room to engage with phenomena. They seemed to take much more ownership of their learning when it was less teacher-driven and more inquiry-based.

Storylines are intentionally aligned to the Next Generation Science Standards (NGSS), which not only focus on the traditionally taught disciplinary core idea, but also weave in the skills, practices, and mindsets of scientists. In the past, I felt like I had to modify my existing lessons to be more aligned with NGSS, which was not always a natural fit. Using storylines, the three dimensions of NGSS are seamlessly integrated and applied. The curriculum was designed around the practices of asking questions, using models, interpreting data, and carrying out investigations. Often, these were within the context of real-world situations. Instead of attempting to adapt past lessons to align with NGSS, storylines enabled me to teach from a fresh perspective, integrating NGSS's best practices.

As an educator, there is no greater satisfaction than witnessing the precise moment when students grasp a concept. Their eyes brighten, enthusiasm bubbles up, and occasionally, they exclaim, "Ah, I get it!" This happened more with using storylines than in my past 20 years of teaching. As the year went on, students started seeing all of the connections and these moments happened more frequently. Of all the reasons to embrace storylines, those intangible moments of student understanding serve as the true motivation for my permanent switch to this teaching method, confident that it is in the best interest of my students for both comprehension and engagement.

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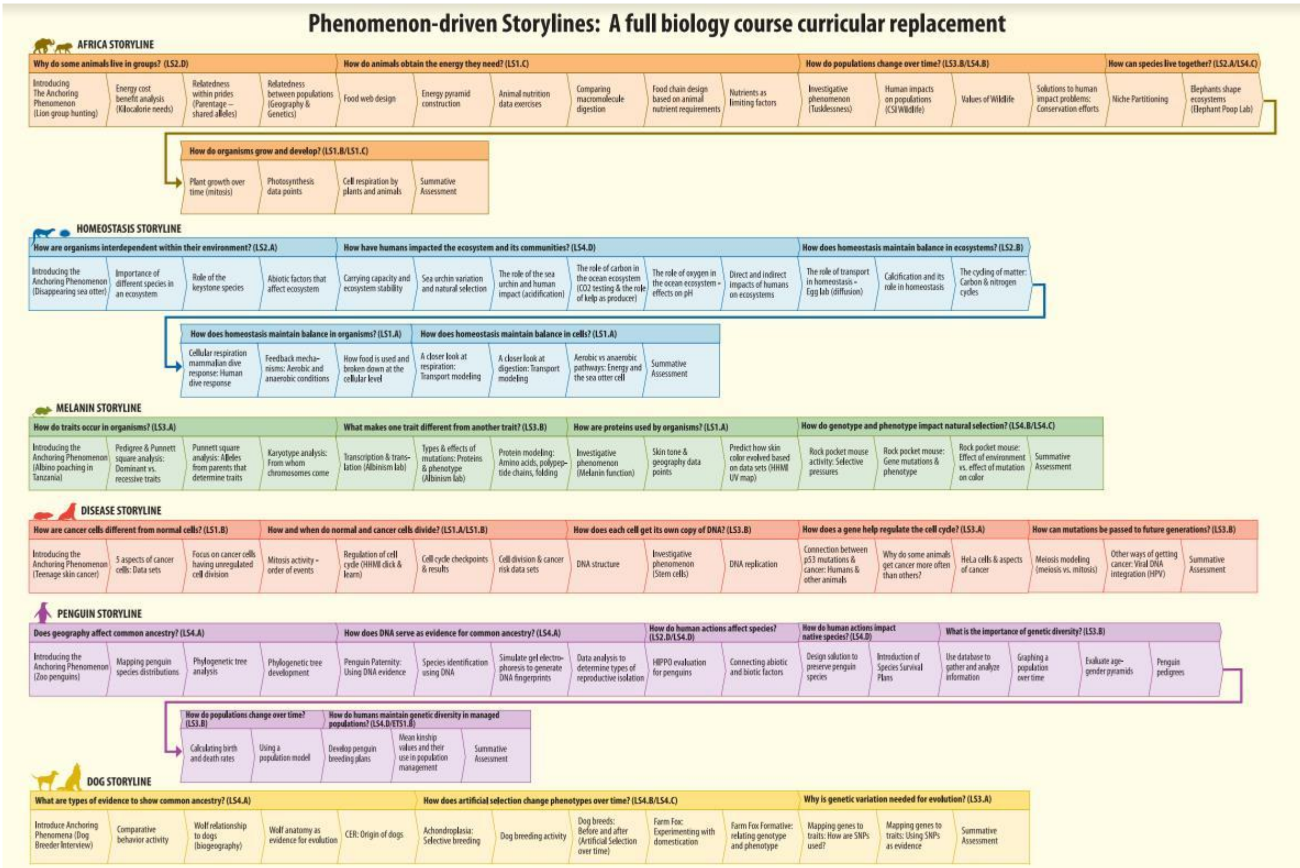
APPENDICES

APPENDIX A

STORYLINE COURSE OUTLINE



(Phenomenon-Driven Storylines, 2015)

APPENDIX B

NEXT GENERATION SCIENCE STANDARDS PERFORMANCE EXPECTATION

ALIGNMENT WITH STORYLINES

NGSS Biology Storylining Working Group Storyline Alignment

IMPORTANT NOTE: The table below provides information regarding which storylines include concepts from the Life Science NGSS Performance Expectations. In some storylines, these are addressed in part to maintain coherence around the selected phenomena. Remember that, regardless as to how these PEs are used, satisfying them all fully within a single course is not recommended. Bundling these PEs around phenomena to allow students to make connections between them is a highly effective and timely way to provide students with a meaningful, rich and rigorous learning experience in your classroom. Also remember that these PEs are suggestions for assessment scaffolds, not a checklist of standards. In some cases, the science practice (beginning of each PE) is changed out for another to reflect what students are actively doing in the storyline. It is also critical that these are revisited throughout the curriculum, not just once in a single storyline. This is why most are revisited in some way to scaffold learning across the storylines, even if not explicitly assessed.

A - Africa H - Homeostasis M - Melanin D - Disease P - Penguin C – Canine		
PE	**Storyline Performance Expectations**	**Units**
LS1-1	**Construct an explanation based on evidence** for how the structure of **DNA determines the structure of proteins** which carry out the essential functions of life through systems of specialized cells.	M, D
LS1-2	**Develop and use a model** to illustrate the hierarchical organization of **interacting systems** that provide specific functions within multicellular organisms.	A, H
LS1-3	**Plan and conduct an investigation** to **provide evidence that feedback mechanisms maintain homeostasis**.	H, M, D
LS1-4	**Use a model** to illustrate the role of **cellular division (mitosis) and differentiation** in producing and maintaining complex organisms.	D
LS1-5	**Use a model** to illustrate how **photosynthesis transforms light energy into stored chemical energy.**	A, H
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.	A, H
LS1-7	**Use a model** to illustrate that **cellular respiration is a chemical process** whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a **net transfer of energy**.	A, H
LS2-1	**Use mathematical and/or computational representations to support explanations** of factors that affect **carrying capacity of ecosystems** at different scales.	H, M
LS2-2	**Use mathematical representations to support and revise explanations** based on evidence about factors **affecting biodiversity and populations** in ecosystems of different scales.	A, H, M
LS2-3	**Construct and revise an explanation based on evidence** for the cycling of matter and flow of energy **in aerobic and anaerobic conditions.**	A, H

LS2-4	**Use mathematical representations to support claims** for the **cycling of matter and flow of energy** among organisms in an ecosystem.	A, H
LS2-5	**Develop a model** to illustrate the **role of photosynthesis and cellular respiration** in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.	A, H
LS2-6	**Evaluate the claims, evidence, and reasoning** that the complex interactions in ecosystems **maintain relatively consistent numbers** and types of organisms in stable conditions, but **changing conditions may result in a new ecosystem**.	H
LS2-7	**Design, evaluate, and refine a solution** for **reducing the impacts of human activities** on the environment and biodiversity.	H, P
LS2-8	**Evaluate the evidence** for the **role of group behavior** on individual and species' chances to survive and reproduce.	A
LS3-1	**Ask questions to clarify relationships** about the **role of DNA and chromosomes** in coding the instructions for characteristic traits passed from parents to offspring.	M, D
LS3-2	**Make and defend a claim based on evidence** that inheritable **genetic variations** may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	M, D, C
LS3-3	**Apply concepts of statistics and probability** to **explain the variation and distribution of expressed traits** in a population.	A, M, C
LS4-1	**Communicate scientific information** that **common ancestry and biological evolution** are supported by **multiple lines of empirical evidence.**	P, C
LS4-2	**Construct an explanation based on evidence** that the **process of evolution** primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.	A, M
LS4-3	**Apply concepts of statistics and probability** to support explanations that organisms with **an advantageous heritable trait tend to increase in proportion** to organisms lacking this trait.	A, H, M
LS4-4	**Construct an explanation based on evidence** for how **natural selection** leads to adaptation of populations.	A, H, M
LS4-5	**Evaluate the evidence** supporting claims that **changes in the environmental conditions may result** in (1) increases in the numbers of individuals in some species, (2) the emergence of new species over time, and (3) the extinction of other species.	H, P
LS4-6	**Create or revise a simulation to test a solution** to mitigate adverse impacts of **human activity on biodiversity**.	H, P

(Phenomenon-Driven Storylines, 2015)

APPENDIX C

MONTANA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD EXEMPTION

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

****
****
THIS AREA IS FOR INSTITUTIONAL REVIEW BOARD USE ONLY. DO NOT WRITE IN THIS AREA.
Confirmation Date: **4/18/22** Mark T. Quinn
Application Number:
****
****

DATE of SUBMISSION: 4/7/2022

-Okay as exempt
-MSSE classroom assessment
-Little/no risk
-Principal approved
-No concerns
MQ 4/18/22

I. INVESTIGATOR:

Name: **Krista Cunningham**
Home or School Mailing Address: **4357 Stout Creek Trail, Billings, MT 59106**
Telephone Number: **406-696-9929**
E-Mail Address: **seth_krista@yahoo.com**
DATE TRAINING COMPLETED: **4/3/2022** *[Required training: CITI training; see website for link]*

Investigator Signature: **Krista J. Cunningham**

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

II. TITLE OF RESEARCH PROJECT:
The effectiveness of a high school biology storyline curriculum for both understanding of concepts and overall student engagement as opposed to a traditional unit curriculum

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

A. **NWEA MAPS testing for science – this digital standardized test is already given by the school district for teacher use to help drive curriculum instruction. The science portion of the test is not currently being used for freshman biology, but this 60-minute test will be administered at the end of the year for data purposes only. It is aligned to Next Generation Science Standards (NGSS). The data will be used to measure overall average student growth in NGSS life science comprehension from middle school through the end of 9th grade biology.**

B. **End of course student survey – this anonymous survey will be used to gain a more qualitative measurement of student engagement. Questions will focus on**

skills and competencies that are not as easily measurable, such as science and engineering practices, retention of information, ability to work in a team, and overall enthusiasm and motivation in the course.

IV. RISKS AND INCONVENIENCES TO SUBJECTS: **The nature of this research will be conducted at a high school level in established or commonly accepted educational settings, involving normal educational practices. Research will only involve educational tests and survey procedures. The research poses no more than minimal risk.**

V. SUBJECTS:

A. Expected numbers of subjects: **100**

B. Will research involve minors (age <18 years)? **Yes** No
(If 'Yes', please specify and justify.)
Subjects will be freshman biology students (age 14-15) at Billings Central Catholic High School. This study is designed to determine the most effective biology curriculum for this demographic of students at this specific school.

C. Will research involve prisoners? Yes **No**

D. Will research involve any specific ethnic, racial, religious, etc. groups of people?
(If 'Yes', please specify and justify.) Yes **No**

VI. FOR RESEARCH INVOLVING SURVEYS OR QUESTIONNAIRES:
(Be sure to indicate on each instrument, survey or questionnaire that participation is voluntary.)

A. Is information being collected about:

Sexual behavior?	Yes	**No**
Criminal behavior?	Yes	**No**
Alcohol or substance abuse?	Yes	**No**
Matters affecting employment?	Yes	**No**
Matters relating to civil litigation?	Yes	**No**

B. Will the information obtained be completely anonymous, with no identifying information linked to the responding subjects? **Yes** No

C. If identifying information will be linked to the responding subjects, how will the subjects be identified? (Please circle or bold your answers)

By name	Yes	No
By code	Yes	No
By other identifying information	Yes	No

D. Does this survey utilize a standardized and/or validated survey tool/questionnaire?
(If yes, see IRB website for <u>required wording</u> on surveys and questionnaires.)
Yes **No**

Administrator Approval

I, Shel Hauser, Principal of Billings Central Catholic High School, verify that I approve of the classroom research conducted by Krista Cunningham.

[signature] Principal
(Signed Name, Title of Position)

Shel Hauser
(Printed Name)

4/7/22
(Date)

Administrator Exemption Regarding Informed Consent

I, Shel Hauser, Principal of Billings Central Catholic High School, verify that the classroom research conducted by Krista Cunningham is in accordance with established or commonly accepted educational settings involving normal educational practices and that I approve the project. To maintain the established culture of our school and not cause disruption to our school climate, I have granted an exemption to Krista Cunningham regarding informed consent.

[signature] Principal
(Signed Name, Title of Position)

Shel Hauser
(Printed Name)

4/7/22
(Date)

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY.

Project Title: The effectiveness of a high school biology storyline curriculum for both understanding of concepts and overall student engagement as opposed to a traditional unit curriculum.

This anonymous 15-minute survey will be used to help shape best practices in high school biology curriculum design. It will be used in a graduate level research project to determine if a traditional unit method of teaching biology or if the use of storylines is more effective for student engagement and content comprehension.

Participation in this research is voluntary. The results of this will remain anonymous and will not be included in your final grade in biology in any way. Proceeding with the survey indicates your consent to participate.

Your constructive criticism and honest answers are appreciated. Thank you for participating in this survey to help create a more effective biology course.

If you have any additional questions, they can be sent to Krista Cunningham at kcunningham@billingscatholicschools.org. You can also address questions about Montana State University graduate research protocols directly to the Institutional Review Board (IRB) at irb@montana.edu.

Krista Cunningham
Biology Teacher
Billings Central Catholic High School

APPROVED MSU 04/19/2022
IRB #KC041922-EX

APPENDIX D

EXAMPLE OF NWEA NGSS 9-12TH GRADE LIFE SCIENCE TEST QUESTION AND

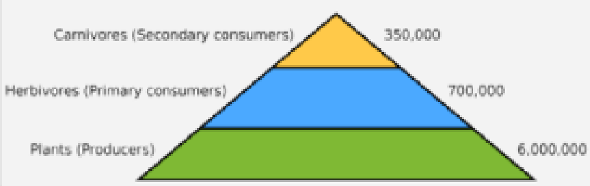
ALIGNMENT TO THE MULTIPLE DIMENSIONS OF NGSS

Instructional area 1: Life Sciences

Sub-area 1b: Ecosystems: Interactions, Energy, and Dynamics

	DCI*	SEP**	CCC**
Aligned PE: HS-LS2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.**	Cycles of Matter and Energy Transfer in Ecosystems	Using Mathematics Computational Thinking	Energy and Matter
NWEA learning statement: Describes available energy at different trophic levels in ecosystems, using models **Item RIT:** 225 **Item DOK:** 2	Cycles of Matter and Energy Transfer in Ecosystems	Developing and Using Models	Systems and System Models

The diagram shows the approximate number of organisms scientists counted in one acre of a grassland ecosystem.



Why are there more producers than consumers in the grassland?

A. Producers have more offspring than consumers.

B. Producer populations stay high because new plants grow when old plants are eaten.

C. Producers have more available energy and use less energy to stay alive than consumers.

D. Producer populations are larger because plants have more sources of food than consumers.

Narrative: This item provides evidence of students' ability to **interpret a food pyramid model to explain the different numbers of producers and consumers in this system**. Though students are demonstrating understanding of a **SEP** and a **CCC** that are different from the PE, the item does provide evidence of growth toward understanding the PE. This item is rated DOK 2 because students are demonstrating their understanding of the **roles of organisms in ecosystems** and how to interpret a **model**.

(MAP Science Sample Items Grades 9-12, 2022)

APPENDIX E

BIOLOGY END OF COURSE STUDENT SURVEY

Biology End of Course Student Survey

Big Ideas

1. What are the most **important ideas** you took away from biology this year?

Science and Engineering Practices

How well do you think you could do each of the following **science and engineering practices**?

Rank your ability from 1 – 10, with 1 being the least able and 10 being the most able:

2. Ask appropriate scientific questions _____________
3. Develop and use models _____________
4. Plan and carry out investigations _____________
5. Analyze and interpret data _____________
6. Use mathematics and computational thinking _____________
7. Construct explanations and design solutions _____________
8. Engage in argument from evidence _____________
9. Obtain, evaluate, and communicate information _____________

Curriculum Engagement

10. Do you feel that you gained skills to help you work effectively in a **team**?

11. How well do you think what you learned in biology this year was **relevant** to the real world? (Rank 1-10. 1 being not relevant or applicable at all, 10 being very relevant and applicable.)

12. How likely are you to **remember** the activities, lessons, and big ideas? (Rank 1-10: 1 being very unlikely and I already forgot everything, 10 being that I will remember these concepts and could talk about them even ten years from now.)

13. How **engaged** did you feel during class this year? (Rank 1-10. 1 being that I was totally checked out and was completely disinterested,10 being that I found the lessons and activities to be engaging and interesting.)

Final Thoughts

Please share any other **constructive feedback** that could help shape the biology curriculum.

APPENDIX F

END OF COURSE VERBAL STUDENT INTERVIEW

1. Did you find storylines to be an effective way to learn biology?

    a. If so, why? If not, why not?

2. Do you feel that storylines helped you stay engaged with the material more than traditional teaching?

3. Do you think using storylines will help you remember the concepts better than traditional linear teaching?

4. Do you think storylines help emphasize NGSS SEPs more than traditional linear teaching?

5. Do you feel that storylines helped you find ways to apply what you learned to the real world?

6. Sometimes students struggle with connecting ideas that they have learned to new ideas to see how they fit together. Do you feel that storylines helped with this issue or not?

7. What was the hardest part about using storylines this year?

8. Is there anything about storylines you think should be done differently in the future?

9. Is there anything else you’d like me to know?