Developing Phenomena-Based Storylines for Middle School Next Generation Science Standard Units

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Developing Phenomena-Based Storylines for
Middle School Next Generation Science Standard Units

by

Kelly Marie Russo

Author Note
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Middle School Next Generation Science Standard Units

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Chapter 1: Overview

Introduction

In 2010, the first public draft of the Framework for the Next Generation Science Standards was released. Designed by the members of the Nation Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve; the framework and standards were designed to be grounded in current research on science learning and science, focusing on identifying the science needed by all K-12 students (NGSS Lead States, 2013).

As the shift towards the next generation of learning begins to take stride in the world of education, newer and more engaging methods to teach science must be developed to achieve the vision set forth by the Next Generation Science Standards (NRC, 2015). As science education shifts from the learning of ideas disconnected from the everyday phenomena we experience, and the rote memorization of facts, learning information as needed while creating explanations using evidence and using modeling as a method to explain phenomena, new curriculum will need to be developed. One of the greatest challenges to this shift is the current lack of curricular materials that reflect these changes. This new three-dimensional learning approach requires the creation of new curriculum materials in order to allow these changes to take effect in the classroom. One such method that has been instituted to meet the demands of these new challenges is the development and use of the Next Generation Storylines (Edwards et al., 2016).

Science education will now focus on learning in three-dimensions. In the case of the Next Generation Science Standards, this is accomplished through the cohesive teaching of the cross-cutting concepts, disciplinary core ideas, and science and engineering practices. Currently a team at Northwestern University has focused science education research on the development of coherent
three-dimensional learning through the use of storylines for elementary, middle and high school classrooms. A storyline is a coherent sequence of lessons where each step of the process is driven by questions posed by students from their interactions with an anchoring-phenomena. However, little has been done with the middle school level storylines (Edwards et al., 2016).

In order to design a three-dimensional lesson, more emphasis is put on asking students what they are trying to figure out and why they are working on a particular topic, within the realm of the scientific practices, disciplinary core ideas, and crosscutting concepts. Storylines lessons are modeled after the 5E learning cycle in which students engage in a phenomena, explore the phenomena and core ideas through various experiences, explain the phenomena using evidence gathered, elaborate on their learning by applying it to a new situation or slightly different phenomena, and then are evaluated based on a variety of assessments, both formative and summative. This method of teaching focuses primarily on building a classroom culture that supports figuring things out—figuring out science idea, next steps, and how to put what is gained together over time.

Storylines are a method by which students are introduced to a phenomenon, something that is authentic and experienced everyday (German, 2018, p.32). One example of such a phenomenon is making ice cream, a process that includes complicated processes such as energy transfer, states of matter, and the kinetic theory of matter (German, 2018, p.32). From the anchoring phenomena, students pose questions for investigation based on observations. Students investigate the phenomena, produce models, and/or use other science and engineering practices outlined by the Next Generation Science Standards to explain the phenomena using evidence. Doing so engages them in a system of routines that are similar to the processes carried out by scientists and deal with more than the previous methods of teaching content to students (Edwards et. al., 2016).
Research has shown that these methods of teaching have shown some promise for student achievement. In particular they allow students to build on prior knowledge and experiences through a flow and sequence of learning activities (Hanuscin et al., 2016, p.395). When students are engaged in the phenomena of storylines, students are engaged with a sensemaking process as they use science practices to make sense of what they are learning. The development of coherence from the perspective of the students rather than from the perspective of the teacher, therefore, allows for students to create thicker, richer, authentic connections with the everyday phenomena around them, teaching them to engage in the science practices on a daily basis rather than within only the classroom environment. This coherence for students, according to the suggestion of the Framework, revolves around a developmental progression in which students build on what they see, focus on limited core ideas, and integrate knowledge and practices. Teachers, therefore, need methods by which students can clearly see progressions among science practices more easily than before.

**Project Design**

This project is designed to be a compilation of no less than 8 storylines aligned with the suggested bundles for the middle school curriculum as per the Next Generation Science Standards. The storylines will be aligned with course 2 and 3, considered the second and third of middle school science (7th and 8th grade) in which the cross cutting concepts, science and engineering practices, and disciplinary core ideas across multiple standards are designed to allow students to see and explore connections between different contents while simultaneously engaging in the language and process of science. Each of the bundle unit for the courses is designed to take place over a time of 6-10 weeks each.
The outline of each storyline is a modification of the templates available from thewonderofscience.com (Andersen, 2017) and the templates available on nextgenstorylines.com (Edwards et al, 2016). The general outline will be as follows:

1. Overarching question / anchoring phenomena to guide the students.
   a. Anchoring phenomena are identified using resources available from thewonderofscience.com (Andersen, 2017).

2. Unpacking of standards that include:
   a. Analysis of statements from the Framework for the Next Generation Standards (National Research Council, 2012) regarding:
      i. Cross Cutting Concepts
      ii. Disciplinary Core Ideas
      iii. Science and Engineering Practices
   b. Suggested Vocabulary

3. Layout of the unit using an anchoring phenomenon / driving question

   a. Teachers and students work together to develop investigations and next steps, constantly looking both at where they came from and where they are going.

5. Development of an investigation routine.
   a. Students use the scientific practices to figure out pieces of science ideas.
   b. Several suggested investigations revolving around phenomena are planned to assist students in determining crosscutting concepts and disciplinary core ideas while engaging in the scientific practices.
   a. Students are pushed to revise and deepen science ideas they have built so far through their investigation.

7. Development of methods by which teachers can help students put together the pieces of the disciplinary core ideas and crosscutting concepts.

8. Development of potential sample short performance assessments for standards not directly tested in labs or other assessments, using evidence statements for each of the disciplinary core ideas (NGSS, MS-LS Evidence Statements, MS-ESS Evidence Statement, MS-PS4 Evidence Statements, 2015).
   a. Short performance assessments are developed using a modified version of those that are found on Stanford University’s website (Stanford University, n.d.).

The intent is for there to be a folder shared with middle school teachers, both within the Cincinnatus Central School District and within the Middle School Listserv (via SUNY Oneonta) in which teachers can access the bundles freely for their use, rather than rely on districts paying for bundled and often costly curriculum. With permission from Paul Andersen, it may also be published on thewonderofscience.com for national teacher use and peer feedback/adaptation from other teachers across the nation.

Significance

Through the exploration of literature and from experiences as a middle school science teacher, finding and creating curriculum that is aligned to the Next Generation Science Standards
is a daunting task for many teachers. The skills and detail needed to create units that encompass the core of three-dimensional learning concept require time that many teachers do not have. My goal was to create these materials, not only for the benefit of my own students but also to the benefit of other teachers who are in middle school but do not have the time nor resources to produce or purchase curriculum within their districts.

The storyline method is one such method for curriculum development that encompasses the wow-factor and curiosity of science, while exposing students and engaging them in three-dimensional learning of science content. My second goal is, therefore, to create materials that are engaging and authentic to students using the routines outlined by Edwards et. al (2016). Furthermore, I intend to complete such a task with the assistance of technology-based research routines. Not only will such methods allow for the development of 21st century skills, but they will also allow for the incorporation of three-dimensional learning with 21st century skills, paving the way for scientifically literate students, as well.

**Definition of Terms**

**Storylines:** “A storyline is a coherent sequence of lessons, in which each step is driven by students' questions that arise from their interactions with phenomena.” (Edwards et. al, 2016).

**Disciplinary Core Ideas:** Ideas that focus K-12 education that contain the most important aspects of science (National Research Council, 2015).

**Cross Cutting Concepts:** An organizational framework that is fundamental to understanding knowledge from different disciplines (National Research Council, 2015).
Science and Engineering Practices: *The practices of science that help students to understand how scientific knowledge is developed* (National Research Council, 2015)

Phenomena: *An observable event used to drive student inquiry* (Andersen, 2017).

MS-LS: *The designation on standards for Middle School Life Science related content* (National Research Council, 2012.)

MS-ESS: *The designation on standards for Middle School Earth and Space Science related content* (National Research Council, 2012.)

MS-PS: *The designation on standards for Middle School Physical Science related content* (National Research Council, 2012.)
Chapter 2: Literature Review

Inquiry – Based Education

Inquiry-based approaches to increasing student achievement in science has become a more preferred approach to science education since the recent adoption of the Next Generation Science Standards. Developing inquiry-based approaches to science means that science education needs to be delicately planned and implemented in order to improve student achievement in science overall. Other factors, however, also affect student learning outcomes. Emotional intelligence is one such factor that, when inquiry-based science instruction is being used, seems to be a factor in student learning (Nasution, 2018). The study conducted in a middle school in Binjai, Indonesia, compared student achievement in 7th grade science using either conventional or inquiry-based teaching approaches, and sought to determine the effect of a student’s emotional intelligence on their science achievement (Nasution, 2018).

The study consisted of 56 students who were divided into two groups. One group was to be taught using a conventional teaching methodology, i.e. lecture, and the other group was to be taught using a six-week inquiry-based approach covering the same material. Students also had their emotional intelligence determined prior to the study in order to compare the effect of teaching approach and emotional intelligence on science achievement. The conventional teaching method and inquiry-based teaching method lasted approximately 6 weeks with 3 times of instruction per week. Researchers proposed four hypotheses. The first was that the two approaches to learning would result in significant differences in science achievement scores when tested at the end of the time frame. The second was that emotional intelligence and the learning approach interacted and influenced the achievement of the students. Third, was that the students who had higher emotional
intelligence and participated in the inquiry-based model would have higher achievement scores. Finally, students who had lower emotional intelligence and participated in the inquiry-based approach would have lower science achievement scores.

All four hypothesis were supported by the evidence collected during the experiment (Nasution, 2018, p.110). Firstly, they found that the difference between the test scores of students who had the conventional teaching method (lecturing) compared to the inquiry-based method was significant. Based on a given assessment worth one hundred points, the conventional teaching method average test scores were found to be 55.86, and the inquiry-based teaching methods were found to be 60.86. This supported a previously cited source from 2016 that noted that inquiry-based learning approaches were more effective in improving student’s science achievement compared to conventional learning approaches. Secondly, they found that emotional intelligence and student learning achievement levels had a significant interaction throughout the study, and students who were exposed to the inquiry-based learning approach and achieved higher student achievement typically had higher emotional intelligence (Nasution, 2018, p.111). Therefore, these were students that were able to recognize and deal with emotions in a healthy way, as well as have qualities of self-motivation (Nasution, 2018, p.107). In fact, those students had a 21.19-point difference between the conventional learning approach the inquiry-based learning approach. They also found that students who had a low emotional intelligence did not have higher science achievement levels using the inquiry-based learning approach, as predicted. Those students had a mean score of 53, while the students with lower emotional intelligence in the conventional teaching model achieved a 62.85 mean score (Nasution, 2018, p. 111).

Based on the study framework, there appear to be three weaknesses: time in science instruction, age of students, and sample size. Students, y received science instruction only three
times a week, rather than a typical five days. Having more time on task and a focus towards science on a daily basis may have improved the achievement of the lower emotional intelligence students using the inquiry-based method. Descriptions given for emotional intelligence within the study itself support this theme. For example, emotional intelligence was noted to include the encouragement and use of emotions for effectively solving problems and producing arguments (Nasution, 2018, p.107). If a number of students will low emotional intelligence perhaps had longer time in science class. It would be feasible to argue that a difference in achievement levels when given more time to process the information and foster the self-motivation? Furthermore, sample size may have been more robust if it had been larger than reported, that is, to have a better understanding a larger sample size from several seventh-grade students in different middle schools would serve the function of this study better. Finally, as noted, in the study, the study was limited to junior-high students (Nasution, 2018, p.112). The overall implications of the study, however, remain important overall despite these possible weaknesses.

Overall, it was recommended to implement inquiry-based teaching methodologies to increase student achievement (Nasution, 2018, p.112). With the shift towards focusing on a cohesive approach to have students participate in scientific practices such as developing methods to solve a problem, the implications behind understanding a student’s emotional intelligence and ability to self-motivate and handle situations with others in a classroom setting are important to be aware of when designing instruction. Teachers and administrators should aim to determine student’s emotional intelligence in order to best approach curriculum instruction that will suit the students’ needs. While conventional approaches to teaching did show a better outcome in student achievement scores for low emotional intelligence students, perhaps time of implementation may increase that achievement for such students overall.
Student attitudes toward STEM and inquiry learning are important factors to consider when designing meaningful instruction. One popular method to involve students in full inquiry-based learning approaches is to have them participate in science fairs. The effect of science fairs on student learning through inquiry has not been studied as in depth as one might have thought. Schmidt and Kelter (2017) conducted a qualitative study on the impact of science fairs on learning through inquiry and student attitudes towards STEM. The study consisted of 41 seventh grade students from three schools participating in the Illinois Junior Academy of Science, science fairs. This particular fair is noted to have aligned their science fairs with the NGSS best practices, standards, and engineering practices. These students volunteered to participate in focus groups, which were intended to uncover the effects of science fair participation on science inquiry understanding (Schmidt and Kelter, 2017, p. 127). Seven questions were asked to the students that aimed to measure their views on what they learned about the process of science and what their thoughts were on a career in science (Schmidt and Kelter, 2017, p. 128).

Each question was designed to measure an area of the NGSS best practices, content standards, and engineering practices. The study found that students generally indicated that they felt they had learned more about science concepts. This typically took the form as direct content knowledge explanation. It was also found that students had an awareness of how to conduct scientific procedure generally, often highlight specific parts of the scientific method that stood out to them, or how their planning process had become more efficient. Overall, the major finding was that students gained an understanding of the scientific process through the planning and execution of their projects during the science fair (Schmidt and Kelter, 2017, p. 128). Surprisingly, however, only 8 of the 41 students showed in interest in a science related field as a career. Furthermore, a
few of the students indicated that the projects were a lot of work, and only nineteen of those students reported the work as worthwhile.

The framework of the study demonstrated an appropriate tool to measure student learning through science fair participation. However, the use of only a seventh-grade sample size presents a weakness. Future research should aim to determine how a wider range of students at different grade levels measured in terms of learning through inquiry following the same or a similar study.

Science fairs are a popular part of science curriculum if educators choose to engage in them with their students. As such, it was recommended to modify the way in which students participate in science fairs to make the experience more conducive to all levels of students. It was noted that some students ended up with a negative attitude towards science during the process (Schmidt and Kelter, 2017, p. 131). It was further suggested to allow students more choices in how they participate. For example, students can work in small groups on shorter projects, or individually if they choose. By doing so, this might alleviate the stress and intimidation for students when they see a daunting task of designing and carrying out an experiment all on their own.

Furthermore, students that did participate were able to speak in great detail and with great enthusiasm regarding the results of their projects (Schmidt and Kelter, 2017, p. 131). This showed that students have learned about the scientific process from the fair. The direct implications of this was not as discussed as the implications on STEM careers. Teachers could use science fairs to allow students to broaden their understanding of science in a way that allows them to have control of a topic that they are very interested in and show the knowledge gained from their own, or a group, investigation of the topic. In addition, collaboration with peers is an important 21st century skill that science fairs can better foster than other classroom only activities as science fairs are generally open to the school population / general population.
For many individuals, science has always been a difficult subject. If one were to look at the previous standards in New York prior to the New York State Science Learning Standards (NYSLSS) recently rolled out, a disconnect would be apparent between the skills and content knowledge standards. Now, with the roll out of the NYSLSS, science process skills and content knowledge have been interwoven into a way that often requires students to learn through inquiry-based approaches. But how do students with learning disabilities do in inquiry-based science classes? This study looked at cases of students and asked three questions regarding student achievement of the knowledge of inquiry, engagement in curriculum, and strategies used by teachers for students to facilitate understanding science knowledge (McGrath & Hughes, 2018, p.133). Six 6th grade students identified with a learning disability, and their teacher, were used in the study. These classes were part of a district in the Mid-Western United States where it had adopted an inquiry-based instruction, teachers received professional development on units of inquiry-based learning, and the science classrooms utilized special education supports for students. Observations during class, portfolios of student work, student interviews, and educator interviews were used as data during the study (McGrath & Hughes, 2018, p.134). The particular content subject revolved around biodiversity.

Of the six students that were observed, interviewed, and work assessed, only one was able to demonstrate all of the skills present in the series of inquiry-based activities. The other five students typically required prompting, and even with prompting, were unable to remember or explain certain parts, or all parts, of a particular activity (McGrath & Hughes, 2018, p.137). For example, several students responded with “I don’t know,” or “I don’t remember,” when interviewed about their data, procedure, and planning of their investigation. On assessments, these students showed that they did not have an independent handle on these tasks (McGrath & Hughes,
2018, p.137). Overall, it was also shown that the students had difficulty with the vocabulary associated with the learning activities, and the students noted that they had trouble with questions because of the difficulty with the vocabulary. Furthermore, these students typically had off-task behavior that may have contributed to the lack of understanding of the concepts, despite the prompting during instruction. If the students were self-motivated and instruction allowed them to discover the meaning of difficult works through the instruction, then they were typically more successful (McGrath & Hughes, 2018, p.139). Students that were on task earned higher grades overall, most likely due to this.

The strategies used with LD students were also assessed, and it was found that the teachers limited strategies may have impacted the student performance during the unit. Peer support played the largest role, but only the LD students that showed self-motivation to engage with peers appropriately (by staying on-task), were able to use such a tool for the purpose it was intended (McGrath & Hughes, 2018, p.138). It was also found that the teachers did not deliberately use supports that were linked with the IEPs of the students. Teachers in their final interviews admitted to not really knowing the students IEP as much as they should have. While their supports did assist students, the teachers remarked the difficulty with giving supports to students during instruction (McGrath & Hughes, 2018, p.139).

As noted in the article, sample size and nonrandomization of classroom participants does limit the generalization of the implications from the study (McGrath & Hughes, 2018, p.140). These weaknesses were the only ones that would be considered weaknesses in this particular study.

The study conducted by McGrath & Hughes (2018), although small, has important implications for the future of science inquiry tasks in classrooms where students have LD or other IEPs. As noted in the study, mathematics and reading gaps, as well as vocabulary gaps, contributed
to the difficulty these students had in their inquiry-based instruction (McGrath & Hughes, 2018, p.139). However, providing the individual support needed for each student that has a unique IEP for one teacher is a daunting task. This particular middle school, as noted in the article, was designed to have supports in place for these students (McGrath & Hughes, 2018, p.140). But, in other schools where the number of students with IEPs may be higher, the structuring of inquiry-based instruction will have to be greatly considered to best benefit the learning outcomes of these students. As such, professional development for teachers regarding inquiry-based instruction in science should be given (McGrath & Hughes, 2018, p.140). Thinking ahead, the purpose of the Next Generation Curriculum to have a vertical alignment that builds skills over time. Therefore, this sort of explicit training would be needed for all teachers, at all levels, in order to best serve all students appropriately.

**Research on Problem-Based Learning**

The importance of 21st century skills within a global community has become ever more apparent as competition between countries in a multitude of markets increases. As such, students in all communities need to develop the appropriate 21st century skills in order to keep up in the ever-changing and demanding needs of today's society. Wan Husain, et al. (2016) focused on the development of 21st century skills in a rural community within Malaysia using Project Oriented Problem Based Learning (POPBL). One-hundred and twenty-five students ages 13-14, from rural areas were involved in a one group quasi-experimental study using one pre and post-test to identify skills before and after participating in a POPBL program. There were five primary skills focused on during the study: digital age literacy, inventive thinking, effective communication, spiritual values and high productivity (Wan Husain, et al., 2016, p.3). The framework uses POPBL as its choice of instruction because of the integration of a real-world problem that requires students to
work in groups, collect and analyze data, communicate findings, and construct a product as a result of the findings (Wan Husain, et al., 2016, p.7-8). Students in the POPBL program were exposed to four units looking at energy, transportation, wireless communication, and urban infrastructure. Units were designed to build on each other over time (Wan Husain, et al., 2016, p.9).

While there was no comparison group for the purpose of the study, results indicated an increase in four of the skill categories initially measured in the pre-test, but spiritual values (the practice of religious knowledge and beliefs) had no significant positive change. Digital age literacy and high productivity showed significant increases, but inventive thinking and effective thinking did not have shown a significant increase, although a minor increase was present, and spiritual values showed a decrease in the mean score (Wan Husain, et al., 2016, p.13). In addition to the changes in these skills, it was also found that students utilized systematic planning skills and communication in order to design new products based on ideas shared with their fellow peers during the various units (Wan Husain, et al., 2016, p.14). Furthermore, the POPBL activities were also shown to have increased students 21st century skills by 4.9% overall when comparing the pre-test to the post-test. Students also perceived an increase in these skills individually as well (Wan Husain, et al., 2016, p.15).

The authors of the study noted a few limitations in the framework of the study which included the lack of a comparison group, there were no performance-based assessments of students (Wan Husain, et al., 2016, p.18), and the students were only from rural communities. In order to further develop the potential use of POPBL programs for students in such areas, more research should be done to analyze students in both urban and rural communities, as well as measure students’ performance-based skills.
The authors noted that the implications and uses of POPBL are relevant to the development of skills needed in the global marketplace. For Malaysia in particular, the need for more individuals to be present in the STEM fields to be considered a developed nation is the driving force behind such studies, but such information can be applied to current developed nations to enrich student learning in the STEM fields. Firstly, as noted, professional development of POPBL for teachers is necessary for the proper implementation in the classroom (Wan Husain, et al., 2016, p.18). The materials need to be student-centered and revolve around real-world and current problems that individuals and groups face.

Other implications not further discussed include the focus on developing POPBL programs for students at various levels in education. The study noted that none of the students scored fairly low on the 21st skills pre-test, all scored in the medium range (Wan Husain, et al., 2016, p.13), but there will be groups of students who do show low acquisition 21st century skills Further research should be done on these groups of students in order to determine methods to assist them in becoming not only digitally literate but scientifically literate and possess some ability to be communicative and innovative in some form that could be applicable in the workforce. In addition to this, it would be feasible to further study the effect of POPBL on student achievement for state performance assessments. While this study showed an increase in 21st century skills, the effect of these skills on student achievement using a particular pedagogical approach should be studied more in-depth and compared to traditional teaching approaches, as similar studies on PBL and inquiry-based learning have done thus far.

Project-based learning (PBL) has been used for more than 40 years in various educational fields including engineering and medicine. Recently, several meta-analyses have been conducted to analyze the effectiveness of PBL instruction compared to traditional forms of instruction, such
as lecture. Strobel and Van Barneveld (2009) conducted a meta-synthesis of various meta-analyses that compared how students performed following the experience in the classroom when educated using PBL methods to traditional methods in the medical field. Strobel and Van Barneveld had two primary purposes for this analysis: (1) determine how differences in the definition and measurement of learning contributed to the determination of the effectiveness of PBL on a variety of assessments, (2) determine valuable statements about PBL that could be made using supported arguments from the meta-analysis synthesized (Strobel and Van Barenveld, 2009, p.45). Data on twenty-five meta-analyses on PBL related topics were collected and synthesized.

Following the conclusion of the analysis, data was grouped and collapsed into four categories: non-performance/skill/knowledge-based assessment, knowledge assessment, performance/skill-based assessment, and mixed knowledge and skill-based assessment (Strobel and Van Barenveld, 2009, p.53). For the first category of non-performance/skill/knowledge-based assessment, PBL was favored overall. In the category of knowledge, short-term knowledge was favored with traditional approaches when assessment was delivered immediately following the conclusion of the course. However, when recall was favored more over recognition—perhaps using a short answer type question for example, PBL was favored overall (Strobel and Van Barenveld, 2009, p.53). In addition, if the assessment focused on long-term retention of the materials learned, with assessments given 12 weeks or more following the conclusion of the course, PBL was again favored with higher achievement scores (Strobel and Van Barenveld, 2009, p.54).

In the category of performance/skill-based knowledge, assessments were typically carried out by supervisor observations, and were also found in the form of patient simulations and other questions that focused on case-studies. In these cases, PBL was also favored with higher achievements (Strobel and Van Barenveld, 2009, p.54). In the mixed knowledge and skill category,
where assessments focused on the application of medical knowledge that are essential for proacting medicine without supervision, PBL was favored in terms of overall achievement. Overall, based on the results of students that had PBL based instruction, long term knowledge retention was higher in all categories where learning was viewed as a long-term endeavor. Traditional learning was only valued for short-term assessments such as Boards Certification Exams, or other post-course assessments. Furthermore, other measurements of learning that focused on performance and skill resulted in students having received PBL outperformed students that were taught traditionally (Strobel and Van Barenveld, 2009, p.54).

The framework of the study focuses only on the analysis of PBL in the preparation of doctors and other medical professionals in the medical field. However, in the introduction, it was noted that the design method has been utilized for over 40 years in other domains as well (Strobel and Van Barenveld, 2009, p.44). As such, perhaps a more robust approach would have been to analyze two different STEM fields overall—such as engineering, in this particular meta-analysis. Furthermore, although 25 studies were referenced in the meta-synthesis of the meta-analysis, more details on the total sample sizes referenced throughout all of the studies would have served as further detail for how substantial the concept of “favoring PBL” was.

The authors suggest a focus into K-12 education for PBL, which at the time of publication, had not been studied as in depth as PBL in various STEM domains. However, the implications of the analysis depend on the outcomes wanted for assessments. If an individual reading the study is aiming for short-term retention of information for an assessment, perhaps a state test for example, then a traditional teaching approach may be more suitable for the students. However, if the goal is for long term, performance-based development of knowledge and skills, PBL shows more promise for students based on the results of individuals in the medical field. In the conclusion, it was further
noted that preference for instruction should focus on developing skills for performance in authentic situations in order to increase long-term knowledge retention (Strobel and Van Barenveld, 2009, p.55). Perhaps one possible implication for future study would be a long-term study of students from kindergarten through adulthood that analyzes retention of long-term skills and knowledge in the work place, especially in order to analyze 21st century skills that are often developed through PBL instruction that is vertically aligned through K-12.

Horak and Galluzzo (2017) the effect of problem-based learning (PBL) on student achievement and their perceptions of the quality of the classroom. A total of 457 gifted students from two middle schools were used to compare traditional teaching methods to PBL teaching methods. PBL groups were made using teachers that participated in professional development that was designed to learn to use PBL to teach middle school science according to the Stepien and Pyke five-phase PBL model (Horak and Galluzzo, 2017, p.34). A total of 223 students that were considered gifted partook in the PBL group (Horak and Galluzzo, 2017, p.35). Students in the PBL group completed a unit on environmental science. The traditional classroom was set up in a difference school with a similar demographic of teachers and students. A total of 252 gifted students participated in the environmental science unit (Horak and Galluzzo, 2017, p.35). Achievement data was collected using an assessment aligned with the state and local objectives before and after the conclusion of the unit Furthermore, data on student perception of the quality of the classroom were collected following the conclusion of the unit using the Student Perceptions of Classroom Quality Scale (SPOCQ) (Horak and Galluzzo, 2017, p.33).

Following the analysis of the pre and post assessments, results indicated that both groups of students had equal prior knowledge prior to the various educational methods used, and each group increased their knowledge at the end of their respective units (Horak and Galluzzo, 2017,
p.38). However, students that participated in the PBL group had significantly outperformed the students in the traditional instruction group (Horak and Galluzzo, 2017, p.39). Student perceptions measured using SPOCQ were not significantly different but did indicate that students typically felt more confident in their ability to succeed using the traditional approach but were more challenged and had more choice using the PBL approach (Horak and Galluzzo, 2017, p.39). These results further indicated that the PBL group, in terms of academic achievement, were more favorable. While students had some reservations about their self-efficacy in the PBL group, they tended to favor a PBL learning environment (Horak and Galluzzo, 2017, p.40). Overall, these results show that a constructivist approach, such as PBL, can give students the means to outperform students that come from a traditional teaching classroom on academic achievement assessments (Horak and Galluzzo, 2017, p.41). Furthermore, the study also found that the students valued the ability to be flexible and have choice in their approach to the material covered, which led to positive perceptions about PBL activities (Horak and Galluzzo, 2017, p.41).

Compared to other education research studies, the framework of this study had a larger sample size, an equally matched population, and the implementation of the unit was not compromised by a lack of fidelity on the part of the teachers. There were two weaknesses and limitations identified based on the framework of the study. Firstly, the study looked only at gifted students in schools that had a dedicated program for these individuals. This is not typically the case in other schools. To further support the findings of this research, a study of middle school science students that are considered average academic students, and a study of students that are considered low, or at-risk, should also be done. Secondly, the teachers were not randomly picked—they volunteered, and the district participating in such a study aligned with their improvement goals (Horak and Galluzzo, 2017, p.42). Rather than having teachers volunteer for the study,
having teachers engage in PBL training for the first time during the summer, similarly to the training these teachers participated in, may provide more information regarding the effect of implementation overall.

The study also noted several implications for stakeholders. For administrators seeking to improve teacher communication in their building(s), training all teachers in an adapted Stepien and Pyke model that includes a meta-cognitive checklist (Horak and Galluzzo, 2017, p.43-44) would serve as a tool to do so. Looking at the structure of the meta-cognitive checklist (Horak and Galluzzo, 2017, p.44), it could also be altered to serve as an informal observational form for teachers to use to evaluate each other during particular aspects of the unit. Furthermore, it serves as an effective reflective tool for teachers to use that targets specific areas of improvement. As further noted by the study, the intentional design of PBL being aligned to core content standards and guiding of the instruction through student questioning allows for a number of improvements in the 21st century skills for students, content understanding, and the additional depth of knowledge gained as they become self-directed learners (Horak and Galluzzo, 2017, p.43). These findings challenge the traditionally held approach that students learn best through traditional teaching methods. Students, regardless of being gifted or not, benefit from the feeling of having a say in their learning—they feel empowered. Focusing that empowerment into inquiry allows students who are open to learning in a new way the ability to get more than just content skills. As noted in the study, 21st century skill development was also a benefit for the students. In particular, data-analysis literacy and being able to make sense of the information, was highlighted as having improved in the PBL group (Horak and Galluzzo, 2017, p.32). Administration and educational leaders focus on 21st century skills could be used a method to bring focused and ongoing
professional development to teachers who are willing to participate in PBL, ultimately allowing students to become more literate in the particular content.

**Assessment in Science Education**

Inquiry-based science investigations are an important pedagogical approach to instilling curiosity and building important science skills for children at young ages. The use of formative assessment to assist students who are struggling is one such tool in science that allows teachers to gather information needed about student learning challenges (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.88). This qualitative study looked at how three teachers in grades 3-5 from schools participating in the Indiana Science Initiative (ISI) used formative assessment to assess student learning in inquiry-based science lessons. Methods of formative assessment addressed three areas for science in particular: identify students in need, providing feedback, and guiding/supporting students. Teachers that are part of ISI use a number of different methods, five of which were focused on in this study: color coding, diagramming, line of learning, post-it notes, and exit tickets (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.89).

Color-coding and exit-tickets were used to identify student needs. The color-coding method was found to be effective for teachers to reduce the amount of time identifying students for support. Students were sorted into three colors: green, yellow, and red. Each color corresponded to a group that would receive targeted support for areas of weakness depending on the topic at hand. However, teachers noted that communication with students from their work often became difficulty to interpret. Teachers implemented the addition of student-drawn diagrams to accompany written work to further determine the level of student understanding. This method was effective for fourth grade students (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.80). For fifth grade
students that were capable of writing more, the teacher also used short exit-tickets as a way to quickly inform him of the student’s ability to understand a concept. These were phrased as questions that asked students to give a statement on what they learned during the class and what they want to know (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.90).

Sticky-notes were used to provide feedback to students in a non-permanent way, as compared to writing comments directly on student work. Sticky-notes were used for similar purposes overall, with some teachers having additional uses depending on the grade level at hand. Sticky-notes were shown to increase student motivation as the removal of sticky notes following the fixing of an issue gave students a sense of accomplishment. Furthermore, it was also shown to increase student communication (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.91). One method included the use of a sticky-note parking lot in which students, assigned to a specific lot number, where students are expected to put their responses and thoughts, and the students in turn recognize that they will get feedback and it is important for them to read the feedback (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.91). The final strategy implemented by the teachers was called Line of Learning. Students were instructed to draw a line under the original notebook entry regarding a phenomenon, with their revised explanations and diagrams underneath their original entry to show the accomplishment of the tasks. One particular teacher, who teaches the 5th grade class, also incorporated class discussions following the use of Line of Learning, which was shown in increase peer communication and allows him to give further feedback to students (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.92). Based the implementation of all of these methods, teachers indicated that all of their students increased in the final assessments (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.93).
As this study, while meaningful in its reported findings, only reported on the teacher’s use of the formative assessment and did not provide any particular data on student growth achievement scores that compared a control to an experimental group of students. Furthermore, the study looked only at grades 3-5. A study looking at 6-8, and 9-12 in each respective content area (if feasible) would allow teachers and other stakeholders to identify formative assessments that are vertically aligned and useful for the particular content area needed.

Formative assessment, as noted in the conclusion of the study (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.93), opens up a number of opportunities for students to understand, investigate, and reflect on their learning through a unit. It was further discussed that, for students particularly struggling with science, these particular methods were found to be very useful and should be implemented by teachers who would find the formative assessments practical in their own classrooms. The learning process further reflected through the process of formative assessment, and the subsequent involvement of students in the process also conveys the message to students that learning is not a one-time deal, but rather it is a continuous learning process for them (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017, p.93). In addition to the implications discussed in the article, it is also noted that, as other previous literature has claimed, stakeholders should also consider the professional development aspect of studying different formative assessments used by other state science initiatives such as ISI. Having concrete data on which ones worked in science classroom situations is an invaluable tool that should be considered.

A study on formative assessment looked at methods to implement measures that would allow science teachers to use formative assessment in inquiry-based education. Previously, it was noted that formative assessment was not always used in the classroom setting, particularly for inquiry-based education (Grob, Holmeier & Labudde, 2017, p.2). Formative assessment, however,
was been noted in literature to be an effective method to foster learning and can be used to support the development of inquiry habits for students (Grob, Holmeier & Labudde, 2017, p.2). The authors conducted a three-semester long study with 11 Swiss science teachers that compared three methods of formative assessment chosen by the teachers: written teacher assessment, assessment by peers, and self-assessment. Teachers then filled out self-reporting forms for each of their trails that included the teaching materials and questions being used in the lesson, and then the reflection of the end of the unit/lesson and how effective the teacher saw the formative assessments as (Grob, Holmeier & Labudde, 2017, p.2-3). Of the eleven teachers participating, a random sample of six teachers were chosen to have their data analyzed.

The data from the study was organized into five categories: content and structure feedback, embedding of formative assessment activities, student engagement with the feedback, relation between formative and summative assessment, and effort needed. Each of these categories reflected overall challenges that the sample teachers noted during the study (Grob, Holmeier & Labudde, 2017, p.3). Issues related to the embedding of formative assessment activities was primarily related to planning the assessments, so they did not become a routine for the students, and that the timing of assessments greatly affected the flexibility when unexpected events occurred (Grob, Holmeier & Labudde, 2017, p.3). In the category of content and structure feedback, teachers noted that, while the amount of feedback was useful, the decision on what feedback was the most useful to give a student was difficult. Students could only handle a certain amount of feedback, and the type of feedback given was also noted by teachers to possibly affect the openness of an inquiry-based investigation. The quality of peer assessment was also called into question by the teachers due to limitation in how well-versed students were in the language needed to effectively
communicate with peers or be honest with themselves in a self-assessment (Grob, Holmeier & Labudde, 2017, p.4).

In the category on student engagement with feedback, teachers noted difficulty in the quality of the feedback from peers depended on how eager the recipients were, how the students interpreted the feedback, and if the students could transfer the feedback from a peer or teacher to a new lab situation. In particular to the latter example, teachers noted that many students had difficulty transferring the feedback to new lab situations overall (Grob, Holmeier & Labudde, 2017, p.4). The relationship of formative to summative assessment was also mentioned as a challenge for teachers, particularly in regard to the difference in the level of importance between summative and formative assessments. Furthermore, students viewed the formative assessments as still assessments, and often this took the enjoyment out of the activities (Grob, Holmeier & Labudde, 2017, p.4). Finally, “effort” was identified as a challenge—effort on the part of the teacher and the student. Time to make useful formative assessments was mentioned as a challenge, and the practice and familiarity of peer and self-assessments was noted as a challenge for students. If students were unfamiliar and unpracticed in the methods, the amount of effort shown was lower compared to what it might have been had they had more practice (Grob, Holmeier & Labudde, 2017, p.4).

The results of the study were also organized into a second part that looked at supports that could be implemented to assist teachers and students with the use of formative assessments in science that were considered effective. These supports were listed as: examples of good practice, time, assessment literacy, reflection opportunities, exchange experiences, and the clarification of formative assessment roles. Teachers noted a number of different questions and suggestions to assist with the implementation of these supports in ways that would have benefited them had they been used during the study (Grob, Holmeier & Labudde, 2017, p.4-5).
The study’s framework was organized as a qualitative study, having relied on teacher feedback on student progress. Based on this information, examples of student work were not shown or explained in the study. Since the study was framed as a qualitative study, actual student reflection from lab notebooks, which were referenced multiple times (Grob, Holmeier & Labudde, 2017) would have added to visualizations of the particular format of the formative assessment questions. In addition, students were not asked for feedback about their opinions on which assessment felt either more natural in the inquiry process, or more useful. Future studies should look to incorporate such information.

As the study focused primarily on successful implementation of formative assessments for science, emphasis on the implications for professional development were the focus. Teachers in the study suggested that, for stakeholders such as administration, professional development on what formative assessment is not as useful as professional development in the use of different formative assessment methods. Furthermore, it was noted that teachers in the study showed greater interest in developing their own assessments and materials rather than using materials from an externally mandated source (Grob, Holmeier & Labudde, 2017, p.6). It would also be feasible to interpret that the study also calls for teachers to be given more time to accomplish these tasks, as this was noted as a challenge to many of the teachers in the study, as well as time to exchange and develop assessments with colleagues.

Kloser, et.al, performed a qualitative analysis of a comparison nine dimensions of effective assessment practice in science classrooms to less effective assessment methods using data collected from middle school science teachers. These dimensions included the following: setting goals, alignment, cognitive complexity, reflection of practice, frequency of assessment, variety of assessment, feedback to students, and adaptations to instruction (Kloser, et. al., 2017, p.212). All
of these dimensions were addressed in teacher notebooks referred to as the Quality Assessment in Science Notebook (QAS), which collected 10 days of lessons, assessments, sample student work, artifacts, reflections, and student performance (Kloser, et. al., 2017, p.210). The researchers were interested in how assessment practices were used when comparing teachers that had high notebook ratings compared to teachers with low notebook ratings. Forty-two eighth-grade teachers from thirty-five California schools were used in the study on assessments, focusing on chemistry and physics notebooks collected during the same time of the year to avoid temporal effects. Following the completion of the year, students completed a survey to identify their feelings on the assessment practices, and the districts provided the state assessment data for the 8th grade science classrooms. A rubric was used to evaluate the teachers on a scale of 1-5 for each of the nine dimensions (Kloser, et. al., 2017, p.216). In total, 8 notebooks were chosen and evaluated using this rubric.

Results of the study on QAS notebooks found that teachers with lower rated notebooks tended to produce goals that only aligned with the lower levels of Bloom’s taxonomy (such as know and understand) and only aligned with state standards. In contrast teachers with higher rated notebooks tended to produce learning goals that aligned with multiple levels of Bloom’s taxonomy, state standards, and personal goals for the students in their units and lessons (Kloser, et. al., 2017, p.22). Teachers with higher rated notebooks were also found to completely meet the rubric standards for the variety dimension—using multiple methods of assessment, both formal and informal, continuously over the course of ten days. These assessments included drawings, lab work, oral conversations, mathematical problems (physics), and much more. However, teachers with lower rated notebooks were found to have gaps of two to four days of both informal and formal assessment, and only used some variety in assessments. These units for such teachers also included discussions, demonstrations, group work, and inquiry-driven labs (Kloser, et. al., 2017, p.221). In
all 8 notebooks, it was evident that student involvement was low and the only real time that students were involved in thinking about their performance was present in only a handful of the books (Kloser, et. al., 2017, p.223). In terms of feedback, lower scoring notebooks showed evidence of providing feedback, but not the quality of feedback that would allow students to move from their current level of understanding to the goal determine by the teacher. Most of these feedbacks came as right and wrong marks and percentages, with little to known guidance on where improvements could be made (Kloser, et. al., 2017, p.224). With all of the data on student performance at hand, surprisingly only one teacher consistently used the data to adapt instruction to meet the needs of the students effectively. Nearly half of the notebooks did not reflect on the use of student thinking to inform instruction as well (Kloser, et. al., 2017, p.226). Analysis of the end of the year student data found that students who had teachers that scored highly in the QAS notebooks outperformed students who had teachers that scored low on the QAS notebooks.

The framework of the study consists of a fairly low sample size, even though there were 42 total participants, only 8 of the QAS notebooks were sampled. This weakness was noted in the study, and its effect on limiting the generalization of claims that could be made (Kloser, et. al., 2017, p.228). Furthermore, the use of hardcopy notebooks limited the in-class observations that could be made. The authors suggested the use of a tablet form of the notebook to capture informal assessment more thoroughly.

Based on the results of the study, it would be feasible to determine that the most important finding is that teachers need more opportunities to see assessment practices in action along with professional development to support the use of concrete tools (Kloser, et. al., 2017, p.229). Although all teachers that participated were trained in the QAS Notebook tool, the variety of implementation practices showed variations in student performance and reflected a need for
support and professional development for teachers. In addition, the QAS Notebook could also be seen as a valuable tool for science teachers to collect data across a district or department on student growth and discuss methods to better implement assessment, both formative and summative. The quality of assessment needs to also be considered by educators, and best practices (according to the dimensions) should include adapting instruction based on student thinking, and actively collected data through a multitude of forms to best see where students are, and where they need to go (Kloser, Hilda, Matrinez, Stecher, & Luskin, 2017). With the shift towards three-dimensional learning in the Next Generation Science Standards (NGSS), professional development for teachers should focus on the demonstration of assessments that best suit the learning goals set forth by the NGSS, and how teachers can implement and record formative and summative assessment in a meaningful way.

**Writing to Learn**

When students can discuss in groups, students typically learn effectively and knowledge is retained longer—particularly when this is done in conjunction with active learning activities (Olde Bekkink, et. al., 2015, p.1). Student centered learning through small group work (SGW) at the post-secondary level is become more evident over time, with students having a say in what they learn in the classroom. This study focused on students’ ability for produce and write written questions to ask peers during SGW. This skill is important in raising curiosity, stimulating active participation, stimulating critical thinking, and gives formative feedback about student performance. The authors focused on whether the generation of questions would produce an increase in medical student achievement, and if there was an effect of gender on the SWG intervention (Olde Bekkink, et. al., 2015, p.2).
The study was conducted with 315 female medical students and 144 male medical students in a bachelor’s levels General Pathology course. The course was organized into four main topics, of which SWG took place during the final topic on tumor pathology. Students were organized into voluntary smaller groups of 12-15 students in which a tutor acted as a facilitator. Questions were stressed to be focused on deeper meanings of tumor pathology rather than simple factual knowledge. At the end of SGW, students were asked to write down at least one question relevant to their learning, which would be discussed in the ten minutes following the activity. At the end of the examination, a total of 444 students participated, 15 dropouts were not analyzed (Olde Bekkink, et. al., 2015, p.2-3).

The study found that students who participated in SWG that used written questions whose purpose was to deepen learning on tumor pathology scored higher than students who did not participate in SWG. Although this was considered board line significant, the results indicate the purposeful formulation of questions that are asked to peer in small group discussions increases student learning (Olde Bekkink, et. al., 2015). In particular it was noted that male students seemed to have a higher positive learning effect compared to female students who showed no significant difference between the experimental and control groups (Olde Bekkink, et. al., 2015, p.4). The reasoning for this seemed to lie in extrinsic and intrinsic motivation. Male tend to be more extrinsically motivated compared to females who tend to be more intrinsically motivated (Olde Bekkink, et. al., 2015, p.3). Since students had to come up with questions, males may have seen this as a competition between who had the better questions for peers, thus perhaps causing an increase in their achievement, and also suggests males need more challenges to increase their motivation (Olde Bekkink, et. al., 2015, p.4).
The framework of the study was limited due to not having been conducted in a proper laboratory setting. Furthermore, the intervention was small, and the results may have been coincidental depending on the cohort's abilities coming in. With a new cohort every year, it would be necessary to compare this method of SWG intervention across a number of years to determine whether the effect was simply a coincidence and if it does have more significance than previously noted (Olde Bekkink, et. al., 2015, p.5). It was also noted that the formulation of questions and the prioritization of formulated questions may have equally contributed to the increase of the scores (Olde Bekkink, et. al., 2015, p.5). It would be interesting to determine if one method, either formulating alone, prioritizing alone, or both, is more effective for student growth. Furthermore, the small group work was a factor in bridging the questions and the performance on the exam. A mixed methods study was indicated as an appropriate tool to systematically evaluate small group work practices and procedures (Olde Bekkink, et. al., 2015, p.5).

The focus of this study has shown implications for education practice in science beyond simply the medical field. It was noted that incorporating dialogue into science curriculum should be a central focus for science curriculum (Olde Bekkink, et. al., 2015, p.5). By asking questions and prioritizing questions, students are engaging in the language of science in the classroom setting, and in the case of medical students, training them to become academic doctors in the process. The authors posed a question on whether or not their curriculum provides enough stimulating questions to produce small group discussion. The same question could be proposed for all teachers and administrators. Are students truly engaging in the content they are learning? How might meaningful and stimulating questions better engage students and increase their performance.

A 2017 study (Hand, 2017) looked at twenty-five years of literacy research regarding writing to learn in science education K-12. Most research in literacy was noted to be focused on
socio-cultural theory and the mastery of strategies to improve student achievement in literacy. This study, however, focused on the cognitive issues and classroom environmental effects on literacy, particularly writing to learn (Hand, 2017, p.1).

Of the twenty-five years of data collected on literacy research, it was noted that writing should be viewed as a process that involves more than the replication of already known ideas that students are given (Hand, 2017, p.2). Earlier research completed focused on the framing of writing tasks around five criteria: topic, type, purpose, audience, and method of text production. It was found that the value of the audience, who students were writing to, was one of the most important factors that increased student learning. When students wrote to peers, or younger students, they had a significant increase in knowledge gained from the experience, noting that because they had to break down difficult words for peers and younger students to understand, they also understood more about the topic (Hand, 2017, p.2). This was also supported from 10 years of interviews collected when using this method of teaching for particular topics (Hand, 2017, p.3).

Earlier methods of writing in science employed by the author and others noted that students needed to live the language of science as it was an extremely important piece for learning about science (Hand, 2017, p.3). In one 2008 study referenced (p.3) the concept of having students live the language through writing shifts the concept from replication of science and reflects how scientists actually engage in the concept of science. In each study referenced, it was noted that student achievement and perception of learning increased over time. Based on the studies, the author argued that there are four knowledge bases, or the knowledge and practices that a learner engages with during learning, that were important to consider when designing writing tasks for science: knowledge of science, science argument, language, and learning environment (Hand, 2017, p.5).
It is through these methods that it was noted students could begin to act more like scientists through their learning in science.

The use of a meta-analysis study on nearly twenty-five years of research into literacy education is no doubt useful for understanding methods for writing to learn, particularly in science. One strength of this metanalysis is that the studies referenced focus on the classroom environment and cognitive issues that arose for students. However, particular student data on a certain topic were not referenced, although generalities were made from the overall literature referenced. It would be interesting to measure how writing to learn using the methods outlined by the research referenced effects student learning in physical science compared to life science. In thinking about the nature of each of these topics, the method of engaging these students into immersive topics, as noted in the meta-analysis, would differ depending on the topic. Furthermore, the number of writing tasks per unit of instruction should also be studied.

Three particular conclusions for stakeholders can be determined from the meta-analysis of the studies referenced by Hand (2017). Firstly, when students engage in a writing approach that focuses on living the language of science compared to simply replicating the language of science, such as through a simple laboratory from a worksheet, students did significantly better on standardized tests (Hand, 2017, p.7). With this understanding, it would be feasible to put forth a strong argument for the reorganization of science curriculum to engage students in more writing to learn tasks that focus on the living of science language. Furthermore, the audience that students write to was shown to effect how well they retained the information, and writing to peers, whether younger or the same age, was more beneficial than writing to the teacher. This also argues for the use of tasks that will engage students in a more meaningful way than simply through constructed short answer questions. Teachers should also consider that the use of these methods will require
professional development in writing to learn, and administrators will need to be open to allowing more teachers to attend such workshops than might typically be considered normal—and such be a further consideration for budget constraints in schools regarding teacher professional development.

How student engage in text is a fundamental process when determine appropriate literacy strategies to engage students in learning science, or really any, content. Sense of scientific literacy, as noted by the authors, includes fluency in the language, patterns of discourse, and communication systems of science. This is different compared to what is known as a derived sense of scientific literacy, which is concerned with being knowledge and educated in science (Bjørkvold and Blikstad, 2018, p. 305). Students engaging in research is one such method to increase student scientific literacy, as students are engaging with the language and procedures of science, while gaining new knowledge over time. With this in mind, the authors of the study were concerned with what and why students write when conducting their own research in science (Bjørkvold and Blikstad, 2018, p. 306). The study was conducted with students who were granted approximately eight weeks to conduct an in-depth research study. They intended to determine what the purpose of the students writing during the research was, and what characterized the initiation of writing tests as the students were conduction research science (Bjørkvold and Blikstad, 2018, p. 309). The study took place in a Norwegian School, concentrating on 21 students in 7th grade science, 15 boys and 6 girls science (Bjørkvold and Blikstad, 2018, p. 310).

Overall, a total of 344 student texts from the 21 participants were analyzed, in addition to video observation of 26 lessons, 22 interviews with the students in small groups science (Bjørkvold and Blikstad, 2018, p. 311). Results indicate that 66% of the texts written by students over the course of the study period were considered working texts, or texts written for the purpose of
research. Examples include notes, data, diagrams, or anything taken during the research project. Eighteen percent of the texts written were considered thinking texts, or texts written for the purpose of focusing research science (Bjørkvold and Blikstad, 2018, p. 320-321). Sixteen percent of the written text consisted of presentation text, which consisted of communication of research findings science (Bjørkvold and Blikstad, 2018, p. 322). Following this analysis, the researchers looked at why the students wrote various types of text. Majority of the purposes for writing text came across as open challenges presented by the teacher. Students decided to complete these challenges through writing, however, and not because the teacher asked them to write directly science (Bjørkvold and Blikstad, 2018, p. 323). Overall, however, only 17% of the writing tasks were done from sole student initiative, suggesting that teacher prompting still plays an important role at the middle school level in the process of conducting scientific research.

One of the major findings within the research was that students produce a lot of writing samples during the process of research projects science (Bjørkvold and Blikstad, 2018, p. 334). Although not much of the writing ends up in the final product, it was noted that the sheer large amount of writing that took place during the process aligns with writing practices that scientists typically undertook. Furthermore, it gives evidence that students are exposed to a range of writing tasks that build on the research process and practice using the language of science through research. This further supports the concept that writing is central to science achievement and to the field of science (Bjørkvold and Blikstad, 2018, p. 334). Important findings also suggested that much of the writing students had done were not formally evaluated, but instead served as guides to help form thoughts during the process of the research project science (Bjørkvold and Blikstad, 2018, p. 334). It was also noted from student interviews that they favored the writing tasks and used them as
methods to understand and interpret complex data gathered during the experiment's science (Bjørkvold and Blikstad, 2018, p. 334).

Limitations to this study include the lack of quantitative data on student achievement. While the study did have excellent records of qualitative data in multiple forms to support each other, there was no tie in to how this research may have transferred over to science curriculum in the school. A further study should be done to look into inquiry-based research studies, student writing, and their outcomes in a similar method as this study.

In addition to the implications already mentioned, it was further noted that the findings of the study opposed previous research that instruction was the dominant method of initiating writing for students, such as giving specific argumentative text science (Bjørkvold and Blikstad, 2018, p. 334). It would be feasible to argue that, with the teacher acting as a facilitator, students would have a better grasp of the language of science when they engage in writing tasks of their own volition. But the question remains on student motivation—if the students are not motivated, how much writing will they truly engage in and will it be a benefit to them? As the study took place in Norway, the American education system is vastly different, and a large amount of scaffolding and front loading might be needed to assist students who are not used to open inquiry-based research, particularly in the secondary school. This is an important consideration for teachers who wish to engage in this method of teaching.
Literacy Strategies focused on Science Education

Determining the necessary curriculum to be taught each year in science, particularly in the elementary years, while having the increased push for Common Core Math and English Language Arts can present a daunting task to teachers across the country. Many teachers are tempted to teach science through writing (West, Sullivan & Kirchner, 2016, p.48), and are less likely to teach writing through science. This study aimed to highlight the effects of a different strategy, whiteboarding, that moves away from simply reading and writing tasks for science. Whiteboard, it was also noted, could be developed in all content areas as a method for literacy intervention. Whiteboarding consists of a cycle, in which students generate ideas, share ideas with classmates, synthesize big ideas with their peers and teachers, and build on ideas (West, Sullivan & Kirchner, 2016, p.48). The study was a qualitative report on how students in a fourth-grade class progressed through a lesson on weather using the whiteboarding strategy (West, Sullivan & Kirchner, 2016, p.49). The students were tasked with 4-ESS1-1, which requires the identification of evidence from patters in rock formations and fossils in rock layers to support an explanation that landscapes change over time (West, Sullivan & Kirchner, 2016, p.49).

Students began by generating ideas. In this case, students were shown an interesting rock formation and were prompted to use words and drawings to propose an explanation for why the formation looked hollowed out. Students were then tasked to work in groups, prompting students to include more information about certain parts of their explanation, or prompt using past events that occurred in the class that related to the task at hand. Following this, students were asked to share out their ideas to the class in which the instructor looked for key information from peer discussions using a set of whiteboard norms developed prior: the use of claims and evidence, questions specific to the topic, words and drawings related to the topic, and discussions of
comparisons of the board to other boards in the room (West, Sullivan & Kirchner, 2016, p.49). As students share, the instructor also consistently asks questions that help students either with science concepts or with writing mechanics. Once discussions are complete, students then synthesize the ideas as a class with their teacher. In the case of this lesson, students determined that wind, water, ice and living things could affect the formation of the rock. From their they went to test each factor by modeling them, recording observations and data on their white boards. Finally, the students share their findings with the class and continue to build on the ideas they had generated throughout the whiteboarding process. Following the end of the process, students completed an exit slip (West, Sullivan & Kirchner, 2016, p.50).

While the article had no particular quantitative data from the results of the exit slip, it did conclude that whiteboards could be used for a multitude of purposes in the classroom as a literacy strategy for students. Namely, the use of whiteboarding in the singular lesson allowed the students to demonstrate knowledge of seven ELA Common Core Standards while also completing 4-ESS1-1 of the NGSS (West, Sullivan & Kirchner, 2016, p.51. This further shows that this method could be effective for younger students where curriculum covered could be considered a complicated area. In addition, it was noted that whiteboarding could be an effective formative assessment tool as well, allowing students to have a medium to practice reading, writing, speaking, use of language in particular contexts, and much more. Furthermore, it allowed the teachers to see students thinking in real time and allowed students to correct their thinking from teacher input more effectively (West, Sullivan & Kirchner, 2016, p.51). —they can neatly erase a whiteboard better than a worksheet.

While this was a qualitative study, it does have some limitations. Firstly, there was a lack of student data reflected in the article. While the observations and procedures noted were affected, it
would be more concrete if teachers had collected data on how students did on assessments of the lesson and reported that data. Furthermore, only one class was observed that used this technique. Using whiteboards could be instituted as a reliable literacy strategy, but more research at the lower grade levels and upper grade levels would be needed.

For teachers, it was noted that the whiteboarding method could be used as both an instructional strategy and assessment tool (West, Sullivan & Kirchner, 2016, p.51). This is extremely useful for teachers to streamline instruction and assessment, particularly in the elementary grade levels when all content areas need to be taught by one individual. Furthermore, the price of whiteboards (a large 4 x 8 piece) was referenced at about $15 (West, Sullivan & Kirchner, 2016, p.53). For most schools this is an affordable expense, further supporting the use of whiteboarding in classrooms where funding is an issue, but technology is a need. In the realm of science particularly, the use of whiteboards and a medium for developing models is a feasible implication from this small study. For many students, developing models is difficult on paper, but perhaps by using larger white boards in a group setting, more feedback can be given quicker to students as they develop these models. It would be interesting to have a study in which whiteboarding was used to facilitate models, and how that strategy compares to a separate strategy for literacy on the same topic.

According to a 2017 article on student success in STEM courses is correlated to post-secondary success, and U.S. students have not performed particularly well on international assessments such as the TIMSS and Programme on International Student Assessment in the past (Reed et.al., 2017, p.77). Furthermore, links between these performances and reading ability have been closely correlated and determined to effect student performance in STEM (Reed et.al., 2017, p.77). The authors of this study aimed to compare student performance following the use of general
or specific literacy strategies to learn from and understand authentic biology texts (Reed et.al., 2017, p.79). The overall idea behind this was to really look at which methods were more effective. General literacy strategies are ones that can be used across all subject areas, while content-specific strategies revolve around those that highlight the specific language employed by the particular content being taught (Reed et.al., 2017, p.78). For example, general literacy strategies may not connect claims to evidence or include aspects of reading that require the understanding of scientific arguments. Science specific literacy strategies, however, would include the previously mentioned characteristics. General literacy strategies, however, would focus on generating a main idea from a passage.

The researchers for this study focused on a single case research design (SCRD) to determine the impact of the literacy strategies employed on student performance. They included 4 students ages 13-17 from an alternative school in the Southeastern United States. They used an adapted alternating treatment design (AATD) to test biology learning outcomes under the different literacy conditions. Students were pre-tested about 2 weeks prior to the start of instruction, and then were post-tested in their final lesson, or at the end of the unit. Due to the nature of the alternative school, some students left during lessons due to court dates or other issues that arose (Reed et.al., 2017, p.81-82). Information was collected in the form of weekly quizzes, social surveys, and pre/post assessments.

Two intervention materials were focused on: a content specific graphic organizer and a general note-taking strategy. The content specific graphic organizer (CGO) focused on 6 pieces: identifying the primary concept, describing the primary concept, evaluating statements against information in the article, supporting scientific arguments with evidence, providing cause and effect relationships, and creating a diagram to represent the topic (Reed et.al., 2017, p.84). General
note-taking strategies (GNT) was a simple chart that had students break the text into sections where they wrote the main idea and the supporting details, followed by a summary at the end. Students were first taught how to use each strategy in a prior unit, and then moved onto the biology concepts following this (Reed et al., 2017, p.85). Since reading levels were a focus of this study, the study found that students who were considered below-average readers typically scores higher overall on assessments when they were taught using the GNT strategy. Average ability readers, however, scored higher when lessons used CGO (Reed et al., 2017, p.89). When measuring the social validity of the instruction, students tended to favor the CGO strategies over the GNT strategies. From observations made by observers, it was noted that CGO strategies lead to more student-initiated responses overall (Reed et al., 2017, p.90).

While the study was effective in giving baseline data for CGOs compared to GNTs as literacy strategies in science, it should be noted that the study only looked at four students in an alternative school setting, and thus generalizations should be made carefully, if at all, based on the research (Reed et al., 2017, p.93). It would be feasible, however, to further supplement this research by completing a study at private schools and public schools at the same grade level to further analyze the effectiveness of CGO and GNTs as a literacy strategy. In addition to these, one area of weakness further mentioned was that students typically didn’t attempt the open response items (Reed et al., 2017, p.93).

Two implications could be determined regarding instruction based on these methods based on the data. Firstly, time was noted as a difficulty. While the GNT could be used in the same format for each lesson, the CGOs had to be redesigned for each lesson. Therefore, if teachers wish to implement CGOs as a literacy intervention, consideration for the time needed to complete the lessons is required (Reed et al., 2017, p.92). Secondly, CGOs were an effective strategy for science
that allowed students to achieve the six areas intended in the CGO. As a specific literacy tool, this meets the unique demands of the science specific content area (Reed et.al., 2017, p.92).

A student’s understanding of the language of science is an important factor in their achievement. One promising learning approach for students is using morphological instruction to teach students how to understand, pronounce, and spell complex words they counter during reading. For science, the Latin and Greek root words pose a particularly difficult challenge for students. The language of science, therefore, is a large barrier for many students (Zoski, Nellenbach & Erickson, 2018, p.57).

The authors, while they did not do a research study directly, produced an analysis and recommendation of morphological teaching approaches as a literacy strategy for students in science. From several different studies, the researchers first determined three reasons for why students struggle with the complexity of science struggles. Firstly, it was noted that these words are multimorphemic—meaning that the words considered particularly large typically rely on a syllable approach. While this helps students pronounce words, studies indicated that this did little for understanding the meaning of the words (Zoski, Nellenbach & Erickson, 2018, p.58). To combat this, students should engage in a morphological approach that helps students to decode and recognize common parts of words in science. A second reason they found that that science words typically have an unfamiliar spelling pattern. While most words have a grapheme-phoneme connection, science words typically have strong spelling-meaning connections, which creates a challenge for students as they learn the words. By giving explicit instruction in how to recognize patterns in complex words, they can read the meanings of words more easily (Zoski, Nellenbach & Erickson, 2018, p.58). A final reason they gave was that the normalization of difficult science words may confuse students further. Research referenced in the analysis particularly pointed to the
use of explicit instruction focusing on the normalization suffixes to helps students access the pronunciation, meaning, and spellings of complex scientific words (Zoski, Nellenbach & Erickson, 2018, p.58).

In addition to the generalizations made regarding the particular strategies referenced, the authors went into more detail on a specific approach based on other research studies that would assist students with achieving a better grasp on understanding technical words in science (Zoski, Nellenbach & Erickson, 2018, p.59). The first is using a method of dissection in which students break the prefixes, roots and suffixes in the multimorphemic words. In this case, students take a technical science term and cut it into the various parts of the word to help recognize patterns, and practice pronunciation. Another specific tool noted was an adapted Frayer Model called parts cards in which students work either with Speech-Language Pathologists or the General Education Teacher, and model the process of breaking down words into its parts, discussing their meanings and drawing a diagram that demonstrates the word (Zoski, Nellenbach & Erickson, 2018, p.59).

Research also suggested sorting words by morpheme, typically through the use of tree diagrams where the center trunk is a morpheme and the branches are words that share the morpheme (Zoski, Nellenbach & Erickson, 2018, p.60). A third method that has seen success with students from research is the process of combining morphemes through combining affixes and prefixes to derive meanings of words.

While the research referenced in the article is valuable, actual student data was not referenced—rather generalizations about data were given. It would be feasible, therefore, to determine that in order to really see how students are achieving when using these tools, a specific study analyzing the systematic approaches and tools described is needed to further the research present.
One of the major implications of this review of research on morphological studies is that explicit and systematic instruction using morphological strategies has been shown to increase students’ vocabulary knowledge in science (Zoski, Nellenbach & Erickson, 2018, p.63). Furthermore, this approach has also been shown to increase a student's ability to decode, spell, and comprehend reading. As a teacher, this method, while perhaps time consuming, would be an invaluable tool to use in science classrooms. When students understand the morphemes of words, they can better understand the content. Furthermore, this also gives teachers an opportunity to work with their Speech-Language Pathologist in order to benefit the students. Peer collaboration among teachers is an important practice to participate in within a school community.

**5E Models and Storylines**

The 5E learning cycle consists of five phases: engagement, exploration, explanation, elaboration, and evaluation. Use of the 5E learning cycle as a method to increase student learning has been noted in a number of literature sources to be effective. However, with the growing technological advancement, newer methods of educating students through technology in effective ways needs to be further explored and developed. Liu et. al., (2009) explored the use of a mobile natural science learning environment that incorporated the 5E learning model to determine if such a method increases student learning (Liu et. al., 2009, p.344). The 5E learning cycle, as noted in the article, can encounter limitations in an outdoor natural-science learning environment. The goal of the study was to supplement these limitations using technology using a mobile device (Liu et. al., 2009, p.344).

This study had three purposes: design mobile learning activities that incorporated the 5E learning cycle, understand the effects of student perceptions of the learning activities, and to discuss the factors contributing to the learning effects and student perception (Liu et. al., 2009,
The study took place in an elementary school in Taiwan as the school was constructing an ecological pool. Students were focusing their studies on aquatic plants through an after-school science club of 46 fourth grade students, 24 males and 22 females. Students used an Ecological Pool website and a tablet. The tablet enabled the students to use the website anywhere they could. Using the mobile devices, seven learning activities using the 5E model were developed for the students. More specific data on the students was collected via five methods: a pre and post-test, a learning activity survey that gathered perceptions of activities from students, observations of students during activities, interviews of the students, and reflective journals of the students following each activity (Liu et. al., 2009, p.350-351).

Each of the mobile learning activities were shown to have had a positively significant effect of the students pre and post-test knowledge and understanding of aquatic plants (Liu et. al., 2009, p.351). It was further indicated that the use of mobile activities that were framed around the model of the 5E learning cycle led to shifts in the students changes in conceptual understanding over time, thus further supporting previous literature on the effects of the use of the 5E model and on the use of technology in the classroom (Liu et. al., 2009, p.352). The use of the website was noted to allow students to correct misconceptions nearly immediately, and the ability of students to manipulative scientific resources was reported to have had a significant effect on their conceptual understanding of aquatic plants. This was further confirmed by their reflective journals and interviews conducted with students. The hands-one experiences further allowed students to engage and explore the content, building understanding of topics more effectively as well (Liu et. al., 2009, p.352). When looking at the results of the survey, it was also reported that nearly sixty-four percent of the students showed positive responses to the use of the mobile learning tools in their investigations,
furthermore supporting the use of technology in engage students in the curriculum (Liu et. al., 2009, p.353).

While the implications of the use of technology in the 5E learning cycle are clearly noted, the study only looked at fourth grade students in one location. More information is needed on students of different age groups and learning abilities. Furthermore, information on the abilities of the learners was not provided in the study, it would therefore be necessary to further determine the effect of mobile learning using the 5E model on student achievement if more information could be gathered for students with particular information on the learning styles and academic abilities of such students.

Despite the limits of the study, a few implications could be garnered. Firstly, it was noted that the use of mobile learning decreased time and location constraints that typically affected learning environments (Liu et. al., 2009, p.355). With the current increase of technology now and the shift towards three-dimensional learning in science, the use of technology to supplement or even guide learning is very applicable and apparent. Much more can be accomplished in classrooms when students have access to technology. Secondly, the engagement of students whilst using the technology to learn about aquatic plants was noted to have increased, and student preferences based on the surveys collected showed that the majority of students preferred the inquiry methods of exploration to common lecture methods that were typically used (Liu et. al., 2009, p.354).

In addition to the previously mentioned implications, and despite being an older study, the use of the information in conjunction with current shifts towards NGSS three-dimensional learning standards and practices is clear. Firstly, the use of 5E model in NGSS units has been noted to be successful in current literature, and the use of technology in the classroom has also been noted to
be successful for students as well. The use of these with each other can give teachers a method in which they can explore phenomenon in science when the constraints of their classrooms might have otherwise prevented students from fully engaging in the 5E learning cycle otherwise. Currently, our technology is so far ahead of where it was in 2009 that so much more could be accomplished.

In elementary science, nearly thirty-nine percent of teachers in the United States have reported that they feel well prepared to teach science. Compare that to teaching English Language Arts in which eighty-one percent of teachers feel ready to do so. Studies from a TIMSS video analysis has further indicated that many elementary science classrooms tend to teach science through a series of often unconnected science activities recommended by colleagues within the building to make up for the lack of confidence that elementary teachers tend to feel towards science (Hanuscin, et al., 2016, p.394). The author conducted a qualitative research study that analyzed the extent to which teachers' lessons showed conceptual coherence in which lessons are designed in a manner that connects phenomenon observed by students in a method that allows the students to make connections and discover science concepts. Furthermore, the author also looked at challenges faced by teachers when producing such conceptually coherent lessons, as well as make suggestions for professional development to target these teachers effectively (Hanuscin, et al., 2016, p.394-395).

Conceptual storylines were indicated in the literature as effective methods for allowing students to build on prior knowledge and experiences through a flow and sequencing of learning activities (Hanuscin, et al., 2016, p.395). Previous literature also indicated that teachers, when given conceptual storylines to analyze, tended to have difficulty identifying a productive anchoring phenomenon to organize their units around based on what they had analyzed (Hanuscin, et al.,
In each of the literature in which such actions, or similar ones, occurred, claims made from the literature focused on the theme that targeted professional development focusing on the construction of conceptual storylines would be a worthwhile endeavor for teachers to improve student learning (Hanuscin, et al., 2016, p.396). The authors of this case study used an instrumental case study approach (Hanuscin, et al., 2016, p.397), which allowed them to focus on the capacity for construction of the coherent conceptual storylines through the supported of targeted professional development on the topic.

In total, thirty-three elementary teachers participated in this case studies, all from 3rd grade classrooms across urban, suburban, and rural communities with a variety of teaching experience. The case study focused on the development of elementary teacher knowledge of physics and the use of the 5E learning cycle model through the professional development program. Teachers in the program used a physics curriculum for adult learners that was produced using the 5E learning cycle and was further designed for the professional development program by incorporating coherent storylines. Prior to the program, teachers were asked to submit lessons plans, and were also required to submit new ones at the end to measure changes in how teachers approached the creation of science curriculum using conceptual coherent storylines (Hanuscin, et al., 2016, p.399-400).

From the information gathered prior to the professional development, two challenges from these teachers were identified. The first was the teacher’s originally submitted lessons tended to focus on a multitude of concepts at once, rather than focusing on a one concept. Ultimately this was interpreted that teachers held the belief that the lessons could allow students to learn as much as possible in one lesson. Furthermore, the activities present in each lesson were not coherent and learning goals were often aligned with an activity-driven orientation (Hanuscin, et al., 2016, p.402). The second challenge identified was that several teachers had lessons that had one single hands-
on activity to support students understanding of a concept. Their lessons also lacked a specificity of a learning goal and were more task oriented overall (Hanuscin, et al., 2016, p.403-404).

Following the implementation of the professional development program, it was noted that teachers preferred the conceptual storyline model overall, but this preference was not related to the way in which the concepts connected and built on each other. But there was an increase in the perception that teachers felt they understood what a conceptual storyline was overall (Hanuscin, et al., 2016, p.405). As the professional development session continued, teachers were instructed and taught to use their activity driven lesson orientation to guide them through a coherent conceptual storyline that followed the 5E learning cycle (Hanuscin, et al., 2016, p.406). By the end of the professional development time, teachers' final lessons showed coherence in content, and allowed for students to build on their ideas which had not been previously seen in the originally submitted lesson samples (Hanuscin, et al., 2016, p.407).

While the implications for professional development for teachers can be determined from this particular case study, it would be feasible to also conduct a study on the effectiveness of these lessons developed from the professional development were for student learning in the classrooms following the return of the teachers. This would further support the implementation of similar professional development for teachers, if student learning was shown to have benefitted from the lessons.

The implications of this study revolve around the applications of this professional development program for the future of teachers as the shift towards Next Generation Science Standards and three-dimensional learning begin to take to the forefront of science education. It is imperative the administration and teachers engage in effective methods to build on cross cutting concepts, science and engineering concepts, and disciplinary core ideas in a manner that is coherent
and allows for students to explore and build on prior knowledge. The methods employed by this particular case study, though small, are important building blocks for the development of necessary professional development programs that allow teachers who do lack a background in science the necessary tools to overcome the challenges noted in the study for the benefit of their students learning.

A 2018 study (Fick, 2018) looked at the development of teaching methods to support student understanding of Cross Cutting Concepts (CCCs) from the Next Generation Science Standards (NGSS). According to the *K-12 Framework* for the NGSS, three-dimensional learning focuses on the content and science practices that students need to engage in and master in order to be successful members of society that are literate in science (Fick, 2018, p.6). Research, however, has not focused on how to support student learning of the CCCs, while there has been other research on student learning of the Science and Engineering Practices (SEP) and the Disciplinary Core Ideas (DCI) (Fick, 2018, p.7). Fick (2018) therefore has developed a model that incorporates support of students when learning CCCs through inquiry-based instruction, grounded in a constructivist theory for education (Fick, 2018, p.8).

The author argues that, in order for students to investigate a DCI through a CCC, they must first gain knowledge and experience with CCC in general (Fick, 2018, p.9). Focusing on a class of 7th grade middle school students, the research demonstrates how students are supported by their teacher when using a particular CCCs for the first time with a DCI and SEP. The particular unit being used focused on the exploration of water in earth’s surface processes, in which the Energy and Matter CCC was used in conjunction with the Systems and System Models CCC to support student learning (Fick, 2018, p.9). Sixty-three students participated in the study. Pre and post-test scores were collected that examined the performance of the students using the CCCs.
and student responses were coded according to whether the action corresponded to evidence of a DCI, CCC or an SEP. The unit developed for the research focused on four areas of interest: a clear content storyline, alignment of learning goals to standards, using a modified learning cycle to develop knowledge, development of knowledge through science practices, and opportunities for students to demonstrate their changing understanding of phenomenon (Fick, 2018, p.11-12). CCCs were integrated into the unit through being used as the framework for the unit (Fick, 2018, p.13).

Findings indicated that students tended to understand the content more when explicit discussion of the components of a system, a CCC, was initiated by the teacher following the implicit exploration of activities that utilized the systems CCC (Fick, 2018, p.21). Secondly, it was also found that by introducing the students to the general terms and structure of a CCC, they were able to use the terms in their explanations without needing to explore the broader concepts referenced in the framework of the CCCs (Fick, 2018, p.22). Furthermore, it was also noted that when teachers framed classroom discussions around the framework of CCCs, misconceptions about general scientific knowledge emerged more easily through the discussions (Fick, 2018, p.22). In addition to the qualitative data gathered, the pre and post-test analysis using a paired t-test indicated significant differences between the students understanding of the concepts in the pre-test compared to the post-test. Furthermore, students showed a greater understanding and ability to demonstrate knowledge of the CCCs regarding systems and systems models (Fick, 2018, p.26).

The research carried out, though useful, was only done on one class at one grade level in the middle school. While the theoretical uses of CCC as a method of framing units for students to develop relevant scientific practices and understandings of the natural world, more research is needed into this area of research. Cross-cutting concepts, as noted in the literature, have not been researched as thoroughly (Fick, 2018).
There are several implications that can be pulled from this study. Firstly, the significant growth between pre and post-test scores for student performance on DCI and CCC is a clear indication that framing units using a coherent storyline focusing on the use of CCC shows potential to students to explore DCI’s more effectively and broaden their understanding of how phenomenon come to be in the natural world. Secondly, CCCs are noted to possess common language that, when used across disciplines accurately, could support students in making connections across disciplines more effectively (Fick, 2018, p.31). However, the author also noted that not all CCC are appropriate for use with DCIs, and careful design of units must be taken into consideration before implementing new material in the grade level bands (Fick, 2018, p.31). Furthermore, it would be feasible to argue that training on the use of Cross-Cutting Concepts as a framework for NGSS units in all grade bands would be a feasible method to allow for vertical alignment K-12 in schools wishing to do so. Administration and Professional Learning Communities, therefore, should take into consideration the time needed to complete such trainings as well as the time needed to produce such units that are considered suitable for the NGSS standards.

3D Learning Progressions, Media and the 5E Learning Cycle

As standards begin to shift it is important to determine how well students make progress toward understanding patterns of evolution through a 3-Dimensional Lens as suggested by the Next Generation Science Standards (NGSS) and K-12 Framework for the NGSS (Wyner & Doherty, 2017 p. 788). A study was conducted in 2017 that evaluated such progress through the design and implementation of a year-long learning progression of evolution and natural selection through various Disciplinary Core Ideas (DCI) and Cross Cutting Concepts (CCS) (Wyner & Doherty, 2017). The learning progression was developed based on evidence from past student learning over time in previous research, and used an assessment triangle that focused on the
interactions between how the students represented knowledge, the assessment tasks used, and the tools use to evaluate student responses and artifacts produced (Wyner & Doherty, 2017 p. 792). The topic focused on scientific observations that led to the naming of street trees and determination of tree relatedness through evolution and natural selection. The learning progression was reevaluated through two cycles with use of the assessment triangle. Results from the study come more from the second cycle of the assessment triangle. Clinical interviews and assessments were developed, the actual alignment of the framework to student performance was investigated, and coding of student interviews and assessments were done to look for patterns and progressions in learning habits and achievement outcomes (Wyner & Doherty, 2017 p. 793).

Twelve middle school teachers in New York City participated in the study with the 6-8 grade band focused. A broad mix of race and socioeconomic status was present within the study. Students were separated into two groups: an implementation group with a total of 305 students’ grades 6-8, and a control group with 265 students grades 6-8 (Wyner & Doherty, 2017 p. 793-795). Students were assessed at four times during the year: once in the fall prior to initial implementation, once following the fall implementation, once prior to the spring implementation, and once following the spring implementation. Students were assigned levels (1-4) based on the progress throughout the various assessments (Wyner & Doherty, 2017 p. 794). Level 1 students had the lowest level of understanding and Level 4 students had the highest level of understanding. This organization was used for two sections of the research study: a look at observational habits and practices, and the understanding of common ancestry and length of change over time (Wyner & Doherty, 2017).

Results were reported in various categories. First, it was noted that interviewed students were able to give rich descriptions of strategies they employed to determine the names of street
trees through observational methods. Second, it was reported that the majority of students progressed from a level 1 or 2 to a level 3 or 4, showing marked improvement in learning of content and science practices outlined in the Framework. When it came to categorizing trees based on relatedness, however, student growth was more difficult to determine. Again, the majority of students were able to show growth, but analysis of written assessments was not enough to assign a level to students. In fact, level 3 students were only determined based on interviews with the students.

The researchers also reported student understanding of common ancestry and length of change over time (Wyner & Doherty, 2017 p. 806). Analysis of interviews and written assessments determined that middle school students expressed three levels of understanding for these topics; the lowest being a Level 1 and the highest being a Level 3. Responses and coding of the responses indicated that students had a general understanding of evolution from common descent, and their misconceptions regarding natural selection or other evolutionary mechanism did not significantly interfere with understanding the importance of common ancestry among the trees (Wyner & Doherty, 2017 p. 807). When looking at the pre/post implementation data, it was noted that prior to the use of the learning progression students were unable to associate relatedness with common ancestry. However, following the implementation of the learning progression, more than half were able to make the previously mentioned connection (Wyner & Doherty, 2017 p. 807).

A number of important implications for curriculum designers and teachers can be determined from the study. Firstly, student performance on observational practices during the learning progression were tied to how well they made observations and could differentiate between useful observation and not useful observations. This came down to the expectations that students held for what they were supposed to notice (Wyner & Doherty, 2017 p. 808). Content specialists
and researchers in the fields of various science are trained and gather a set of expectations for observations that apply within their particular field. Biologists notice different things that physics, in other words. When students are trained and practice observing under the framework of particular expectations, the nature of their observations tend to reflect such expectations within the field. This was supported by the growth in student learning and ability to name and identify trees following the implementation of the learning progression (Wyner & Doherty, 2017). Therefore, the authors suggest that an all-purpose scientific guide to science practices may not be enough for students (Wyner & Doherty, 2017 p. 811).

Implications regarding assessment design were also noted in the study. Essentially, the understanding of concepts cannot be measured apart from the scientific practices used. Assessments that incorporate the demonstration of scientific practices in real life situations is needed to supplement that discrepancy between paper assessments and real-life interactions (Wyner & Doherty, 2017 p. 813). Teachers and curriculum designers, therefore, need to carefully produce assessments that cover a wide range of performance and content expectations that are assessed in a multi-modal fashion. This may prove difficult as time is a constraint for many, if not all, teachers.

The authors of a 2016 study sought to determine the effect of the 5E learning model with support for learning through WebQuest media on student achievement and their satisfaction in relation to learning (Sahin & Baturay, 2016, p.158). With the shift towards more inventive and active teaching methodologies in the advent of new standards and shifts in pedagogical approach, the use of WebQuest media has become one such area of interest for many teachers. The study highlights the benefits of WebQuest for teaching as developing students' academic and cognitive skills more than other internet based activity, improves critical thinking skills, increase motivations,
allows for access to the Internet, allows collaboration, and improves logical thinking (Sahin & Baturay, 2016, p.160).

The study consisted of a K-12 school in Turkey, in which 104 students participated in the study within a 10th grade class. Participants were randomly assigned to groups. The experimental group consisted of learning through the 5E model with support for instruction via the WebQuest media designed for the unit. The control group consisted of learning through the traditional 5E model approach for the same curricular material. Data was collected via an achievement test, and information regarding student’s computer familiarity was also gathered prior to implementation of the material (Sahin & Baturay, 2016, p.162). Further information was gathered via survey that included level of interest in computers, and daily internet use. Following the completion of the learning segment, students were also given a survey modeled after the Likert scale regarding the satisfaction of students in the experimental group (Sahin & Baturay, 2016, p.163). The content of the unit focused on the basics of computer science and communication via the internet.

When comparing the pre and post-test scores, data analysis determined that post-test scores favored the experimental group rather than the control group. It would be feasible to therefore ascertain that the student achievement of the experimental group increased more than the control group. Furthermore, analysis of the satisfaction survey indicated that female students were more satisfied with the WebQuest materials than the male students (Sahin & Baturay, 2016, p.168). Furthermore, while there were differences in the years of computer experience between the students in the experimental group, there was no statistical significance in the responses of students with different amounts of experience in computer use on the satisfaction survey (Sahin & Baturay, 2016, p.169). Interest in computers and daily internet use factors were found to not be statistically significant in the satisfaction survey.
When designing curriculum that is more interactive, interesting, and active for students, the interests of students should be kept in mind. With the constant changes in technological innovations, students are naturally more open to using technology in the classroom. Furthermore, numerous studies have found that proper use of media and the internet in the classroom has a positive effect on student learning, and the 5E model has also been found to be an effective pedagogical approach to teaching as well. Combination of the two, based on the results of this study, would be a good way to allow students to further develop critical thinking skills, collaborative skills, and maintain interest in the subject matter at hand. Curriculum designers and educators, therefore, should consider the benefit of transitioning curriculum to the online world possibly to allow students to be able to have the breadth of the internet at their fingertips. Not only has this method been indicated to make learning more fun for the students, but other studies have indicated it also has a positive benefit for the teachers as well (Sahin & Baturay, 2016, p.169). High satisfaction levels can be attributed to high motivation in students as well (Sahin & Baturay, 2016, p.170).

Furthermore, educators should seek to give students the opportunities to discover new knowledge and challenge their previously held knowledge (Sahin & Baturay, 2016, p.170) In order to produce such activities, teacher will need professional development on both the 5E learning process (if unfamiliar) and how to produce WebQuests. The WebQuests produced for this study, however, were modeled after the 5E Learning model and were therefore organized so that certain sections of the website had an engage area, explore area, etc. If teachers were to adopt this particular method, training in computer science would also be needed, but it would also be feasible to achieve such without producing an entire website for the features used in this study.
A 2015 study chose to determine the effect of a context-based approach on pre-service primary school teachers’ understanding of matter and phases of matter, and their general attitude towards chemistry. As matter is considered the heart of the chemistry content (Demircioglu et. al., 2015, p.2), a student’s understanding of matter carries a particular importance as they progress through school from a very young age. Because misconceptions, referred to as alternative concepts in the study, may arise from teacher interactions, the authors of the study wanted to also know if using a storyline approach to learning through context in particular would alleviate some of the misconceptions the pre-service primary teachers currently had (Demircioglu et. al., 2015, p.3). Furthermore, they also intended to determine if the attitudes toward chemistry following the implementation of the context-based approach had a significant effect on the teacher's attitudes towards chemistry as well (Demircioglu et. al., 2015, p.5).

Thirty-five pre-service primary school teachers enrolled in General Chemistry in a Turkish University took part in the study. A simple pre-test and post-test analysis and comparison was used during the experiment, with no control group present. Furthermore, interviews with three random male and three random female students following the conclusion of the context-based approach implementation was also done to explore more on the attitudes of chemistry. Following the post-test was the use of a delay test to also measure whether the implementation of the context-based approach truly had an effect on long term retention of the content (Demircioglu et. al., 2015, p.6-7).

The results indicate that students had a significant increase in their post-test scores, some that were considered to be, on average, higher than other studies in science education literature (Demircioglu et. al., 2015, p.12). The effect of the context-based approach was shown to statistically significant for the multiple choice and the open-ended portion of the exam
(Demircioglu et. al., 2015, p.13). In addition, the delayed test showed no difference when compared to the post-test, likely showing that the context-based learning approach was successful at developing long term retention of the content learned (Demircioglu et. al., 2015, p13). When the exam was broken down into subtopics for further analysis, the pre-service teachers showed notable increases as well. Similar findings have also been reported in previous literature, strengthening the theory that such context-based approaches are effective for teaching chemistry concepts as well, more so than the typical traditional approaches to chemistry (Demircioglu et. al., 2015, p.14). When looking at the effect of the storyline approaches on reshaping alternative concepts the pre-service teachers came in with, it was found that progress was shown with eliminating the misconceptions and even corrected two misconceptions completely during the process for many of the pre-service teachers in the class (Demircioglu et. al., 2015, p.16).

Student interviews following the conclusion of the implementation showed that students generally found chemistry much more enjoyable. Teachers reported that they found the storylines easier to remember than other more formal text (Demircioglu et. al., 2015, p.20), and they felt they understood the material more through the storylines (Demircioglu et. al., 2015, p.21). Furthermore, a comparison of the attitudes reported via survey and the post-test showed a statistically significant relationship (Demircioglu et. al., 2015, p.19).

One of the most notable implications of this study is the correction of the alternative concepts/misconceptions of the primary pre-service teachers (Demircioglu et. al., 2015). In a K-12 education system, misconceptions passed on by teachers to student, typically unintentionally one would imagine, no doubt effect student understanding and attitude towards content areas. With the use of context-based approaches such as the storylines referenced in the study, identifying, addressing and fixing such misconceptions becomes more doable for teachers. Furthermore, the
clear increase from pre to post-test is strong evidence for the employment of such methods in the classroom when teachers are adequately trained in the content enough to do so. This method further allows teachers and students to make connections between theoretical knowledge and real-life applications (Demircioglu et al., 2015, p.22). This concept is an important staple of context-based approaches and aligns with the 5E model in which students build off of prior knowledge and experience.

In addition to the aforementioned implications, the necessity to more effectively train primary level teachers in unfamiliar content was also apparent. A number of the teachers in the study carried misconceptions regarding matter that would make upper level science in middle school and high school more challenging when students leave them due to the passing on of such misconceptions. While this intervention method assisted these particular sets of teachers, future work on the part of the post-secondary institutions should be done to help remedy the gaps in education for primary school teachers that are expected to effectively teach every core content and do so correctly and well. Teacher preparation programs should look to develop content that achieves similar results as this study did to better the future of our students, particularly in the United States where such practices are not typically employed.

**Methods of Teaching Science Using the 5E Model with 3-Dimensional Learning**

As states shift towards the Next Generation Science Standards (NGSS), changes in the common approaches to teaching science are needed to keep up with the changing requirements of students. The 5E learning cycle is one such model that, while notably successful, requires some adaptation in order for lessons to be realigned with the NGSS Standards. Part of the NGSS focuses on the learning and practicing of science and engineering practices. As noted by the author,
however, the initial release of the NGSS led to a myth that if a learning activity was formatted to be a form of inquiry, that activity build science and engineering practices (Forsythe, 2018, p.74). This is not true. Students require more than simulation of the actions carried out by scientist’s they need specific activities in which they continuously refine their understandings of the actions and how to make decisions about the actions carried out in investigations (Forsythe, 2018, p.74).

The author recounts an example of a modification to a 5E inquiry lesson regarding modeling of seed dispersal methods and plant adaptation, and brings the reader through each of the 5E learning steps for the particular lesson, detailing how each step builds on and amplifies students understanding of science and engineering practices, while engaging in the language of science (Forsythe, 2018). The engage portion of the lesson revolves around the introduction of a storyline in which students explore the changes of the landscape of Krakatoa in the several years following the last major eruption that occurred. This engagement phase is noted to be an ideal way to build connections between themes across the scientific content areas, also known as the cross-cutting concepts. The identification of these connections in this phase is essential to notifying students that the engineering practices built upon in previous units continue to be applicable in this lesson (Forsythe, 2018, p.74).

Following the revamping of the engage phase to meet these new practices for students, there should also be a shift in the explore phase in which the students are put in the positions of scientists. Important in this phase is to create activities that emphasize that learning is about practices as equally as it is about the core ideas (Forsythe, 2018, p.75). As students engage in these discussions that model the practices of scientists, the explain phase should also support these practices seamlessly. The author of this study opted to adjust her older explore/explain lesson to advance students practice of planning and conducting of investigations—helping students to make
proper and useful observations, design investigations based of observations, conduct discussions that incorporate the various aspects of the phenomenon being explored (Forsythe, 2018, p.76).

The elaboration phase typically results in new questions and investigations regarding the phenomenon. One suggested method from the author that worked in their lesson was the use of activities that allowed students to propose new questions and data collection plans to continue their investigations, as well as tie their ideas to next steps taken by the particular scientists in the field of interest (in this case they were ecologists) (Forsythe, 2018, p.77). This phase, as noted by the author, was changed nearly every year based on the students interests and data collected.

Evaluation of their practices and core ideas helps to document their growth and signal where instruction should be changed and adapted. The author uses a rubric to assess students that builds on the practices throughout the curriculum for the year. These can be modeled into formative assessment checklists and reflected by summative assessments (Forsythe, 2018, p.78).

The author’s description of a modified 5E learning model that incorporates the NGSS best practices for science and engineering in conjunction with cross cutting concepts and disciplinary core ideas gives us a unique example of how to engage students in science aligned to a new curriculum standard set that can seem a bit daunting. One of the most important implications from this article is that most inquiry based activities as they are now, may not be sufficient enough to connect students' knowledge to their scientific practices (Forsythe, 2018, p.75), and teachers are going to need to find ways to adapt their current methods of teaching to allow students more opportunities to build on these practices in a progressive manner. Furthermore, it would be feasible to ascertain that current approaches to inquiry-based investigations for many teachers will need to be carefully looked at to determine if such activities do fit the best practices models determined by the NGSS. Regardless of such, the author’s example of a new 5E model approach focused on the
best practices of the NGSS gives teachers an important starting point for revamping curriculum to better suit the needs of the future generations of students.

When designing a 5E learning progression or a storyline approach for a particular set of NGSS disciplinary core ideas and cross cutting concepts, it is important to develop not only an engaging anchoring phenomenon, but also proceed through the learning of the phenomenon using a routine. The author suggests the use of the Anchoring Phenomenon Routine developed by Brian Reiser, Michael Novak, and Tara McGill from Northwestern University. This routine, as noted by the author, provides an opportunity for students to describe observations, ask questions, and develop explanations to tentatively answer their proposed questions. This method does not require that the teacher is solely in charge of developing the particular sequence of lessons. Instead, the student questions drive the lesson sequence, allowing the investigations to become more meaningful to the students (German, 2019, p. 32).

In order to accomplish using an effective anchoring phenomenon, the author stresses that teachers write their own explanation of the phenomenon, causing them to thoroughly think through the content involved in the phenomenon (German, 2019, p. 32). Following this, there are four essential elements to properly introduce the anchoring phenomenon to the students. These are to explore the anchoring phenomenon through observation/interaction, create initial explanations, identify related phenomenon, and develop questions/next steps to target the science concepts present (German, 2019, p. 32-33). In particular, the author notes that class discussion following each of the four steps of the Anchoring Phenomenon Routine are essential for developing students’ communication skills (German, 2019, p. 33). Through each of these steps, student conceptual development and learning can be monitored. This is done as students individually record their own individual thoughts as they progress through the phenomenon (German, 2019, p. 34). The final
portion of the Anchoring Phenomenon Routine, in which students determine their next steps for investigation, will typically fit well for students to write an explanation of the anchoring phenomenon.

The example given by this author revolves around student's exploration of a phenomenon in which striking two steel balls against each other with a paper in the middle produces a hole in the paper, and a subsequent burning smell when the process is repeated. As students' progress through the Anchoring Phenomenon Routine, they initially surmise the hole and smell is due to the forces applied only. As they continue to progress through the Anchoring Phenomenon Routine making connections to other phenomenon, they proposed several questions that can give an explanation to the anchoring phenomenon when they are carried out (German, 2019).

When developing engaging curriculum, it is extremely important for anchoring phenomenon to connect to student interests and engage them. As such, when developing such phenomenon as a central point for a lesson segment, the Anchoring Phenomenon Routine is seen as an effective method by which teachers can engage students in the practices of science. This is the first major implication of the reading is such. In addition to this, the clear gains in the student’s ability to communicate as reported by the teacher are feasible to infer. Students use terms such as “round,” “slower,” “collision,” and refer to topics like composition and energy in relation to the phenomenon. This clearly shows that, while the students were not outright taught the content, they discovered it through continued investigation of the phenomena. When thinking about the best practices outlined in the framework of the NGSS, the progression of student learning through the use of the Anchoring Phenomenon Routine is a clear method by which to accomplish this. More teachers and curriculum instructors, therefore, should consider the use of the Anchoring Phenomenon Routine method when developing new curriculum to best suit student needs to
accomplish the performance expectations in the Next Generation Science Standards. However, as with any particularly new approach to curriculum, professional development and time to develop curriculum will be needed by teachers and should be thought about before simply rolling it out. Based on previous literature on the subject, and the example the author provided, it would be feasible to infer that this particular method requires more time and thought than teachers might typically think of.

It has been argued in a 2017 article that in order to achieve the goals of the NGSS Framework and Standards in the classroom, a shift in the approaches to teaching science in which instructional approaches and materials support coherence from the perspective of the student is required (Reiser et.al., 2017, p.1). For example, a well-designed series of lessons incorporating demonstrations that each demonstrate a different topic that connects to each other through a cross cutting concepts makes coherent sense to the teacher, but to the student this may not be so clear (Reiser et.al., 2017, p.2). This coherence for students, according to the suggestion of the Framework, revolves around a developmental progression in which students build on what they see, focus on limited core ideas, and integrate knowledge and practices. Teachers, therefore, need methods by which students can clearly see progressions among science practices more easily than before.

The authors further present that coherence from the student perspective is demonstrated when the classroom community partakes in meaningful investigations into phenomenon. During these investigations, students develop the core ideas over time and through their own driving questions—engaging in sensemaking. This, however, requires that teachers co-construct the lesson with the students, not merely allowing them to adventure out on their own (Reiser et.al., 2017, p.3). It would be feasible, therefore, to infer that teachers act more as guides for the students through
this process. This, as the author notes however, requires a shift in the mindset in which science classrooms typically operate—shifting the power structure in classrooms (Reiser et.al., 2017, p.3). Essentially, this is also an epistemic agency argument. Students must be partners in the knowledge-building work as they engage in a classroom community involved in the meaningful science practices outlined and suggested by the Framework (Reiser et.al., 2017, p.4).

The authors also note that the building of this knowledge requires investigations to test, generalize and refine models regarding the phenomenon in question. This, in itself, requires more than the basic pattern recognition and relationships between experimental factors skills typically taught in science classrooms. Rather, it requires the students to produce a question in which they determine how the manipulation of the materials in the phenomenon supports or refutes explanations of how/why the phenomenon occurs (Reiser et.al., 2017, p.4).

The result of these arguments put for by the authors is the conceptualization of a coherent storyline for NGSS standards in which teachers build units around a central anchoring phenomenon, determine methods to motivate students through student-driven questioning, develop methods to use practices to help students figure out pieces of the phenomenon, and pushing students to delve deeper into the ideas they learn as a group. All of this surrounds the idea that they have a classroom community that engages consistently in the scientific practices outlined by the Framework (Reiser et.al., 2017, p.5-9). The authors proposed four questions to guide teachers in developing these coherent storylines. The first is how do you kick the investigation off (Reiser et.al., 2017, p.5)? This question revolves around the concept of an anchoring phenomenon—something to ground the unit. It is an engaging phenomenon that provides room for questions and investigations to occur. A major implication from this question is that teachers will need to evaluate the demonstrations they use to engage students and choose ones that are
investigable at the level and in the classroom that they teach. It’s inevitable that some phenomenon will not be useful in certain rooms, and teachers must take the time to evaluate and choose ones that best suit their students and environment.

The next question is motivation—how do you motivate the students to investigate their observations and questions further? The authors propose that this process of investigation should be ongoing and is a process if looking forward and looking back. This method allows students to evaluate what they have already answered, and what they need to look into next as part of their next investigations (Reiser et.al., 2017, p.6). A major implication that can be pulled from this is that teachers will need to be able to allow students some control of what they learn, again, shifting the control of the classroom as noted by the authors previously (Reiser et.al., 2017).

The third question revolves around how we, the teachers, help the students use the scientific practices to figure out the pieces of the phenomenon and driving scientific ideas. The authors note that students should see the practices they are engaging in during this process. Coherence becomes evident during this portion of the lessons, in which students relate the practices to the core ideas of the lesson, ultimately tying it to the work they are currently completing for the investigation (Reiser et.al., 2017, p.7).

The fourth question relates to determine how to push students further and revise the science concepts and ideas they have concluded as a classroom community. The authors suggest doing so by identifying a possible problem or a gap in the current community knowledge gained (Reiser et.al., 2017, p.7). The final question is how do teachers help the students put all the pieces together? As noted in the NGSS Framework, the standards are set up so that they need to be built one piece at a time. Teachers need to design these storylines so that each investigation produces a piece of the puzzle while producing new questions at the same time. This can be seen as a daunting task
for teachers, but not impossible. With proper time and training on phenomenon-based approaches for NGSS, teachers can accomplish using a coherent storyline-based model to educate students. For curriculum developers, this is particularly important in order to develop coherence for textbooks and other materials provided to schools that are aligned to NGSS standards and best practices. Furthermore, the ideas outlined in this article provide a framework for tackling the NGSS framework in a productive manner.

**Technology and Three-Dimensional Learning in Science.**

Chen et. al (2017) sought to investigate the effectiveness of a three-dimensional cognitive mapping approach to support learning through inquiry for students. The authors were interested in the mapping approach’s effectiveness in an online learning environment, how scaffolding of different ability level students compared in the inquiry environment, and the effect on student motivation and emotional experience in reference to their attitudes to the inquiry learning approach, the perceived level of skill for inquiry learning, anxiety levels, overall confidence (Chen et. al., 2017, p.192). The study consisted of forty-eight students in eleventh grade—twenty-four males and females respectively. Students were ranked according to pre-test scores as either high, medium, or low academic students, then randomly dived into groups of three with one student from each rank (low, middle and high) (Chen et. al., 2017, p.196).

Students were tasked to create a Three-Dimensional Cognitive Map, which is an external representation of the students’ learning progression through an inquiry-based phenomenon in which students demonstrate knowledge gained through notation and mapping of their hypothesis as it changes over time (Chen et. al., 2017). After initial hypothesizing, students begin group discussion and collaboration. During this process the students can only support or refute a
hypothesis when they have gathered relevant data and made observations (Chen et. al., 2017, p.196).

Results from the post-test indicate no significant difference between the high, middle, and low-level learners. Results also showed that there was a significant knowledge gain in all three categories of students, and the low-level students showed the greatest change overall compared to the other students (Chen et. al., 2017, p.198). Responses from student interview questions noted that twenty-six students mentioned that the systematic thinking brought on by the Three-Dimensional Cognitive Map helped them to organize their thoughts in a logical manner overall (Chen et. al., 2017, p.199). Student attitudes were also noted as showing a positive trend in response to the inquiry activity, and that the development of the external representation helped them to generate hypothesis, reasoning and draw relevant conclusions per post-test and survey/interview results (Chen et. al., 2017, p.200).

The most noticeable implication drawn from this study is the use of Three-Dimensional Cognitive Mapping as external representation for the scaffolding of lower academic level students. With significant gains in achievement shown from this particular method, teachers should look to employ such methods in their inquiry-based activities and curriculum to best support lower students. Learning through inquiry requires that students learn how to build ideas and hypothesis in a logical manner, which can be difficult for some students. The use of this model, therefore, would allow for students that find inquiry generally difficult to show and have more confidence in their skills, as well as increase student achievement overall. This is, of course, if it is done correctly. It should be noted that proper training on the implementation of such a tool should be provided for teachers who wish to use such and should be included in tool kits for the Next Generation Science Standards.
The authors also noted that this tool for support could assist with narrowing the academic gap between high and low students, and while high level students did not make significant gains, the gains made by lower students (as already noted) help to narrow such a gap (Chen et. al., 2017, p.201). This approach also has an important impact on student emotions. Results of the study also indicated students had higher levels of confidence and lower levels of anxiety following the use of the mapping tool. With a focus on mental health apparent in today’s society, teachers should look to include tools that reduce learning anxiety and improve their confidence, which is connected to their inquiry abilities (Chen et. al., 2017, p.201).

Little research, however, has been done on the effectiveness of this model. More research is needed in all grade levels and is thus a limitation to the validity of the claims put forth by this study. Furthermore, inquiry skills were assessed with a survey at the end of the learning segment and should be assessed authentically (Chen et. al., 2017, p.202). Nonetheless, the potential importance and use of this tool is still inherently present from the results of the study and should be strongly considered when developed Three-Dimensional Learning Progressions in new curricula.

The increasing use of mobile devices, in particular laptops and mobile phones, have shown positive potential in the classroom and in outdoor learning. Previously to this meta-analysis, little quantitative research has been conducted to determine the effects of integrating mobile technology into classrooms (Sung, et. al 2016). The purpose of this study is to (1) provide an overview of what subjects are using such devices, (2) quantify the effectiveness of mobile technology on student achievement, (3) determine how the moderator variables influence the effect of the technology on achievement, (4) summarize advantages and disadvantages of mobile technology use (Sung, et. al 2016, p. 254). A total of one-hundred and ten articles were used for the analysis (Sung, et. al 2016,
There were six moderator variables used in the study: subjects taught, objectives of mobile learning, software/hardware used, rules of engagement with mobile tools, context of activity, and method of interaction between students/participants (Sung, et al. 2016, p. 255).

A number of results were reported from this analysis. Firstly, the mobile devices were not effective with mix-aged students (Sung, et al. 2016, p. 260). Next, the implementation of handheld devices resulted in higher learning outcomes compared to laptop use (Sung, et al. 2016, p. 261). Short-term interventions with students using mobile technology were found to be the most effective, furthermore with long-term intervention showing little increase in achievement through use of mobile technology (Sung, et al. 2016, p. 263). Software used by the teachers was primarily general-purpose software (i.e. a word processor) and fewer teachers achieved the goal of greater efficiency and effectiveness using technology adapted instruction. Learning oriented software, however, showed more promise for student achievement and promoted formative assessment, cooperative learning and social interaction between students (Sung, et al. 2016, p. 262). The study also found that inquiry-oriented teaching methods were the most effective methods used in conjunction with mobile technology use in the classroom (Sung, et al. 2016, p. 263). One particular find was also that game-based learning did not have a significant effect in mobile learning, but rather affected motivation (Sung, et al. 2016, p. 263).

The authors highlighted three major implications from the results of the study. The first one was that mobile devices may be able to enhance certain teaching methodologies such as self-directed study and inquiry-based learning, as well as increase the use of formative assessment (Sung, et al. 2016, p. 265). The second is that intervention duration was most effective during short term use, and this is an indication of the need to enhance such duration through closer integration of curriculum and technology, followed by an assessment of higher-level skills. In particular, the
authors note the need for problem-solving and critical thinking skills to be assessed, and for curriculum to be developed in which mobile technology is used to enhance such higher-level skills (Sung, et. al 2016, p. 266). Finally, teachers should be encouraged to modify curriculum to better implement the use of mobile technology (Sung, et. al 2016, p. 266).

With the advent of software like Google Suite, and with the push for more schools to adopt such software into their curriculum, more development of learning tasks in which students develop higher level skills and higher learning achievement is needed. The study noted that primarily ELA and Science classrooms used the technology, particularly laptops (Sung, et. al 2016), and furthermore, it could be implied that other subjects should start to use such technology more often as well, perhaps even developing cross-curricula activities. Training in such software, naturally, would need to occur in order to develop such curricula, and furthermore teacher-preparation programs should also look to include mobile learning in their curriculum as well. Further studies would be needed to look at the effect of such methods over time, but the general outlook looks positive for student learning. In particular, the authors currently suggest teachers to modify software that is already available for their purposes, rather than produce new programs. In addition, they also argue for research-based programs to be customized in conjunction with university level researchers as mentors to teachers (Sung, et. al 2016, p. 266). While this makes teaching a bit more complicated, the connection of K-12 and College Education is clear from this argument, as is a further reason for the use of mobile learning software in the classroom more often.

Inquiry-based learning has been suggested as an effective and efficient method for motivating students and fostering curiosity in science education. Integration of learning with mobile technology allows for a new level of guidance and interactivity in inquiries supported by such technology. Thus, such methods look to provide opportunities for students to engage in a
large range of learning activities that given them a large sense of freedom over their learning. With such autonomy, however, not all students are poised to do well. In particular, increasing the autonomy of learning with less support tends to lead to less than desirable gains in learning achievement for students. The authors of this study complete a meta-analysis of 62 studies that looked at mobile learning, inquiry-based learning, supporting students with both methods respectively (Súarez et al., 2018, p.39).

Six dimensions of analytical framework were used to evaluate the sixty-two studies referenced in the meta-analysis. These dimensions were goals, action, strategy, reflection, content, and monitoring, in which degrees of learner autonomy were analyzed (Súarez et al., 2018, p.41). Furthermore, with the intent to deepen the analysis of the studies, a three-step processes were carried out. The first step was the categorization and clustering of the type of mobile activities. These types were found to be direct instruction, access to content, collection of data, communication between peers/teachers, and context support for students. These initial types were further distinguished and became the twelve types of activities that are supported in inquiry-based learning. The next step was the development of the analytical framework already noted. The final step was the analysis of the twelve supported mobile activities according to the six analytical frameworks (Súarez et al., 2018, p.41-42).

Results indicated that 91% of the studies used data collection in conjunction with mobile activities, followed by direct instruction (70%), access to content (69%), social interaction (32%) and interactions between context and student (25%) (Súarez et al., 2018, p.42). Direct instruction had more studies focused on location guidance (using GPS, QR codes, and Geocaches for example) and had the fewest that studied metacognitive support through mobile learning (i.e. interpretation of data) (Súarez et al., 2018, p.43). Direct instruction was noted to allow learners to
execute autonomy with their learning in a step-by-step process. Looking at the access to content, it was found that while students received support and guidance, that did not necessarily translate to the delivering of content (Súarez et al., 2018, p.44). For data collection, learner autonomy and agency are reflected in each of the six analytical categories (Súarez et al., 2018, p.45). Peer to peer interactions demonstrate these categories as well, although the degree to which students can reflect on learning depends on whether or not interactions are synchronous or asynchronous. More reflection tends to happen with asynchronous learning (Súarez et al., 2018, p.46). Finally, contextual support was broken down into three subcategories: augmented experience, immersive experience and adaptive feedback. Immersive experiences are shown to increase student learning agency/autonomy, but adaptive feedback is more useful when looking to have student reflect on their learning as it provides incremental support (Súarez et al., 2018).

Mobile learning activities have shown to support inquiry-based learning, giving learners opportunities to be in charge of their learning, to a degree. Depending on the type of activity, the learning agency, or autonomy of the learner, has been shown to change in one or more of the six categories outlined in the framework of this meta-analysis. In general, this study determined twelve inquiry-based learning mobile activities to support learners in a variety of ways. For teachers, this information can be used to support student learning. For example, students that are not very independent or get distracted easily, can be supported with activities that do not give them full agency, while still ensuring that they inquire and build on their observations and questions in a meaningful way. However, if a very independent and focused student takes part in the inquiry-based activities, they can be given activities that allow for greater control of the dimensions of learner agency (Súarez et al., 2018).
In science education in particular, the use of inquiry-based learning is an ever present and ever-growing movement to support students three-dimensional learning of science content and development of science skills. Teachers, therefore, should look to studies such as this one to determine effective inquiry-based mobile activities that are suited to their students’ needs. While individual student needs is more time consuming and requires more planning time, software and curricular designers should look to develop software that allows students to engage in inquiry based learning at vary degrees, with suggested uses for teachers in order to better align the curriculum writers, educators, and software designers in an ever growing industry. In the case of Next Generation Science Standards, course bundling in conjunction with the use of mobile activities can be used as anchoring phenomenon to a degree, and depending on the student, the anchoring phenomenon could be adjusted in order to better scaffold student questioning, observation making, data collection, and evidence-based conclusion skills.

**Phenomenon-Based Teaching and Assessments in 3-Dimensional Learning.**

German (2018) describes the methods by which teachers can use every day phenomena to drive storyline development aligned for the Next Generation Science Standards, and reports the results and observations from research done with her own students using everyday phenomena. Phenomena, as defined by the author (German, 2018, p.32), are observable events that increase student engagement and allow for subsequent lessons that provide a focus for learning through a narrative using the phenomena. In essence, phenomena are used to guide storylines. These phenomena are referred to as anchoring phenomena and control the storyline of a series of lessons or unit. However, the author notes that many teachers find determining an anchoring phenomenon as particularly difficult, often overlooking some everyday phenomena that are more ordinary rather than extraordinary (German, 2018, p.32).
The author uses the example of making ice cream for her unit of study with her middle school students. Ice cream, though often overlooked, includes complicated processes such as energy transfer, states of matter, and the kinetic theory of matter. From the interactions with her students from such activities previously, she notes that it will take more than one class period to develop their explanations for the phenomenon. Storyline units require the use of student driving questions and research by the student to come to their own conclusions regarding how a phenomenon occurs. She recommends focusing students with a task statement that directly mentions in the phenomenon observed in class—in this case making ice cream. This task statement limits their explanations to only the making of ice cream in class, and final explanations must include charts, data, and models from classroom investigations (German, 2018, p.32). The author highlights that, following the use of these every day phenomenon in her classroom (such as making ice cream), student learning and engagement have shown overall positive increases and the students have been connecting their learning to their personal experiences (German, 2018, p.34).

Direct implications for stakeholders were not necessarily mentioned in this article, but several can be drawn from it. Firstly, the positive gains in student engagement (German, 2018, p.34) shows promise as an interactive addition to science teaching methodology. Furthermore, increases in student learning through the use of the phenomena as a narrative to guide student learning through a learning progression is a clear positive. However, the time required to develop such methodology for students must be taken into account by teachers that wish to pursue such teaching styles. For example, the author suggests to work through the conceptual storyline in the view point of a student—working through desired explanations that students would produce as well as the thought process for researching, and finally assessing using the phenomena as an assessment task (German, 2018, p.32). This requires an in depth understanding of new
performance expectations, familiarization with content and thought practices that, for some teachers (particularly general science) might not be as familiar as they once were. Some teachers have only taught physical science for several years at the general science level, and although this particular example of ice cream production focuses on only physical science performance expectations, there are other content standards that are perhaps best taught together. Time and patience will be needed on the parts of the teachers and students to partake in the use of phenomenon to guide conceptual storylines as well as to develop and use them to their full capabilities.

While the author highlights the importance of everyday phenomena in science education, a further implication regarding such phenomena is the whether or not the phenomena is authentic. Students should be presented with real-world examples that are relatable for them, and thus teachers should understand that there will be no one size fits all phenomena that can be used for conceptual storylines that are well-designed enough for their particular set of students. In other words, phenomena that are used in rural communities will not necessarily be the same in urban communities—depending on the performance expectation of course. Therefore, teachers will need to determine the best authentic phenomena appropriate for their students that will produce engagement and hopefully lead to the increases in learning and engagement that was reported in this article (German, 2018, p.34).

The development of assessment tasks that allow students to demonstrate proficiency with disciplinary core ideas, crosscutting concepts, and the science and engineering practices are often at the forefront of many educators' minds when it comes to implementation of the Next Generation Science Standards. The assessments should be authentic and of a multicomponent nature in which students are able to produce or perform something that is akin to what would be needed in a real-
world situation (German, 2019, p.28). The author highlights a particular set of teaching tools from a STEM Teaching Tools Practice Brief that could be used as a guideline for the development of an authentic assessment aligned to the Next Generation Science Standards.

German first outlines the development of a learning claim based off of the performance expectations for one or more of the disciplinary core ideas, science and engineering practices, and/or cross cutting concepts (German, 2019, p.28). German uses an example of her students trying to determine why more drops of water fit on a penny than they may have expected. She outlines the steps students would take to research and propose an evidence-based explanation for the everyday phenomenon (German, 2019, p.28). Her learning claim, prior to student work, included DCIs related to properties of matter and gravity. She found that her students discovered such content through their independent and group research, as well as through class discussions (German, 2019, p.28). Following this, she explains the importance of determining the possible scenarios needed to have students understand the concepts more in depth. These scenarios should be authentic examples, and in the case of her students, she used a NASA video of an astronaut demonstrating the behavior of lemonade in microgravity on the International Space Station (German, 2019, p.29). Following this is the use of task formats, which are found in the STEM Teaching Tools Practice Brief, which provides questioning stems for the crosscutting concepts and the science and engineering practices (German, 2019, p.30). In the example on microgravity, these task formats were used to prompt students to develop models that demonstrate solutions to their problem, as well as develop a version of their model when one variable change occurs, and then to write an explanation for the phenomena using the model as supporting evidence (German, 2019, p.30). German found that 75% of her students did not reference gravity in their models, thus
indicating the need for revising the task, but 93% of the students were able to include gravity as a difference between Earth and the International Space Station (German, 2019, p.31).

While these tasks are consistently a work in progress and should be revised with colleagues (German, 2019, p.32), the implications of the use and development of assessment tasks in the learning segments of new science units can be clearly determined from the article. Firstly, these assessment tasks are ongoing throughout the unit, and often will need to be redefined depending on your target student population. Secondly, the author notes that these tasks should be reorganized to better elicit student thinking regarding certain practices, like cause and effect, prior to asking them to produce models. Furthermore, the assessments should be tied to the anchoring phenomenon, such as the surprising number of water drops on a penny and water droplets in the International Space Station (German, 2019), but should present the information in a new scenario in which students are required to use their knowledge of the familiar phenomena to demonstrate knowledge of the particular performance expectation.

Aside from the curriculum implications this article demonstrates, the importance of communication between other educators for the purpose of feedback is also clear. In order to develop authentic assessments, more than one individual will be needed to develop tasks appropriate for the content. Furthermore, the use of STEM tools such as the ones highlighted by the author (German, 2019), are integral to the development of such authentic assessments that demonstrate three-dimensional learning as the one described by the author in this article. In particular, the development of these assessments, not only summative but formative as well, will take time for educators. Being able to determine differences between indications that the students did accomplish something compared to evidence that they can accomplish something will take
getting used to—especially if districts have not shifted yet. New ways of thinking for students and teachers will become apparent during the switch.
Chapter 3: Storylines (7th Grade)

Cells to Organisms

<table>
<thead>
<tr>
<th>Unit</th>
<th>Cells to Organisms</th>
<th>Course(s)</th>
<th>2 (7th Grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
<td>Time Frame</td>
<td>8-10 Weeks</td>
</tr>
</tbody>
</table>

Adapted from The Wonder of Science (Andersen, 2017) and Next Gen Storylines (Edwards et al, 2016)

Unit Overview

Livings things are made of cells, can respond to stimuli, reproduce, grow, take in nutrients, and will eventually die. All organisms respond to stimuli at both the microscopic and macroscopic levels and respond in different ways depending on the body systems and organisms being observed. Some responses are turned to memories. The body responds to these stimuli through the interaction of other body systems.

Bundle Breakdown

Performance Expectations:

- MS-LS1-1. Plan and conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells. [Clarification Statement: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or many and varied cells.]
- MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. [Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.] [Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their relationship to the whole cell. Assessment does not include the biochemical details related to the functions of cells or cell parts.]
- MS-LS1-3. Construct an explanation supported by evidence for how the body is composed of interacting systems consisting of
cells, tissues, and organs working together to maintain homeostasis. [Clarification Statement: Emphasis should be on the function and interactions of the major body systems (e.g. circulatory, respiratory, nervous, musculoskeletal).] [Assessment Boundary: Assessment is focused on the interactions between systems not on the functions of individual systems.]

- MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli, resulting in immediate behavior and/or storage as memories. [Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.]

### Disciplinary Core Ideas

**LS1.A: Structure and Function**

- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2)
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (MS-LS1-3)

**LS1.D: Information Processing**

- Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. (MS-LS1-8) (NYSED) Plants respond to stimuli such as gravity (geotropism) and light (phototropism). (MS-LS1-8)

### Science and Engineering Practices

**Asking Questions**

- Ask questions about a phenomenon (MS-LS1-1,1-2,1-3,1-8)

**Developing and Using Models**

- Develop a model to describe phenomena. (MS-LS1-2)

**Planning and Carrying Out Investigations**

- Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation. (MS-LS1-1)

**Constructing Explanations and Designing Solutions**

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (MS-LS1-3)
Obtaining, Evaluating, and Communicating Information

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8)

Cross-Cutting Concepts

**Cause and Effect**

- Cause and effect relationships may be used to predict phenomena in natural systems. (MS-LS1-8)

**Scale, Proportion, and Quantity**

- Phenomena that can be observed at one scale may not be observable at another scale. (MS-LS1-1)

**Systems and System Models**

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-LS1-3)

**Structure and Function**

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function. (MS-LS1-2)

### Unpacking the Unit

<table>
<thead>
<tr>
<th>Statement from K-12 Framework</th>
<th>Relevant Concepts from Statement</th>
<th>Cross-Cutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organisms that are alive meet a set of characteristics that include, growth, reproduction, and death. In addition, this also includes respiration, and response to stimuli.</td>
<td>Organisms that are alive meet a set of characteristics that include, growth, reproduction, and death. In addition, this also includes respiration, and response to stimuli.</td>
<td>Structure and Function, Systems and System Models</td>
</tr>
<tr>
<td>Cells, Tissues, Organs and Organ Systems are parts of organisms that respond to changes in their external and internal environment.</td>
<td>Cells, Tissues, Organs and Organ Systems are parts of organisms that respond to changes in their external and internal environment.</td>
<td>Structure and Function, Systems and System Models</td>
</tr>
<tr>
<td>All living things are made of cells</td>
<td>All living things are made of cells</td>
<td>Scale Proportion and Quantity</td>
</tr>
<tr>
<td>Cells give rise to other cells</td>
<td>Cells give rise to other cells</td>
<td>Scale Proportion and Quantity</td>
</tr>
<tr>
<td>Organisms may be made of one cell or many cells</td>
<td>Organisms may be made of one cell or many cells</td>
<td>Scale Proportion and Quantity</td>
</tr>
</tbody>
</table>

A central feature of life is that organisms grow, reproduce, and die. They have characteristic structures (anatomy and morphology), functions (molecular-scale processes to organism-level physiology), and behaviors (neurobiology and, for some animal species, psychology).

- Organisms and their parts are made of cells, which are the structural units of life and which themselves have molecular substructures that support their functioning.
The relevant parts of a cell for grade 7 include cell wall, cell membrane, mitochondria, chloroplast, cytoplasm, and the nucleus.

An organism’s ability to sense and respond to its environment enhances its chance of surviving and reproducing. Animals have external and internal sensory receptors that detect different kinds of information, and they use internal mechanisms for processing and storing it.

The nervous system governs the response of the body to stimuli both internally and externally.

<table>
<thead>
<tr>
<th>Anchoring Phenomenon</th>
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<tbody>
<tr>
<td>Do all organisms react the same to stimuli?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Enduring Understandings</strong></th>
<th><strong>Essential Questions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Living things are composed of cells, either one type or may different types of cells.</td>
<td>What makes something alive?</td>
</tr>
<tr>
<td>- All cells are able to respond to their environment.</td>
<td>How does a cell become an organism?</td>
</tr>
<tr>
<td>- Organelles within cells allow them to respond to the environment.</td>
<td>How do organisms maintain homeostasis?</td>
</tr>
<tr>
<td>- Emphasis on cell membrane, cell wall, chloroplast, mitochondria, nucleus, and cytoplasm.</td>
<td></td>
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<tr>
<td>- Living things carry out specific life functions at different scales.</td>
<td></td>
</tr>
<tr>
<td>- Organisms are made of interacting subsystems of cells, tissues, organs, and organ systems that maintain homeostasis within the body.</td>
<td></td>
</tr>
<tr>
<td>- The nervous system is one particular system that responds to internal and external stimuli.</td>
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</tr>
</tbody>
</table>
### Vocabulary

- Cells
- Plant Cell
- Animal Cell
- Stimuli
- Response
- Cell membrane
- Cell wall
- Chloroplast
- Mitochondria
- Nucleus
- Cytoplasm
- Nervous System
- Muscular System
- Skeletal System
- Circulatory System
- Respiratory System
- Homeostasis
- Stimulus
- Response

### Assessments

- Formative Assessments
- Feedback on Labs
- Summative Unit Exam
- Short Performance Assessments

### General Lesson Sequence

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Learning Performance</th>
<th>Learning Experiences</th>
<th>Overarching Vision for Lesson</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Do all organisms experience stimuli the same?</th>
<th></th>
<th>Students build towards performance expectations by asking questions and engaging their curiosity.</th>
<th>Students are presented with an example of a stimuli/response relationship (deer running away from a sound, or other example). Students are asked to give examples of stimuli and response relationships in their lives. Students will then ask questions that they would like to know about how organisms respond to stimuli. These questions should be recorded on poster paper and posted in a place within the room. Afterwards, students are to be given a mini lecture on stimuli/response relationships. Then students, using that information, will develop a model that demonstrates how organisms respond to stimuli. Finally, students will add questions based on their models.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask questions and develop a model on how organisms respond to stimuli. (Cause and Effect)</td>
<td>Students ask questions relative to the scope of what can be answered in the science classroom.</td>
<td>Teacher should first moderate a discussion between students within the class under the lens of patterns. Open the discussion with the question “what makes something alive?” Have students bullet answers on sticky notes and place them on the white board anonymously. After all the students have come up with an answer, read the sticky notes and organize them according to the answers. Most answers should be organized according to characteristics of living things. Ask the students if they are satisfied with the categories, or if they want to add any more. As a class, come up with a list of words that summarizes the sticky notes answers and will act as your list of characteristics.</td>
<td></td>
</tr>
<tr>
<td>Ask questions about the patterns of what is or is not alive in an example.</td>
<td>Students conduct an investigation that examines what is alive and not alive in a sample of pond water.</td>
<td>Acquire pond water samples with the students, or prior to the investigation and store them in an appropriate area. Day 2: Ask the students “how can we investigate if something is alive or not?” Discuss with the student’s ways to set up an investigation in which they can collect data on the behavior of objects within a sample to determine if they are alive or not. Using their lab notebooks/or other method of lab tracking, have them design an experiment in which they can determine if something in pond water is alive or not using the characteristics listed the day prior. Finally, collect data, analyze, and share out as a group prior to producing a conclusion using a claim, evidence, reasoning</td>
<td></td>
</tr>
<tr>
<td>Pond Life</td>
<td>Class comes to a consensus on the characteristics of living things.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheek Cell vs Onion Cell</td>
<td>Students conduct an investigation that compares plant and animal cells.</td>
<td>Students should have noticed the pond water organisms are made of smaller cells that we would not have normally seen within the assistance of a microscope. To support this information regarding cells, have the students conduct an investigation in which they compare the cells of their cheek to the cells of an onion. Differences in these cells will eventually lead students to the conclusion that not only do all living things have cells, but there are many different types of cells. Following the investigation, a mini lesson on plant, animal, unicellular and multicellular should occur.</td>
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<tr>
<td>Osmosis and Diffusion in Cells</td>
<td>Conduct an investigation on the effect of a stimuli on a cell’s response.</td>
<td>Following an exploration of plant and animal cells, students will begin to explore and observe stimuli/response relationships at the microscopic level. This will be done by having the students conduct an investigation that will answer the question “How do cells respond to salt?” Students will be using onion and cheek cells again and collect data in the form of observations that allows them to answer the question. Having completed the investigation, introduce students to the parts of plant and animal cells again. Now, with evidence in their hand, have them compare and contract cell functions, and discuss the role of the cell membrane and cell wall, in particular, for the cell. Following this, have a mini lesson on diffusion to add to notes.</td>
<td></td>
</tr>
</tbody>
</table>

- Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells with complex functions (Scale, Proportion, and Quantity, Structure Function)
- Students engage in research and communication with peers to illustrate these differences through the development of models.
- Mini lesson on plants and animal cells
- Mini lesson on unicellular and multicellular.
| Salt on Slugs | Analyze and interpret data on the effect of salt on the cells and tissues of slugs. | • Ask questions about phenomena.  
• Analyze data on slug size following the application of salt.  
• Relate slug decrease in size to diffusion of water out of the cell.  
• Mini lesson on levels of organization. | Present students with data regarding slug size when salt is applied. Note: don’t actually perform this experiment. Instruct students to work in partners/small groups to identify patterns in data. Discuss as a whole class the patterns determined in data. End class with students producing a claim, evidence, reasoning writing piece that answers the question: How does salt affect slugs? Students will relate the data on slugs to what they saw in their investigation on cells and salt. Ask students questions that are focused on scale and patterns. |
| --- | --- | --- | --- |
| Pulse Rate and Exercise | Conduct an investigation to provide evidence that organisms are made of interacting systems (Cause and Effect) | • Ask questions about the effect of exercise on heart rate.  
• Plan an investigation  
• Collect data related to the phenomena  
• Relate data to effect of exercise on the rest of the body  
• Class discussion and instruction on body systems follows.  
• Mini lesson on homeostasis | Introduce students to a familiar phenomenon: when you exercise, heart rate and breathing rate increase. Ask students to propose questions under the lens of cause and effect in reference to the phenomena. Students will use these questions to plan an investigation using bromothymol blue as an acid indicator. Students will write a procedure, with your assistance regarding tools in the classroom (indicator safety, class supplies available), then collect data according to their procedure. Discuss data results under the lens of patterns and cause and effect and allow students to discuss in small groups regarding the interconnected systems of the body and maintenance of homeostasis. Following the conclusions of the lab, give a brief lesson on homeostasis and interconnectedness of body systems. |
| Cystic Fibrosis | Obtain, and communicate information that organisms are made of up interacting systems. (Cause and Effect) | • Students will research use articles on cystic fibrosis from a suggested list of sources to obtain and communicate information that explores how diseases affect the body, and the effect that occurs within multiple body systems. | With an understanding of basic body systems and homeostasis, present the students with a video or short article on a person who suffers from cystic fibrosis. Ask the students to research, obtain, and find a method to communicate information regarding how cystic fibrosis affects the body’s ability to maintain homeostasis. |
| Optical Illusions | Ask questions about how sensory receptors respond to stimuli, resulting in | • Have students make the dinosaur optical illusion – [Link](Andrus, n.d.).  
• Ask questions about how sensory receptors respond to stimuli, resulting in | Using the popular dinosaur optical illusion created by the late magician Jerry Andrus, students experience an optical illusion as their lesson phenomena. Have the students ask questions using sticky notes about how the nervous system might |
<table>
<thead>
<tr>
<th>Optical Illusions</th>
<th>Develop a model about how sensory receptors respond to stimuli, resulting in immediate behavior and/or storage as memories (Structure Function)</th>
<th>receptors interpret optical illusions.  ● Gather questions  ● Sort/classify questions  ● Prompt them toward asking stimulus / response questions</th>
<th>interpret the stimuli of the dinosaur optical illusion. Sort and classify questions on the basis of stimulus/response and structure/function.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Rate</td>
<td>Plan and conduct an investigation that sensory receptors respond to stimuli. (Cause and Effect)</td>
<td>● Perform a reaction rate experiment.  ● Compare response rate of individuals based on stimuli (verbal, tactile, or visual)  ● Give data tables to students with an IEP, do not give data table to Gen Ed Students.</td>
<td>Using the model as a basis, have students plan and conduct an investigation in which they test how fast reactions to certain stimuli occur. Have students design data tables but give data tables to students who you feel may need assistance.</td>
</tr>
<tr>
<td>Reaction Rate</td>
<td>Analyze and interpret data, and write an explanation related to sensory receptors take in stimuli and produce a response in various parts of the body. (Cause and Effect)</td>
<td>● Graphing  ● Discuss data as a class  ● Give feedback to peers  ● Use claim-evidence, reasoning to support conclusion writing habits.</td>
<td>After graphing data, have students discuss in small groups the meaning of the data. Following the discussion, have students develop a conclusion in a claim, evidence, reasoning format. Give students the chance to critique each other's writing in a peer-review setting.</td>
</tr>
</tbody>
</table>
| Muscle Contraction | Develop a model of a system that shows how the body is made of interacting systems. (Systems and System Models) | • Mini lesson on muscle contraction  
• Update the models to include muscle contraction and information from investigation. | Have a mini lesson on muscle contraction within the body, connect the information to previous ones on nervous system and body systems. Allow students to update models to include muscle contraction as well as information gathered from results of investigation. Allow students to produce new models if needed. |
| --- | --- | --- | --- |
| Fight or Flight | Ask questions about how sensory receptors respond to stimuli and affect body systems. (Structure Function) | • Ask questions about the fight or flight response.  
• Gather questions  
• Sort/classify questions  
• Prompt them toward asking stimulus / response questions  
• Save questions for later reflection (notebooks or wonder wall) | Introduce students to a video of an organisms demonstrating fight or flight response (could be a deer vs a car, or something similar). Have students ask questions that further develop into how a stimuli reaction could. |
| Fight or Flight | Develop a model that demonstrates that sensory receptors respond to stimuli and affect body systems. | • Individual modeling on whiteboards  
• Gallery walk and edit own models  
• Come up with a group or classroom consensus model, record in notebook | Have students update models using their questions on structure/function that shows how the nervous system takes in stimuli to respond. Focus on individual whiteboarding and then a classroom consensus model. Allow students to have a gallery walk in which they critique models. |
| Long Term vs Short Term Memory | Gather and synthesize information that includes how sensory receptors respond to stimuli, resulting in immediate behavior and/or storage as memories (Structure Function) | • Students will use articles and internet sources to investigate long term vs short term memory  
• Students can update their model to include the storage of memories as a response to stimuli.  
• Make a claim supported by evidence about how the body can respond to stimuli. | Have students research how memories form in the nervous system. Following their research have students make a claim supported by evidence about how the body can respond to stimuli. |
| Do all organisms experience stimuli the same way? | Use an argument supported by evidence that includes how sensory receptors respond to stimuli, resulting in immediate behavior and/or storage as memories (Structure Function) | ● Update models to include information on stimuli/response, brain receptors, etc.  
● Engage in argumentation from evidence that describes that organisms have similar reactions to stimuli, but individual organisms also react differently to stimuli for a number of different reasons that depend on the interacting body systems present. | Assess student understanding of concepts by having them engage in argument supported by evidence that uses models, investigations, research, and other information from reliable sources to explain how sensory receptors respond to stimuli, forming memories and/or results in immediate behavior. |
### Unit Overview

Students will explore the role of matter and energy in the cycling within ecosystems as a method to explain how Amazonian Tribes have survived in the rainforest for such a long period of time. Students will analyze data, plan and conduct investigations, develop and revise several models, as well as continually ask questions as they build toward an understanding of the flow of matter and energy within ecosystems.

### Bundle Breakdown

**Performance Expectations:**

- **MS-LS1-6.** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]
- **MS-LS1-7.** Develop a model to describe how food molecules are rearranged through chemical reactions to release energy during cellular respiration and/or form new molecules that support growth as this matter moves through an organism. [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for respiration or synthesis.]
- **MS-LS2-1.** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]
- **MS-LS2-3.** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about shifts in populations due to changes in the ecosystem.]

Disciplinary Core Ideas

- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6)
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. (MS-LS1-7)

LS2.A: Interdependent Relationships in Ecosystems
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MSLS2-1)
- Growth of organisms and population increases are limited by access to resources. (MS-LS2-1)

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)

PS3.D: Energy in Chemical Processes and Everyday Life
- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary to MS-LS1-6)
- Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary to MS-LS1-7)
### Science and Engineering Practices

- Asking Questions
- Develop a Model
- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence

### Cross-Cutting Concepts

**Cause and Effect**
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1)
- Energy and matter
- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-LS1-7)
- Within a natural system, the transfer of energy drives the motion and/or cycling of matter. (MS-LS1-6)
- The transfer of energy can be tracked as energy flows through a natural system. (MS-LS2-3)
- Stability and Change
- Small changes in one part of a system might cause large changes in another part. (MS-LS2-4)

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### Unpacking the Unit

<table>
<thead>
<tr>
<th>Statement from K-12 Framework</th>
<th>Relevant Concepts from Statement</th>
<th>Cross-Cutting Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naturally occurring food and fuel</td>
<td>The chemical reaction by which plants produce complex food molecules</td>
<td>Energy and...</td>
</tr>
</tbody>
</table>
contain complex carbon-based molecules, chiefly derived from plant matter that has been formed by photosynthesis. 

| Matter |  
|---|---|
| (sugars) requires an energy input  
- carbon dioxide and water combine to form carbon-based molecules and release oxygen. |  

The chemical reaction of these molecules with oxygen releases energy; such reactions provide energy for most animal life and for residential, commercial, and industrial activities. 

| Energy and Matter |  
|---|---|
|  
- Both the burning of fuel and cellular digestion in plants and animals involve chemical reactions with oxygen that release stored energy.  
- Complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. |  

Sustaining life requires substantial energy and matter inputs. 

| Energy and Matter  
| Stability and Change |  
|---|---|
|  
- Energy needed for life is derived from the sun.  
- Plants, algae, and other energy fixing organisms use sunlight, water, and carbon dioxide to perform photosynthesis.  
- Plants and algae are what run the rest of the food chain, without them it would collapse.  
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. |  

Ecosystems are ever changing because of the interdependence of organisms of the same or different species and the nonliving (physical) elements of the environment. 

| Stability and Change  
| Patterns |  
|---|---|
|  
- Organisms and populations are dependent on their environmental interactions with abiotic and biotic factors.  
- Growth of organisms is limited by access to resources. |  

Ecosystems have carrying capacities 

| Patterns |  
|---|---|
|  
- Growth of organisms is limited by access to resources. |
that limit the number of organisms (within populations) they can support.

<table>
<thead>
<tr>
<th>Individual survival and population sizes depend on such factors as predation, disease, availability of resources, and parameters of the physical environment.</th>
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<tbody>
<tr>
<td>Predatory interactions may reduce the number of organisms or eliminate whole populations of organisms.</td>
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<table>
<thead>
<tr>
<th>Ecosystems are dynamic in nature; their characteristics can vary over time.</th>
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<tbody>
<tr>
<td>Increases or decreases in resources cycled within the ecosystem can lead to shifts in all of its populations.</td>
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</table>

<table>
<thead>
<tr>
<th>Transfers of matter into and out of the physical environment occur at every level.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals acquire matter from food, that is, from plants or other animals.</td>
</tr>
<tr>
<td>Energy from light is needed for plants because the chemical reaction that produces plant matter from air and water requires an energy input to occur.</td>
</tr>
<tr>
<td>Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments.</td>
</tr>
<tr>
<td>When molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Anchoring Phenomenon/Problem</th>
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<tbody>
<tr>
<td>How are Amazonian tribes able to survive in the Amazon for generations</td>
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<tr>
<th>Enduring Understandings</th>
<th>Essential Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matter and energy are cycled through different levels within ecosystems. Producers, decomposers, and consumers rely on each other to gather the energy and matter needed to survive.</td>
<td>How does an organism grow?</td>
</tr>
<tr>
<td>How does the amount of resources within an ecosystem affect populations?</td>
<td></td>
</tr>
</tbody>
</table>
Both living and nonliving matter interact in a continuous cycle of transformation within the abiotic and biotic pieces of an ecosystem. The amount and types of resources available will affect population sizes over time. Organisms interact among multiple ecosystems. Photosynthesis and Cellular Respiration are key processes in the cycling of matter and energy within an ecosystem.

How does matter and energy cycle through an ecosystem? What relationships typically occur within an ecosystem and between ecosystems?

### Vocabulary

Energy  
Matter  
Photosynthesis  
Cellular Respiration  
Producer  
Consumer  
Primary Consumer  
Secondary Consumer  
Autotroph  
Heterotroph  
Decomposer  
Tertiary Consumer  
Biotic  
Abiotic  
Population  
Community  
Ecosystem

### Assessments

Formative Check-Ins through submitted work for feedback.  
Summative labs and assessments  
Short performance assessments

### General Lesson Sequence
<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Learning Performance</th>
<th>Learning Experiences</th>
<th>Overarching Idea for Lesson</th>
</tr>
</thead>
</table>
| Amazonian Tribes have survived for hundreds of years in the Amazon | Ask questions about how an organism is able to survive. (Energy and Matter) | ● Get students interested in the phenomena, build curiosity  
● Generate questions  
● Sort questions based on similar topics.  
● Prompt students to ask questions about growth, energy and matter. | To get students interested in ecosystems, have students read an article (linked here) on Amazonian Tribes that have survived for hundreds of years in the Amazon. Following their reading of the article, have them write questions on sticky notes about what they wonder about the phenomenon. As they write, prompt them with questions about growth, energy, matter, human interactions, etc. Have students place these sticky notes on a designated place in the room (white board, wall, poster). Sort the questions with students into categories based on their questions. |
| Amazonian Tribes have survived for hundreds of years in the Amazon | Develop a model that demonstrates how an organism is able to survive. (Energy and Matter) | ● Individual modeling on white boards  
● Classroom consensus model | Using the sorted questions, have students produce models about what they think is allowing these tribes to survive for so long. Focus on individual modeling to view student’s current thinking of the concepts. Ask the students to include energy in their model. Have the students complete a gallery walk of their models, allowing them to provide specific feedback to peers. Following this, create a classroom consensus model that utilizes common themes between student models. As the teacher, remember to serve as a guide for writing the model. Students should copy the classroom model into their notes somewhere. |
| Cracker and Saliva | Develop a model that demonstrates what happens to the molecules of food as they are digested by saliva. | ● Individual modeling on white boards  
● Make observations of cracker taste following several minutes of chewing.  
● Individual modeling on white boards  
● Classroom consensus model | Pose the following questions to students at the beginning of class: “How do humans get the nutrients needed for their cells?” Have students chew on saliva until they notice something different about its taste (that it becomes sweet) Have students' model what they think happens to food in the body at the macroscale and the microscale levels. Have |
<table>
<thead>
<tr>
<th>(Energy and Matter)</th>
<th>(Energy and Matter)</th>
<th>students include in their model's energy and matter.</th>
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</table>
| **Gum Chewing**     | **Conduct an investigation and develop a model that sugar molecules are transformed into energy (Energy and Matter)** | - Students develop a model of what happens to the sugar within the gum before, during and after it is chewed.  
  ○ Individual Modeling  
  ○ Group Consensus  
- Students will compare the mass of gum previously to being chewed and following being chewed for 10 minutes of time.  
- Students will update their model to demonstrate the change in mass to show a transformation in matter. |
|                     |                     | Have students use their models to develop a plan for an investigation which they focus on what happens to the macromolecules of sugar in gum when it is chewed for long periods of time. Have them focus on the question “Why does gum loose flavor when you chew it?” Have students design an experiment in which they compare the mass of gum prior to chewing and after chewing. Using their data, have students hypothesize why the change in mass would have occurred when the Law of Conservation of Mass state the exact opposite of what they have seen. |
| **Lactic Acid in Muscles** | **Obtain and communicate information that includes organisms use food to perform activities and that food is transformed into other molecules for use in the body. (Energy and Matter)** | - Students will research how lactic acid is formed.  
- Students will construct and explanation that food is transformed through a series of chemical reactions into a form that can be used by the body for energy.  
- Mini lesson on heterotrophs, cellular respiration, and digestion. |
<p>|                     |                     | Have students experience the phenomena of muscle fatigue, and then ask the question “Why do our muscles become fatigued?” Allow students to research this topic using a list of sources suggested by the teacher that are acceptable for their grade level (i.e. middle school sources. Have students share information gathered with other groups in order for them to create a claim that explains why muscles fatigue. Instruct them to include information about energy within their answer. End the lesson with a mini lesson on heterotrophs, cellular respiration, and digestion. |
| <strong>Amazonian Tribes</strong> | <strong>Revise a model to include the flow of matter and energy between organisms.</strong> | - Revise models to include energy and matter flow. |
|                     |                     | In small groups, allow students time to revise their initial models of Amazonian Tribe survival to include energy flow and the flow of matter based on their investigations. Groups can choose to update their models or produce entire new models. Update the classroom consensus model based on |</p>
<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Notes</th>
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</thead>
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<tr>
<td>Student input to demonstrate whole classroom thought processes at the current time.</td>
<td>Using a corn cob growing in water, instruct students to ask questions related to the cross-cutting concept of energy and matter. Prompt them with questions like “what lets the corn grow?” What do you know of that also grows like this?” or other questions to focus them on plant growth over time.</td>
<td></td>
</tr>
</tbody>
</table>
| Corn cob growing in water | **Ask questions about the role of photosynthesis in the cycling of matter and energy.** | ● Get students interested in the phenomena, build curiosity  
● Generate questions  
● Sort questions based on energy and matter  
● Prompt students to ask questions about growth, energy and matter. |
| Corn cob growing in water | **Develop a model to demonstrate the role of photosynthesis in the cycling of matter and energy.** | ● Partner modeling on white boards  
● Classroom consensus model |
| Elodea and light | **Plan and conduct an investigation to demonstrate the role of photosynthesis in the cycling of matter and energy.** | ● Make observations of what happens when elodea is placed in water and put under a light.  
● Mini lesson on photosynthesis and autotrophs |
| | | Using elodea, or other available aquatic plant, have students observe the aquatic plant in a test tube. Ask students questions about what they observe and then prompt them to plan an investigation in which they test the role of photosynthesis in plant growth using bromothymol blue solution as an acid indicator to indicate relative amounts of carbon dioxide and water. Instruct students to really focus on the process of photosynthesis that they already know about and design an experiment around that concept and based on their models. In other words, how can they develop an investigation that collects evidence for a model? Using their gathered evidence and models, have a mini lesson on photosynthesis and autotrophs. |
| Biosphere 2 | **Develop a model on the relationships of organisms in the cycling of matter and energy.** | - Individual modeling on white boards  
- Classroom consensus model | Present to the students Biosphere 2, a large-scale experimental tool that houses several different ecosystems to model Earth’s biosphere on a smaller level. Ask students to take the information they know already about autotrophs and heterotrophs and produce a model that demonstrates how these organisms interact within an ecosystem. Instruct them to include energy and matter in their models, as well as the information gathered in their investigations thus far. |
| --- | --- | --- | --- |
| Biosphere 2 | **Obtain and communicate information that includes the relationships of organisms in the cycling of matter and energy.** | - Research the Biosphere 2 incident during its first two years of use.  
- Propose an explanation based on gathered evidence for the cause of the Biosphere 2 issue.  
- Mini lesson on ecosystem relationships and food pyramids | Biosphere 2 was not a comfortable environment to live in, according to those that lived in the space for two years (Nelson, 2018). For the first two years there was an unexplained loss of oxygen and an extinction of various species within the biosphere. Using their models and current knowledge, have students research the issues of Biosphere 2 and propose an explanation that utilizes the role of organism relationships and the cycling of matter to explain why Biosphere 2 had such a large set of issues in the beginning of its use. Using their gathered evidence, have a mini lesson on ecosystem relationships and food pyramids, as well as biotic and abiotic factors. |
| What is happening to Pteropods? | **Conduct an investigation about the relationships of organisms and the effects of resource availability in the cycling of matter and energy and the stability and change an ecosystem experience.** | - observe variation in a pteropod population  
- record and display data  
- analyze and interpret data  
- construct an argument  
- recognize that a good argument uses evidence to justify claims and that to oppose counterclaims, one needs to use evidence and not assertion | Using the activity from “Arguing from Evidence in Middle School Science (Osborne et al, *What Factors Affect the Number of Moose on Isle Royale?*, 2017) “students conduct a simulated field study in which they observe the condition of shells of pteropods collected off the West Coast of the United States. They count the number of pteropods that have undergone different levels of shell dissolution and compare their findings to estimates of shell dissolution in “preindustrial” oceans. Students represent and analyze their data and present arguments for whether pteropod shells look different than preindustrial times at their site. They have an opportunity to offer constructive feedback to their peers during a “gallery walk” at the conclusion of the activity.” |
| What Factors Affect the Number of Moose on Isle Royale? | Analyze and interpret data about the relationships of organisms and the effects of resource availability in the cycling of matter and energy and the stability and change an ecosystem experience. | • examine how two populations interact with each other and with other biotic and abiotic factors in an ecosystem  
• use evidence to justify claims  
• understand that the quality of an argument is based on the amount of evidence supporting a claim  
• recognize that effects in ecosystems can be observed on different time scales (i.e., that some changes can be observed in the short term, but more stable patterns emerge over longer time scales)  
• learn and consolidate the concepts about ecosystems (e.g., interactions between abiotic and biotic factors, interdependence of species, predator-prey interaction, competition)  
• mini lesson on predator/prey interactions, species interdependence and competition. | Using the activity from “Arguing from Evidence in Middle School Science (Osborne et al, *What Factors Affect the Number of Moose on Isle Royale?* 2017) “students learn about an island that has been studied continuously for many years. They look at long-term data collected on the moose population on the island and the various biotic and abiotic factors that affect that population. Rather than simply asking students to argue about whether the wolves affect the moose population and support this argument using graphs of the predator and prey populations, this activity asks students to consider the many factors that might matter and make an argument for which factor is most strongly associated with changes in the moose population.” End with a mini lesson on predator/prey interactions, species interdependence and competition. |
| Amazonian Tribes | Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations | • Engage in student discourse  
• Use evidence gathered over the course of the unit to explain how Amazonian tribes have relied on the amazonian forest to survive for generations and why this was possible.  
• Focus is on the use of data, models, and research to answer the question in groups.  
• Create a final revised model. | Using the knowledge that students have gained over the course of their investigations, instruct students to construct an explanation that answers the question asked in the beginning of the unit. They should us the claim, evidence, reasoning format to complete this. Special focus on evidence should be given with prompts to include references to specific data gathered. |
Unit Overview

Students will explore the effect and influence of the environment, humans, and organism-organism interactions on the passing on and expression of genetic traits. Focus is put upon the structures and functions of parts of sexually reproducing organisms, how the development of such parts is influenced by the environment and genetics, and how changes to genes can influence an organism’s growth over time. Students also explore the role humans play in the selection of traits for organisms for various purposes, and the effects those can have on the environment and on future generations of such organisms.

Bundle Breakdown

Performance Expectations:

- MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants, respectively. [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]
- MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and...
water. Examples of genetic factors could include the genes responsible for size differences in different breeds of dogs. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds. [Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, biochemical processes, or natural selection.]

- MS-LS3-1. Develop and use a model to explain why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. [Clarification Statement: Mutations in body cells are not inherited. Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.] [Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.]
- MS-LS3-2. Develop and use a model to describe how asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. [Clarification Statement: Emphasis is on using models such as diagrams and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring.]
- MS-LS4-5. Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, selective breeding, gene therapy); and, on the impacts these technologies have on society.]

**Disciplinary Core Ideas**

- LS1.B: Growth and Development of Organisms
  - Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2)
  - Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4)
  - Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4)
  - Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5)

- LS3.A: Inheritance of Traits
  - Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. (MS-LS3-1)
  - Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2)

- LS3.B: Variation of Traits
In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. (MS-LS3-2)

In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Some changes are beneficial, others harmful, and some neutral to the organism. (MS-LS3-1)

(NYSED) Mutations may result in changes to the structure and function of proteins. (MS-LS3-1)

In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. (MS-LS4-5)

Science and Engineering Practices

- Asking Questions
- Developing and Using Models
- Constructing Explanations
- Engaging in Argument from Evidence
- Obtaining, Evaluating and Communicating Information

Cross-Cutting Concepts

- Cause and Effect
- Structure and Function
- Patterns

Unpacking the Unit

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<th>Cross-Cutting Concepts</th>
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<tr>
<td>Animals engage in behaviors that increase their chances for reproduction, and plants may develop specialized structures and/or depend on animal behavior to accomplish reproduction.</td>
<td>- Behaviors differ between organisms, and organisms will engage in behaviors that have the greatest ability to allow them to pass on their genetic information to the next generation of organisms.</td>
<td>• Structure and function</td>
</tr>
</tbody>
</table>
In all organisms, the genetic instructions for forming species’ characteristics are carried in the chromosomes.

- Chromosomes vary in size, length and number for each species.
- Chromosomes are condensed forms of DNA.

DNA molecules contain four different kinds of building blocks, called nucleotides, linked together in a sequential chain. The sequence of nucleotides spells out the information in a gene.

- DNA is coded in a series of repeating combinations of nucleotides.
- Scientists represent these codes as four letters, and the combination of these letters/nucleotides is unique for each individual that leads to the expression of unique traits.

Variations result from mutations, which are changes in the information that genes carry.

- Mutations may be beneficial, harmful or neutral.
- Most mutations that occur are neutral.

Natural selection occurs only if there is variation in the genetic information within a population that is expressed in traits that lead to differences in survival and reproductive ability among individuals under specific environmental conditions.

- Humans can influence the inheritance of traits through technological advances such as CRISPR.

<table>
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<td>Why do we see so much diversity in the biosphere?</td>
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<tr>
<td>- In order to produce new cells, cell must divide.</td>
<td>- Why does diversity exist?</td>
</tr>
<tr>
<td>- Cells can divide via mitosis or meiosis</td>
<td>- How can we predict the outcome of genetic crosses?</td>
</tr>
<tr>
<td>- When cells divide, they copy the genetic information from the parent cell.</td>
<td>- How do mutations affect survival in different species?</td>
</tr>
<tr>
<td>- DNA is the genetic code that contains all the information a cell needs to function.</td>
<td>- How can humans influence diversity?</td>
</tr>
<tr>
<td>- DNA condenses into chromosomes.</td>
<td></td>
</tr>
<tr>
<td>- The average number of chromosomes for an organism is unique for each species.</td>
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</tr>
</tbody>
</table>
- Genes are specific locations on a chromosome.
- Differences in the form of a gene are called alleles, they can be dominant or recessive.
- Alleles interact with each other to result in the traits we physically see.
- The physical traits that occur in an organism are the result of the combination of alleles within the organisms DNA.
- Humans and the environment have an influence in the expression of genes.
- Genes can be artificially selected for by humans, or inserted using technology like CRISPR.
- Gregor Mendel could predict the outcome of trait crossing using a Punnett Square.

**Vocabulary**

- Gene
- DNA
- Chromosome
- Dominant Allele
- Recessive Allele
- Punnett Square
- Gregor Mendel
- Beneficial Mutation
- Neutral Mutation
- Harmful Mutation
- CRISPR
- Heredity
- Homozygous
- Heterozygous
- Trait
- Genotype
- Phenotype
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| Diversity in the biosphere | Ask questions related to why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. | • Asking questions with white boards.  
• Categorize the questions students have about biological diversity. | Present students with images of organisms from various biomes that have unique characteristics (tropical organisms have a lot of diversity). Have students ask questions related to structures of organisms, and traits of organisms. Prompt students to think about what they already know about organisms and the differences between different organisms. |
| Biracial twins          | Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. | • Asking questions with white boards,  
• Categorize the questions students have about genetics  
• Develop a model that demonstrates how traits might be passed on. | Present to the students the phenomena of biracial twins (Inside Edition 2015). Have students ask questions about what they wonder about the twins, prompt them with questions related to genetics, traits, genes, etc., to guide their question thinking in a certain direction. Discuss with students their thoughts, then prompt them to develop a model that demonstrates how offspring with different traits arise. |
| Collect information as to how variations of inherited traits between parent and offspring arise from genetic differences | • Use the Brain Pop video on heredity to collect information. |                                                                                                                                                            | Have students research DNA using the CK-12 site. Allow students to choose articles that they can understand and collect information about why traits can vary between parents and offspring, and how traits are passed down. Then allow students |
| Planarian Reproduction | Construct an explanation that organisms reproduce, either sexually or asexually, and transfer their genetic information | • Make claims based on observations  
• [Amoeba Sisters](https://www.amoebasisters.com)  
• [Fuse School - Advantages](https://www.fuseschool.org) | Have students watch a time lapse of planarian reproduction, which is asexual. Ask the students to make a claim about the traits the new planarian have compared to the parent based on their observations and knowledge of reproduction this far. Present to the students the concept of asexual reproduction. Have the students |
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<td></td>
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<td>• Use a model to demonstrate how in sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. These variations will result in different phenotype and genotype outcomes.</td>
<td>Present the students with a Punnett Square as a method to model how sexually reproducing organisms can result in offspring varying traits. Have students color code alleles in the beginning to allow for ease of learning, then challenge students as they become more adept at the squares. End with a mini lesson on genotype and phenotype, then have students calculate percent chances of certain phenotypes and genotypes. Allow students to finally update their model on biracial twins to demonstrate the passing of traits in the form of allele pairs.</td>
</tr>
</tbody>
</table>
| | | • Use a Punnett Square as a model.  
• Calculate percent chances of acquiring certain traits from a genetic cross. | |
| | | • Explore the CK-12 Website to gather information.  
• Use Monster Maker to explore how traits arise from genetic differences and similarities between parents and offspring.  
• Mini lesson on DNA, traits, and sexual reproduction | to use the Monster Maker (Arizona Science Center) website to explore how traits arise from genetic differences. Allow students time to update their models to include chromosomes and other information they find important to include. End with a mini lesson on DNA, traits, and sexual reproduction. |
| Why do leaves have different shapes? | Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. | • Analyze and interpret data about trees, leaves and sunlight • Use evidence to justify claims • Recognize that a good argument uses evidence to justify claims and that to oppose counterclaims to your argument, you need to rely on evidence rather than assertions • Individual and group white boarding | Using the activity from “Arguing from Evidence in Middle School Science (Osborne et al, 2016) “students generate an argument about why leaves on different parts of an oak tree have different shapes. Then, they compare two hypothetical arguments for the differences in shape and decide which they agree with more and what the problem is with the alternative.” |
| Orchid Sexual Deception | Construct an explanation that plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (Structure and Function) | • Making observations • Collecting and communicating information • Constructing explanations • Claim - Evidence - Reasoning Practice | Present students with the video on the sexual deception of orchids (Gaskett, TED-ed, & Holmriis, "The sexual deception of orchids "). Have students create a list of various ways that orchids have evolved to maximize their ability to pass on their genes over time. Then, using the data collected from the previous lesson and the information from the video, have students construct an explanation in which they explain how animal behaviors and plant behaviors affect sexual reproduction and the passing on of traits to new offspring. |
| **Ernest Hemingway’s Polydactyl Cats** | Develop and use a model to explain why mutations located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. | • Get students interested in the phenomena, build curiosity  
• Discuss with partners  
• Model microscopic scale interactions  
• Individual modeling on white boards  
• Classroom consensus model | Present the students with the video of Ernest Hemingway’s Polydactyl Cats. Have students discuss in partners whether or not animal behavior and sexual selection would have resulted in being born with extra toes. Have students then model how traits like polydactylism in cats can develop. Students should model individually, focusing on the incorporation of DNA and chromosomes into the model, as well as genes located on chromosomes. Upper level students could be given codon sheets that allow them to dive further into the genetic code. |
| **Ernest Hemingway’s Polydactyl Cats** | Use argument based on gathered evidence and scientific reasoning to support an explanation to explain why mutations located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. | • Use evidence to justify claims  
• Recognize that a good argument uses evidence to justify claims and that to oppose counterclaims to your argument, you need to rely on evidence rather than assertions  
• Individual and group white boarding  
• Claim - Evidence - Reasoning | Students should work to gather evidence on other forms of polydactylism, as well as other mutations and their effects on an organism's ability to survive and efficiently pass on their genetic information to offspring. |
| **CRISPR** | Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. Cause and Effect | • Research various phenomena associated with Crispr  
• Engage in conversations with peers  
• Use evidence to justify claims  
• Recognize that a good argument uses evidence to justify claims and that to oppose counterclaims | Students should work to gather evidence on other forms of polydactylism, as well as other mutations and their effects on an organism's ability to survive and efficiently pass on their genetic information to offspring. |
to your argument, you need to rely on evidence rather than assertions
Unit Overview

Students will ask questions and conduct investigations on the properties of different types of waves. These properties include amplitude, frequency, and wavelength, which can be applied as mathematical models. Both electromagnetic and mechanical waves experience these properties. Students will also model and determine effective methods by which waves can be transferred for the purposes of communication and will research whether analog or digitized signals are more effective for this purpose.

Performance Expectations:

- MS-PS4-1. Develop a model and use mathematical representations to describe waves that includes frequency, wavelength, and how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment is limited to comparing standard repeating waves of only one type (transverse or longitudinal).]
- MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, ray diagrams, simulations, and written descriptions. Materials could include plane, convex, and concave mirrors and biconvex and biconcave lenses.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]
- MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in Wi-Fi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment
Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.

Disciplinary Core Ideas

- **PS4.A: Wave Properties**
  - A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

- **PS4.B: Electromagnetic Radiation**
  - When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light. (MS-PS4-2) (NYSED)
  - The path that light travels can be traced as straight lines, except when it hits a surface between different transparent materials (e.g., air and water, air and glass) obliquely where the light path bends. (MS-PS4-2)
  - A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2) (NYSED) However, because light can travel through space, it cannot be a mechanical wave, like sound or water waves. (MS-PS4-2)

- **PS4.C: Information Technologies and Instrumentation**
  - Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)

Science and Engineering Practices

- Asking Questions
- Developing and Using Models
- Obtaining, Evaluating and Communicating Information

Cross-Cutting Concepts

- Patterns
- Structure and Function
- Energy and Matter

Unpacking the Unit
<table>
<thead>
<tr>
<th><strong>Statement from K-12 Framework</strong></th>
<th><strong>Relevant Concepts from Statement</strong></th>
<th><strong>Cross-Cutting Concepts</strong></th>
</tr>
</thead>
</table>
| A simple wave has a repeating pattern of a specific wavelength, frequency, and amplitude. | ● The frequency of a wave is the number of waves that occur in one period of time.  
● The amplitude of the wave is the strength of a wave.  
● Wavelength is the size of the wave from crest to crest. | ● Structure and Function |
| Waves, which transfer energy and any encoded information without the bulk motion of matter, can travel unchanged over long distances, pass through other waves undisturbed, and be detected and decoded far from where they were produced. | ● Waves pass through many materials but will bounce off of some.  
● Matter itself will not travel with these waves. | ● Structure and Function  
● Energy and Matter |
| Resonance is a phenomenon in which waves add up in phase (i.e., matched peaks and valleys), thus growing in amplitude | ● When waves resonate with each other their peaks and troughs match up, thus increasing their overall power (amplitude) | ● Patterns |
| Electromagnetic waves can be detected over a wide range of frequencies, of which the visible spectrum of colors detectable by human eyes is just a small part. | ● Wave models are used to describe brightness and color, but the light wave cannot be a matter-wave.  
● Waves can be detected over long distances and are done via their frequency. | ● Patterns |
| Electromagnetic radiation’s speed in any given medium depends on its wavelength and the properties of that medium. | ● The materials waves pass through can influence their speed. | ● Patterns |
| Light waves, radio waves, microwaves, and infrared waves are applied to communications systems, many of which use digitized signals as a more reliable way to convey information. | ● Analog methods of sending information are less reliable and less clear.  
● Digitized signals have more resolution and are more precise in their deliverance of information via different types of waves. | ● Energy and Matter  
● Patterns |

**Anchoring Phenomenon/Problem**

Why do we not always get good cell phone reception?

**Enduring Understandings**

**Essential Questions**
- The technology we use is based on wave properties.
- Waves carry energy.
- There are different types of waves that travel in different ways.
- Light allows us to see color.
- Visible light is composed of all different colors.
- Light travels differently through different materials.
- Light can bounce or go through an object.
- When light hits an object, the objects absorb certain colors and reflect others.
- The color of an object depends on the which color(s) it reflects.

Vocabulary

Wave
Wave properties
Wavelength
Frequency
Amplitude
Wave energy
Mechanical wave (e.g. sound and water waves)
Medium
Light waves (amplitude is brightness and frequency are color)
Materials
Reflection
Absorption
Refraction
Transmission
Digital signals
Analog signals

Assessments

- Why don’t we always get good cell phone reception?
- How can energy be used for communication?
- How does a wave carry energy from one location to another?
- How much energy can waves carry?
- Why does an object look different through water?
- Why do objects appear in different colors?
- Why does a rainbow always appear in the same color order?
## General Lesson Sequence

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Learning Performance</th>
<th>Learning Experiences</th>
<th>Overarching Vision for Lesson</th>
</tr>
</thead>
</table>
| Cell phone dead zones | Ask questions about the structure and function of cell phones and their ability to send digitized signals | ● Get students interested in the phenomena, build curiosity  
● Generate questions  
● Sort questions based on energy and matter  
● Prompt students to ask questions about structure and function and energy and matter. | Discuss with students the effects of dead zones on cell phones. Have students ask questions about cell phones that they are interested in. Sort questions based on structure and function and energy and matter. |
| Cell phone dead zones | Develop an initial model to explain how energy is used to transmit information. | ● Individual modeling on whiteboards  
● Classroom consensus model | Using their questions sorted as energy and matter, have students develop a model in which they predict how energy is transferred in order to transmit information. Have students give peer feedback during a gallery walk of individual models, then create a classroom consensus model that can be used to test the overall main ideas being shown from student models. |
| Cell phone dead zones | Obtain information about the structure and function of cell phones and their ability to send digitized signals. | ● Students will research how a cell phone is structured.  
● Students will communicate their information to a peer and come up with a consensus set of information | Prompt students to research how the structure and function of a device affects how signals can be sent as different forms of energy. Students should focus on change in cell phone structures over time and communicate their information to peers as the class |
<table>
<thead>
<tr>
<th>Wave Type</th>
<th>Activity Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slinky Wave</td>
<td>Students will <strong>carry out investigations</strong> about waves patterns to show that a wave has a repeating pattern with a specific wavelength, frequency, and amplitude.</td>
<td>Students will be able to create simple mathematical representations of waves and identify the characteristic properties of waves. Using what they have learned about the structure of cell phones and their model of energy transformation, students will carry out an investigation that will create mathematical representations of the characteristics of waves. Focus should be on collecting data and presenting the data as graphs that best represent student learning according to what students feel the data should be represented as.</td>
</tr>
<tr>
<td>Sound Wave</td>
<td>Students will <strong>carry out investigations</strong> about waves patterns to show that a wave has a repeating pattern with a specific wavelength, frequency, and amplitude.</td>
<td>Students will be able to create simple mathematical representations of waves and identify the characteristic properties of waves. Using what they have learned about the structure of cell phones and their model of energy transformation, students will carry out an investigation that will create mathematical representations of the characteristics of waves. Focus should be on collecting data and presenting the data as graphs that best represent student learning according to what students feel the data should be represented as.</td>
</tr>
<tr>
<td>Light Waves</td>
<td>Students will <strong>carry out investigations</strong> about waves patterns to show that a wave has a repeating pattern with a specific wavelength, frequency, and amplitude.</td>
<td>Students will be able to create simple mathematical representations of waves and identify the characteristic properties of waves. Using what they have learned about the structure of cell phones and their model of energy transformation, students will carry out an investigation that will create mathematical representations of the characteristics of waves. Focus should be on collecting data and presenting the data as graphs that best represent student learning according to what students feel the data should be represented as.</td>
</tr>
<tr>
<td>Subject</td>
<td>Activity</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
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</tr>
<tr>
<td>Cell Phone Dead Zones</td>
<td>Update an initial model to explain how energy and are used to transmit information.</td>
<td>Students will update their models to include mathematical representations of waves (frequency, amplitude) to demonstrate their thought process progression. Using the data gathered through the course of several investigations, students will use their mathematical models to update their initial models of energy transformation to include the mathematical representations of waves measured by students. Models at this point should include energy waves, matter, amplitude, frequency, and wavelength.</td>
</tr>
<tr>
<td>Morse Code</td>
<td>Students will design a method by which they can send a signal via energy wave.</td>
<td>Students will use their models of energy to design methods by which they can effectively transmit information via some sort of wave. Using the updated models, have students design a method by which they can communicate using an energy wave of their choice, or more than one wave. Emphasis is on the use of a consistent investigation routine and the incorporation of their current knowledge from models to test what they believe will work in a systematic way.</td>
</tr>
<tr>
<td>Analog vs Digitized Signals</td>
<td>Students will conduct an investigation to determine that digitized signals are more effective than analog signals. (Patterns)</td>
<td>Students will collect information on digitized vs analog signal effectiveness through research and investigations. Students will support the results from their previous investigation with research on analog and digitized waves. Students will collect information as a research investigation and organize it in a way that can be utilized effectively.</td>
</tr>
<tr>
<td>Analog vs Digitized Signals</td>
<td>Students will construct an explanation that digitized signals are more effective than analog signals. (Patterns)</td>
<td>Students will use the Claim-Evidence-Reasoning format to construct an explanation that utilizes their models. Using the data collected by various kinds of investigations, students will construct an explanation that explains why digitized signals are more effective than analog signals using their researched information and results from multiple investigations. The focus of their explanation should be focused on the cross-cutting concept of patterns.</td>
</tr>
</tbody>
</table>
Chapter 4: Chapter 3: Storylines (8th Grade)

Evolution

<table>
<thead>
<tr>
<th>Unit</th>
<th>Evolution</th>
<th>Course(s)</th>
<th>8th Grade</th>
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</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
<td>Time Frame</td>
<td>10 Weeks</td>
</tr>
</tbody>
</table>

Adapted from The Wonder of Science (Andersen, 2017) and Next Gen Storylines (Edwards et al, 2016)

Unit Overview

Using the always interesting story of dinosaur extinction, students will develop models and conduct investigations to gather evidence on evolution, development, and determine what happened to dinosaurs and why only some of the species of dinosaurs evolved into the birds we see today. Students will focus on the development of their science and engineering practices using the cross-cutting concepts of patterns and cause and effect.

Bundle Breakdown

Performance Expectations:

- MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]
- MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. [Clarification statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures as evidence of common ancestry.]
- MS-LS4-3. Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy. [Clarification Statement: Emphasis is on inferring general
patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures. [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]

- **MS-LS4-4.** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment. [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

- **MS-LS4-6.** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [Assessment Boundary: Assessment does not include Hardy Weinberg calculations.]

### Disciplinary Core Ideas

- **LS4.A: Evidence of Common Ancestry and Diversity**
  - The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. (MS-LS4-1)
  - Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (MS-LS4-2)
  - Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully formed anatomy. (MS-LS4-3)

- **LS4.B: Natural Selection**
  - (NYSED) Natural selection can lead to an increase in the frequency of some traits and the decrease in the frequency of other traits. (MS-LS4-4)

- **LS4.C: Adaptation**
  - Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population change. (MS-LS4-6)

### Science and Engineering Practices

- Asking Questions
- Making Models
- Analyzing and Interpreting Data
- Constructing Explanations
- Using Mathematics and Computational Thinking
### Cross-Cutting Concepts

- **Patterns**
- **Cause and Effect**

### Unpacking the Unit

<table>
<thead>
<tr>
<th>Statement from K-12 Framework</th>
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<tbody>
<tr>
<td>Biological evolution explains the unit and diversity of a species.</td>
<td>● The history of living organisms can be traced using fossils, and the traits exhibited by these fossils and remains demonstrate the complicated but connected relationships between seemingly unrelated species over long periods of time.</td>
<td>● Patterns</td>
</tr>
<tr>
<td>Biological unity is illustrated by similarities between species, which can be explained by the inheritance of characteristics.</td>
<td>● There are certain characteristics that are common between species at the embryological level, demonstrating the similarities between seemingly unrelated species.</td>
<td>● Patterns</td>
</tr>
<tr>
<td>Biological diversity can be explained by the branching and diversification of lineages.</td>
<td>● As populations adapt via natural selection to local ecosystems, individual species branch away from ancestors.</td>
<td>● Patterns</td>
</tr>
<tr>
<td>Genetic variation in a species results in individuals with a range of traits.</td>
<td>● Organisms that can successfully reproduce and pass on favorable traits to the next generation of offspring are seen as fit.</td>
<td>● Patterns</td>
</tr>
<tr>
<td>Natural selection occurs only if there is a variation in the genetic information within a population that is expressed in traits that lead to differences in survival and reproductive ability.</td>
<td>● Natural selection is only seen when a particular genetic variation affects the survival of members within a population.</td>
<td>● Cause and Effect ● Patterns</td>
</tr>
<tr>
<td>The distribution of traits within a population will change over time. Over time, populations with diverse enough traits in a different ecosystem may evolve to become a separate species.</td>
<td>● Traits that are more favored in a population-based on ecosystem pressures will be seen more often than traits that are unfavorable. ● Location and separation from populations due to geography may eventually lead to speciation events such as the Galapagos Finches.</td>
<td>● Cause and Effect ● Patterns</td>
</tr>
</tbody>
</table>
## Anchoring Phenomenon/Problem

Where did all the dinosaurs go?

### Enduring Understandings

<table>
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<th>Essential Questions</th>
</tr>
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<tbody>
<tr>
<td>● Fossils are mineral replacements, preserved remains, or traces organisms that lived in the past.</td>
<td>What happened to dinosaurs?</td>
</tr>
<tr>
<td>● The collection of fossils in chronological order is known as the fossil record.</td>
<td>How can a population go extinct?</td>
</tr>
<tr>
<td>● Genetic variations in individuals sometimes give them an advantage over others.</td>
<td>How can we learn about extinct organisms that existed before us?</td>
</tr>
<tr>
<td>● Adaptation by natural selection that occurs over generations is an important process by which species change over time.</td>
<td>How do organisms change over time?</td>
</tr>
<tr>
<td></td>
<td>How do species change over time?</td>
</tr>
</tbody>
</table>

### Vocabulary

- Adaptation
- Darwin
- Evolution
- Extinction
- Fossil
- Fossil record
- Fossilized
- Index fossil
- Natural selection
- Species
- Theory
- Trace fossil
- Law of Superposition
- Sedimentary Rock
- Embryo
- Cladogram
### Assessments
- Exit Tickets
- Labs - Formative and Summative Assessment
- Unit Quiz and Unit Exam

### General Lesson Sequence

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<tr>
<td>Microraptor!</td>
<td>Ask questions on the traits of organisms in a population and how new traits are gained over time <em>(Cause and Effect)</em></td>
<td>- Students build towards performance expectations by asking questions and engaging their curiosity.</td>
<td>Using the phenomena of microraptor <em>(BBC Earth, 2013)</em>, have students ask questions about how birds could have evolved from dinosaurs like microraptor. Questions should be sorted according to traits or organisms and cause and effect relationships.</td>
</tr>
</tbody>
</table>
| Dinosaurs Among Us | Develop a model using information gathered from an article and lab to demonstrate how dinosaurs are closely related to modern day birds. *(patterns)* | - Develop a model that demonstrates how organisms inherit new characteristics.  
  - Engage in research and communication with peers to illustrate how dinosaurs are closely related to birds. | Following the article on Dinosaurs Among Us, students will draw a model that demonstrates how organisms inherit new characteristics. Students should focus on showing patterns in trait inheritance. Following this, students will conduct a research investigation that gathers information from a list of approved sources gathered by the teacher. Students should focus their research on locating and evaluating evidence of patterns in bird and dinosaur evolution. |
| The Taste of a T-Rex | Analyze and interpret data on patterns of bird evolution that will determine what a dinosaur might have tasted | - Ask questions about phenomena.  
  - Analyze data to build a cladogram  
  - Use Claim-Evidence and Reasoning to communicate information. | Using patterns in fossil records, students will use fossils to build a cladogram to determine what a T-Rex might have tasted like. |
### Turning a Chicken into a Dinosaur

Gather and communicate evidence on the social behaviors and other anatomical features reported by leading paleontologists (Patterns)

- Students will use a video from Jack Horner’s 2011 Ted Talk on Dinosaurs to further build on their evidence gathered for how birds are related to dinosaurs.

Using Jack Horner’s TED Talk on Turning a Chicken into a Dinosaur (TED, 2011), students will continue to collect information on developmental data on social behaviors and anatomical features reported from a primary source.

### Archaeopteryx

Analyze and interpret data to improve models of bird evolution. (Patterns)

- Students will use their information gathered to update their models of bird evolution to include Archaeopteryx.

Students will use gathered data from the research investigations and presented information to continue to update their model of evolutionary patterns to account for the presence of Archaeopteryx in bird evolution over time.

### Fossils of Past Ecosystems

Conduct an investigation to describe changes in local ecosystems over time from fossil evidence (patterns, scale)

- Students will collect fossil information via research on any particular location in the US and construct an explanation of how the ecosystem of that area has changed over time.

Using an area of location of choice in the United States, students will collect data on the types of fossils in different areas of the United States over millions of years. Students will then build a to scale timeline of the ecosystems of that particular area over time based on the types of fossils found.

### How a Fossil is Formed

Analyze and interpret pictures of fossils to determine some likely characteristics of the organisms (Patterns)

- Students will watch a video on fossil formation
- Students will use the information to explain how they think scientists determine the external features of these fossil remains

Students will learn how a fossil is formed and then will analyze and interpret pictures of related fossils to determine likely characteristics of certain organisms based on patterns observed.
| **Mass Extinction** | Use data to identify and explain how scientists use fossils and rock strata to determine how the dinosaurs went extinct. (Cause and Effect) | • Analyze and interpret data  
• Communicate information  
• Mini lesson – rock strata, rock formation, fossil formation, evolution over time |  |
| **Embryological Evolution** | Conduct an investigation to provide evidence that living things that are seemingly unrelated are related embryologically (Patterns) | • Students will use Guess the Embryo and The Zoo of You from NOVA to conduct their investigation. | Students will use an online simulation and reserve of data to determine patterns of embryological similarity between seemingly unrelated organisms. |
| **Avian Fossils and Dinosaur Fossils** | Ask questions and develop a model about the patterns what successful traits and unsuccessful traits in an example are. | • ask questions relative to the scope of what can be answered in the science classroom.  
• Develop a model of how traits can be gained or lost within species. | Students will ask questions following the observation of several extinct and non-extinct species of dinosaurs and avian fossils (respectively). They will develop a model that demonstrates how the traits of organisms can be gained or lost within a species. |
| **Big Lizards** | Students will design a study to test the evolution of larger feet in a species of lizard. (Cause and Effect). | • Engage in how scientists design studies to test hypotheses about evolution about  
• Learn the social processes involved in the funding of scientific research to apply evolutionary ideas, such as variation, inheritance, selection, and time. | Using the activity from Arguing from Evidence in Middle School Science (Osborne et al, *How Do You Design a Test of Evolutionary Theory*, 2017), “students will design a study to test the evolution of larger feet in a species of lizard. In the first lesson, students engage in argument to design a study in a small group to test a hypothesis based in evolutionary theory” |
| **Big Lizards** | Students engage in argument in a peer-review process to evaluate how well another group’s study tests evolutionary theory. | • Evaluate a biological study  
• Construct arguments about the quality of a scientific study design | Continuing the activity from Arguing from Evidence in Middle School Science (Osborne et al, *How Do You Design a Test of Evolutionary Theory*, 2017), “students engage in argument in a peer-review process to evaluate how well another group’s study tests evolutionary theory.” |
| Natural Selection | Gather and communicate evidence on the process of natural selection through research (Patterns) | • Mini-Lesson: Natural Selection | Using all of the previous lessons and information gathered, students will work together to summarize and create a class set of notes on natural selection with a focus on patterns. |
| What is Killing the Cats in Cortland County? | Conduct an investigation to provide evidence that evolution only occurs when selection causes a shift in the frequency of a heritable trait within a species. (Cause and Effect) | • Evaluate a claim about the evolution of cats by sorting individual pieces of evidence from a fictional case study.  
• Envision mathematical representations of data that could be used to support a claim about the evolution of cats. | Using the activity from Arguing from Evidence in Middle School Science (Osborne et al, What's Killing the Cats in Warner County, 2017), “students are asked to evaluate a claim about the evolution of cats by sorting individual pieces of evidence from a fictional case study. Then, students are asked to envision mathematical representations of data that could be used to support a claim about the evolution of cats.” |
| What is Killing the Cats in Cortland County? | Construct an argument based on evidence that evolution only occurs when selection causes a shift in the frequency of a heritable trait within a species. (Cause and Effect) | • construct a scientific argument about evolution based on the evidence they have collected. | Continuing the activity from Arguing from Evidence in Middle School Science (Osborne et al, What's Killing the Cats in Warner County, 2017), students will “construct a scientific argument about evolution based on the evidence they have collected.” |
| Where did all the dinosaurs go? | Construct an argument based on evidence that evolution only occurs when selection causes a shift in the frequency of a heritable trait within a species. (Cause and Effect) and that these shifts are typically in favor of individuals who are more fit for a particular environment, those that are not will go extinct. | • construct a scientific argument about the evolution of birds that demonstrates their knowledge of natural selection, inheritance of traits, and fossil evidence for evolution. | Using all of the information collected over the course of the unit, students will construct an explanation using Claim, Evidence, and Reasoning to produce a conclusion that demonstrates their understanding of natural selection, genetics, inheritance of traits, and ability to use fossil evidence as part of their conclusion. |
Earth’s Systems

<table>
<thead>
<tr>
<th>Unit</th>
<th>Earth’s Systems</th>
<th>Course(s)</th>
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</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
<td>Time Frame</td>
<td>10 Weeks</td>
</tr>
</tbody>
</table>

Adapted from The Wonder of Science (Andersen, 2017) and Next Gen Storylines (Edwards et al, 2016)

Unit Overview

Students will explore the various methods by which the systems that work within Earth affect the surface and interactions of spheres within Earth. Students will focus on the development of science and engineering practices through the cross-cutting concepts of energy and matter, stability and change, and cause and effect. Students will, at the end of the unit, be able to explain the formation of mountains and similar geologic features and highlight the effect of various processes like erosion, plate tectonics, weathering and similar processes on the changing surface on Earth under the theme of energy and matter transformations.

Bundle Breakdown

Performance Expectations:

- MS-ESS2-1. Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process. [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth’s materials.] [Assessment Boundary: Assessment does not include the specific identification and naming of minerals and rocks but could include the general classification of rocks as igneous, metamorphic, or sedimentary.]
- MS-ESS2-4. Develop a model to describe the cycling of water through Earth’s systems driven by energy from the Sun and the force of gravity. [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models could include conceptual or physical models.] [Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.]
- MS-ESS3-1 Construct a scientific explanation based on evidence for how the uneven distributions of Earth’s mineral, energy, and groundwater resources are the result of past and current geologic processes. [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes could include petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction]

**Disciplinary Core Ideas**

- **ESS2.A: Earth’s Materials and Systems**
  - All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms. (MS-ESS2-1)

- **ESS2.C: The Roles of Water in Earth’s Surface Processes**
  - (NYSED) Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation, sublimation, deposition, precipitation, infiltration, and runoff. (MS-ESS2-4)
  - (NYSED) Global movements of water and its changes in form are driven by sunlight and gravity. (MS-ESS2-4)

- **ESS3.A: Natural Resources**
  - Humans depend on Earth’s land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (MS-ESS3-1)

**Science and Engineering Practices**

- Asking Questions
- Making Models
- Analyzing and Interpreting Data
- Constructing Explanations
- Using Mathematics and Computational Thinking
- Designing Solutions

**Cross-Cutting Concepts**
## Unpacking the Unit

<table>
<thead>
<tr>
<th>Statement from K-12 Framework</th>
<th>Relevant Concepts from Statement</th>
<th>Cross-Cutting Concepts</th>
</tr>
</thead>
</table>
| All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. | ● Energy creates change in a system.  
● Earth’s system runs on input from the Sun’s energy and the energy from the core of the Earth | ● Energy and Matter |
| Earth is a complex system of interacting subsystems: the geosphere, hydrosphere, atmosphere, and biosphere. | ● The geosphere includes the layers of the Earth: Crust, Mantle, Core  
● The biosphere includes all living beings  
● The atmosphere includes the gas surrounding the planet  
● The hydrosphere includes all sources of water. | ● Energy and Matter |
| Humans are of course part of the biosphere, and human activities have important impacts on all of Earth’s systems. | ● The use of natural resources on the part of humans has both direct and indirect effects on the natural world. | ● Stability and Change  
● Cause and Effect |
| Solid rocks, for example, can be formed by the cooling of molten rock, the accumulation and consolidation of sediments, or the alteration of older rocks by heat, pressure, and fluids. | ● As energy moves about a system, materials are changed into different forms. | ● Stability and Change  
● Energy and Matter |
| These (waters) properties include water’s exceptional capacity to absorb, store, and release large amounts of energy as it changes state; to transmit sunlight; to expand upon freezing; to dissolve and transport many materials; and to lower the viscosities and freezing points of the material when mixed with fluid rocks in the mantle. | ● The properties of water play a key role in how water affects other systems.  
   ○ Ex: Ice expansion can lead to rock erosion | ● Energy and Matter |
Humans depend on Earth’s land, ocean, atmosphere, and biosphere for many different resources, including air, water, soil, minerals, metals, energy, plants, and animals.

- Although humans typically use many non-renewable resources, we can also use these resources to make changes to our environment in order to better the land around us.

| Cause and Effect | Stability and Change |

### Anchoring Phenomenon/Problem

How can Earth’s surface change over time?

### Enduring Understandings

- Energy drives all of Earth’s processes
- Energy causes changes in systems
- All matter is transformed, it cannot be created or destroyed.
- The rock cycle allows for the transfer of matter into different types through the input of energy.
- The water cycle allows for the transfer of water into different forms through the input or release of energy.
- Rocks are eroded away by various forces that cause the wearing down of materials.
- Mountains and volcanoes form from the interaction of tectonic plates.

### Essential Questions

- How do Earth's major systems interact?
- How do the properties and movements of water shape Earth's surface and affect its systems?

### Vocabulary

- Sedimentary Rock
- Igneous Rock
- Metamorphic Rock
- Plate Tectonics
- Oceanic Crust
- Continental Crust
- Mountain Formation
- Stratovolcanoes
- Erosion
- Rock Cycle
### Assessments

Formative Assessments - Labs, Homework Review, Vocabulary
Summative Assessments - C.E.R from Labs, Quizzes, Exams.

### General Lesson Sequence

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Learning Performance</th>
<th>Learning Experiences</th>
<th>Overarching Lesson Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shells Found on Top of a Mountain</td>
<td>Students will ask questions about how seashells can be found on top of a mountain. (Cause and Effect)</td>
<td>• Build curiosity&lt;br&gt;• Ask questions based on cause and effect relationships&lt;br&gt;• Organize questions based on cause and effect.</td>
<td>Students are presented with images of various fossils that can be found on the top of Mt. Everest and other Himalayan Mountains. Students will begin to ask questions about the phenomena under the theme of cause and effect. Students then will sort the questions with the teacher into similar categories.</td>
</tr>
<tr>
<td>Activity</td>
<td>Description</td>
<td>Methods</td>
<td>Notes</td>
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<tr>
<td>----------------------------------------------</td>
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</tr>
</tbody>
</table>
| Shells Found on Top of a Mountain            | Students will **model** how seashells could be found on top of a mountain.  (Cause and Effect) | ● Develop a model (systems, cause and effect)  
● Individual whiteboarding  
● Classroom consensus model | Using their knowledge of science, students will develop a model based on their questions on how mountains formed with marine fossils at the top. A classroom consensus model should be developed from the themes of the student models. |
| Rock Cycle                                   | Students will **conduct an investigation** on the formation of rocks through the use of candy as a model. (Cause and Effect, Stability and Change) | ● Describe the formation of rocks  
● Explore sedimentary, igneous, and metamorphic rocks. | Students will define the three types of rocks and then conduct an investigation that demonstrates how these rocks form using candy as a model.                                                                 |
| Marianas Trench                              | Students will **collect and communicate information** about how the Marianas Trench formed. (Cause and Effect) | ● Research and collect information from reliable sources  
● Communicate information with peers.  
● Mini lesson: ocean trenches | Students will research the formation of the Mariana Trench, which contains marine fossils. Following the research, the teacher will have a mini lesson on the formation of deep ocean trenches and plate tectonics. |
| Mountain Formation                           | Students will **model** how a mountain is able to form as the continental crust and continental crust collide. (Cause and Effect) | ● Modeling  
● Demonstration of how materials can move within the geosphere in different forms. | Students will model how a mountain forms over time using clay and something to represent fossils.                                                                                                           |
| Volcano Formation                            | Students will **model** how a volcano is able to form as the continental crust and oceanic crust collide. (Cause and Effect) | ● Modeling  
● Demonstration of how materials can move within the geosphere in different forms. | Students will model how a volcano forms over time using similar materials as the last investigation and will then demonstrate other methods by which materials can move within the geosphere. |
| Plate Tectonics                              | Students will **collect and communicate information** about plate tectonic movement contributions to the changing Earth. (Stability and Change) | ● Update models to include content  
● Peer developed notes | Using their investigations, models, and research, students will update models to include plate tectonics, and will create classroom notes with peers on the formation of mountains, volcanoes and plate tectonic interactions. |
| Mountain Erosion | Students will model how a mountain is able to change shape over time. (Stability and Change) | ● Modeling  
● Demonstration of how materials can move within the geosphere in different forms. | With the knowledge on how mountains form, students will model how mountains are able to break down over time. |
| Mountain Erosion | Students will conduct an investigation on how erosion contributes to the cycling of matter and energy within the geosphere. (Energy and Matter) | ● Conduct an investigation  
● Analyze observations (data)  
● Construct explanations | Using their models as a guide, students will plan and conduct an investigation that requires them to observe how wind and water affect mountain formation over time. |
| Mountain Erosion | Students will update their models to include information about erosion. (Energy and Matter) | ● Update models to include content | Students will use the results of their investigation to update their models to include the breakdown of mountains over time. |
| Drought in the UAE | Students will ask questions about the cause of droughts and water loss in the UAE. Cause and Effect | ● Build curiosity  
● Ask questions based on cause and effect relationships  
● Organize questions based on cause and effect. | Students will look at the effect of drought in the United Arab Emirates. Students should ask questions based on cause and effect and then organize their questions into categories. |
| Towing an Iceberg to the United Arab Emirates | Students will model how towing an iceberg to the UAE would provide adequate fresh water. (Cause and Effect) | ● Develop a model (systems, cause and effect)  
● Individual whiteboarding  
● Classroom consensus model | Using their knowledge of geoscience processes, students will model how the towing of an iceberg could be used to provide the UAE with adequate water. |
| UAE Building a Mountain to Increase Rainfall | Students will construct an explanation based on evidence on how the building of a mountain will change the distribution of resources in the UAE. (Cause and Effect) | ● Using evidence to construct claims  
● Communicating Information | Students will construct an explanation that includes how the building of a mountain will increase rainfall using their knowledge from this unit, and from the weather unit. |
Weather

<table>
<thead>
<tr>
<th>Unit</th>
<th>Weather</th>
<th>Course(s)</th>
<th>8th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
<td>Time Frame</td>
<td>12 Weeks</td>
</tr>
</tbody>
</table>

Adapted from The Wonder of Science (Andersen, 2017) and Next Gen Storylines (Edwards et al, 2016)

Unit Overview

Students will explore the fundamentals of weather prediction (meteorology) as they learn how to predict weather outcomes based on observations made from data. Students will work on asking questions, planning and carrying out investigations, and modeling gas particle interactions, system relationships, cause and effect relationships and will practice searching for patterns in data as they investigate the causes of various weather patterns.

Bundle Breakdown

Performance Expectations:

- **MS-ESS2-5.** Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions. [Clarification Statement: Emphasis is on how air flows from regions of high pressure to low pressure, the complex interactions at air mass boundaries, and the movements of air masses affect weather (defined by temperature, pressure, humidity, precipitation, and wind at a fixed location and time). Emphasis is on how weather can be predicted within probabilistic ranges. Data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [Assessment Boundary: Assessment includes the application of weather data systems but does not include recalling the names of cloud types, weather symbols used on weather maps, the reported diagrams from weather stations, or the interrelationship of weather variables.]

- **MS-ESS2-6.** Develop and use a model to describe how unequal heating and rotation of Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. [Clarification Statement: Emphasis is on how patterns vary by latitude,
altitude, and geographic land distribution. Emphasis is on the sunlight-driven latitudinal banding causing differences in density that create convection currents in the atmosphere, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the coastlines of continents. Examples of models could include diagrams, maps and globes, or digital representations. [Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.]

Disciplinary Core Ideas

- ESS2.C: The Roles of Water in Earth’s Surface Processes
  - The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (MS-ESS2-5)
  - Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (MS-ESS2-6)

- ESS2.D: Weather and Climate
  - Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6)
  - Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5)
  - The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. (MS-ESS2-6)

Science and Engineering Practices

- Asking Questions
- Developing Models
- Planning and Conducting Investigations
- Constructing Explanations
### Cross-Cutting Concepts

- Stability and Change
- Systems and System Models
- Cause and Effect
- Energy and Matter

### Unpacking the Unit

<table>
<thead>
<tr>
<th>Statement from K-12 Framework</th>
<th>Relevant Concepts from Statement</th>
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</table>
| Water is found almost everywhere on Earth, from high in the atmosphere (as water vapor and ice crystals) to low in the atmosphere (precipitation, droplets in clouds) to mountain snow caps and glaciers (solid) to running liquid water on the land, ocean, and underground. | • Water is constantly cycled among the spheres of the Earth.  
• Complex patterns in these movements are governed by winds, landforms and ocean temperatures | • Cause and Effect  
• Stability and Change |
| Global movements of water and its changes in form are propelled by sunlight and gravity. | • Gravity pulls materials towards the Earth  
• Sunlight’s energy allows for the transformation of water into different states. | • Cause and Effect  
• Systems  
• Energy and Matter |
| Weather, which varies from day to day and seasonally throughout the year, is the condition of the atmosphere at a given place and time. Climate is long term and location sensitive; it is the range of a region’s weather over 1 year or many years, and, because it depends on latitude and geography, it varies from place to place. | • Climate are yearly weather patterns that occur over long periods of time.  
• Weather changes on a day to day basis.  
• The latitude and longitude of an area affects the climate of a region. | • Patterns  
• Systems |
| The ocean exerts a major influence on weather and | • The ocean controls much of the climates. | • Cause and Effect |
| climate. | ● Oceans absorb a large amount of energy from sunlight.  
● The ocean releases this energy very slowly, which results in moderation of the climates.  
● The movement of energy occurs from ocean currents. | ● Systems  
● Cause and Effect |
| --- | --- | --- |
| Sunlight heats Earth’s surface, which in turn heats the atmosphere. The resulting temperature patterns, together with Earth’s rotation and the configuration of continents and oceans, control the large-scale patterns of atmospheric circulation. | ● The Earth’s tilt on its axis leads to unequal heating of the planet.  
● Earth’s rotation and movement upon the axis contributes to atmospheric patterns.  
● The layout of the oceans and continents directs how the ocean and atmosphere circulate over time. | |

**Anchoring Phenomenon/Problem**

We are able to predict weather patterns on a daily basis

**Enduring Understandings**

- Water is constantly cycled among the spheres of the Earth.
- Gravity pulls materials towards the Earth.
- Sunlight’s energy allows for the transformation of water into different states.
- Climate are yearly weather patterns that occur over long periods of time.
- Weather changes on a day to day basis.
- The latitude and longitude of an area affects the climate of a region.
- We can observe patterns in ocean circulation and air mass movements.
- Weather patterns are predictable, but not always correct.
- The interactions of air masses and ocean circulation drive weather patterns.

**Essential Questions**

- How do the properties and movements of water shape Earth's surface and affect Earth’s systems?
- What controls weather and climate?
- How do living organisms alter Earth's processes and structures?
- How do people model the effects of human activities on Earth's climate?
- How do people predict the effects of human activities on Earth's climate?

**Vocabulary**
Assessments

Formative Assessments - Labs, Homework Review, Vocabulary
Summative Assessments - C.E.R from Labs, Quizzes, Exams.

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<tbody>
<tr>
<td>Data - Severe Weather Patterns</td>
<td>Students will ask questions about the causes of severe weather pattern increases over the last several years.</td>
<td>• Build curiosity</td>
<td>Students are presented with data on severe weather patterns in their local area / state over the last several years. Using the data presented, students will organize data and ask questions based on data with the theme of cause and effect about the severe weather patterns.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Analyze data and patterns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Organize questions based on cause and effect.</td>
<td></td>
</tr>
</tbody>
</table>
| Local Rainstorm | Students will create a model that demonstrates how rainstorms occur. (Systems) | • Develop a model (systems)  
• Individual whiteboarding  
• Classroom consensus model | Students will create a model that demonstrates how rainstorms occur based on their current knowledge of science. A classroom consensus model should be constructed from themes agreed upon by the class. |
|-----------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Absolute Zero   | Students will build on their understanding of temperature and absolute zero as they conduct an investigation (Cause and Effect, Patterns) | • Describe the motion of gas particles  
• Explore gas laws through simulations  
• Plot data points to search for patterns | Students will use online simulations (via multiple sources that are available) and explore gas laws through the lens of cause and effect and patterns. Any data collected via simulations will be plotted by students to build of mathematical and computational development skills. |
| Charles Law     | Students will conduct an investigation that explores the interactions of density, temperature, and pressure of gases within a balloon. (Patterns) | • Describe the motion of gas particles  
• Explore gas laws through investigations  
• Plot data points to search for patterns | Using a balloon, students will explore the effects of temperature, density and pressure on the inflation of a balloon. Students will collect observations and data and plot quantitative observations to observe patterns from data. |
| How to make a cloud in your mouth | Students will develop a model on how a cloud is able to form in your mouth (Cause and Effect) | • Modeling  
• Demonstration of how materials can move between the hydrosphere and the atmosphere. | Students are presented with the phenomena that a cloud is formed in an individual’s mouth following repeated clicking on the roof of the mouth. Students will develop a model of how this happens to demonstrate their current understanding of gas laws and particle interactions. Students will then research the cause and compare their model to the cause to see if they were supported. |
| Water Mass Interactions | Students will collection information and produce a model that demonstrates the different types of air masses and air fronts that exist. (Structure and Function) | • Conduct an investigation through research to gather and communicate information about air masses  
• Model concepts | Students will research the different types of air masses that exist, using the cloud in the mouth as a jump start phenomenon. Students will use gathered materials to create a model to demonstrate the movement of water and energy in the atmosphere that can determine weather patterns. |
| Build a Barometer | Students will build a model that measures atmospheric pressure, interpret how this model can be used to determine air pressure, investigate air pressure, track weather using their weather devices, and study atmospheric pressure. (Stability and Change). | • Build and test a model  
• Interpret data  
• Collect data | Students will build a model that measures atmospheric pressure, then interpret how this model can be used to determine air pressure, investigate air pressure, track weather using their weather devices, and study atmospheric pressure. The teacher should discuss how the materials work with the students and give them a list of procedures to follow to build a barometer (Keser, *Build a Barometer*, 2015) |
| Severe Weather Patterns | Students will update their models to include atmospheric pressure and air masses in their models. | • Update models to include content  
• Create peer notes | Using their collected data from investigations, students will update their models to include everything they’ve learned that applies to their models, then will create peer notes with a partner utilizing the information gathered. |
| Atmospheric Layers | Students will be able to develop and use a model to understand the characteristics of the different layers of the Earth's Atmosphere. (Systems) | • Use data on atmospheric pressure, density, and temperature to produce a model that includes the layers of the atmosphere.  
• Individual modeling  
• Classroom consensus model | Provide students with data on atmospheric pressure, density and temperature. Have students organize the data in a way to develop a model that will accurately show the layers of the atmosphere. |
| Data from Earth’s atmosphere in the last 24 hours. | Students will graph and analyze data in order to make claims about the relationship of changes in pressure, temperature, wind speed and dew point in Earth's atmosphere. (Cause and Effect) | • Use data to graph and analyze  
• Interpret data  
• Define cause and effect relationships | Students will graph and analyze live data on the atmosphere that will allow them to see and make claims on the relationships of changes in pressure. |
| Cloud formations | Students will determine the conditions necessary for cloud formation and model the relationship between pressure and cloud formation and the relationship between temperature and cloud formation. (Cause and Effect) | ● Individual modeling  
● Cause and Effect relationships  
● Conduct investigations | Students will determine conditions necessary for cloud formation and model the relationship between pressure and cloud formation and the relationship between temperature and cloud formation. Add 5 mL of tap water to the Erlenmeyer flask then place the balloon over the opening to seal the flask then place it on a hot plate. Heat the water, but do not let it all boil away. Carefully remove the flask from the hot plate and ask students to share what they observe. Have students explain to you why the balloon inflates by drawing on their prior learning from previous labs and investigations. Repeat the procedure with a second Erlenmeyer flask but this time do not stretch the balloon over the opening until after you remove it from the hot plate. Place the flask into the ice water bath. If done correctly the balloon should be inverted into the flask. (Keser, *Cloud in a Bottle*, 2015) |
| Temperatures across different geographic regions | Students will identify and describe patterns of similar temperature and pressure (isobars and isotherms) over a given geographic region | ● Pattern relationships  
● Communicate information  
● Analyze and interpret data | Using live data, have students identify and describe patterns of different geographic regions. Focus should be on the learning of isobars and isotherms, as well as identification of general weather patterns over time. |
| Broadcast of Weather | Students will produce a model that predicts the weather for a given day having analyzed data from previous days. | ● Explore and make predictions from data  
● Individual and peer feedback on models | Using what has been learned, students will predict the weather for the following day based on given data. |
Climate and Climate Change

<table>
<thead>
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<th>Course(s)</th>
<th>8th Grade</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Kelly Russo</td>
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<td>10 Weeks</td>
</tr>
</tbody>
</table>

Adapted from The Wonder of Science (Andersen, 2017) and Next Gen Storylines (Edwards et al, 2016)

Unit Overview

Students will explore the fundamentals of climate change (climatology) as they learn how to interpret and discuss climate data based on observations made from data. Students will work on asking questions, planning and carrying out investigations, and modeling gas particle interactions, system relationships, cause and effect relationships and will practice searching for patterns in data as they investigate the causes of various climate patterns and the effect of human impacts on climate change.

Bundle Breakdown

Performance Expectations:

- MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. [Clarification Statement: Examples of factors could include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence could include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]
• MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* [Clarification Statement: Examples of the design process could include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts could include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

• MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth’s systems. [Clarification Statement: Examples of evidence could include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts could include changes to the appearance, composition, and structure of Earth’s systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the action’s society takes.]

**Disciplinary Core Ideas**

**ESS3.C: Human Impacts on Earth Systems**

• Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)

• Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3), (MS-ESS3-4)

**ESS3.D: Global Climate Change**

• Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth’s mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)
### Unpacking the Unit

<table>
<thead>
<tr>
<th><strong>Statement from K-12 Framework</strong></th>
<th><strong>Relevant Concepts from Statement</strong></th>
<th><strong>Cross-Cutting Concepts</strong></th>
</tr>
</thead>
</table>
| Humans affect the quality, availability, and distribution of Earth’s water through the modification of streams, lakes, and groundwater. | ● As human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth | ● Systems  
● Cause and Effect |
| Human activities now cause land erosion and soil movement annually that exceed all-natural processes. | ● Drastic changes to land have occurred due to the building of cities, changing of mountainous territory to farmland, the building of factories, etc.  
● These changes have impacted surrounding populations within ecosystems and damaged supplies of water over time. | ● Cause and Effect  
● System and System Models |
| Some negative effects of human activities are | ● Renewable energies have become an important part of our | ● Stability and |
| reversible with informed and responsible management. | movement to try to reduce our impact on the Earth’s natural systems. | Change
● Systems |
| Global climate change, shown to be driven by both natural phenomena and by human activities, could have large consequences for all of Earth’s surface systems, including the biosphere | ● Humans release of greenhouse gases through various activities are a major driving force in the rise of Earth’s surface temperature. | ● Cause and Effect
● Patterns |
| Climate models are important tools for predicting... | ● Climate models rely on historical and current data to make predictions
● Climate models are not perfect but do provide valuable information for the possible future of the Earth. | ● Patterns |

**Anchoring Phenomenon/Problem**

How has Earth’s climate changed over time?

<table>
<thead>
<tr>
<th>Enduring Understandings</th>
<th>Essential Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Materials are constantly cycling through ecosystems and get re-used in the environment.</td>
<td>● How do humans change the planet?</td>
</tr>
<tr>
<td>● Living things depend upon one another and their environment to survive.</td>
<td>● How do people model and predict the effects of human activities on Earth's climate?</td>
</tr>
<tr>
<td>● Humans have the power to change the environment more than any other living thing.</td>
<td></td>
</tr>
<tr>
<td>● Earth’s weather and climate systems are the result of complex interactions between land, ocean, ice, and atmosphere.</td>
<td></td>
</tr>
<tr>
<td>● Scientists use weather variables to describe weather and study weather systems.</td>
<td></td>
</tr>
<tr>
<td>● Climate is the long-term average weather conditions that occur in an area.</td>
<td></td>
</tr>
<tr>
<td>● Climate data has been collected over several decades and is used to model future outcomes of the Earth.</td>
<td></td>
</tr>
</tbody>
</table>
### Vocabulary

- Climate
- Climate Change
- Ice Cores
- Reflectivity
- Albedo Effect
- Glacial Melt
- Sea Level Rise
- Green House Gases
- Feedback Loops
- Temperature
- Heat
- Carbon Dioxide
- Water

### Assessments

- Formative Assessments - Labs, Homework Review, Vocabulary
- Summative Assessments - C.E.R from Labs, Quizzes, Exams.
<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Learning Performance</th>
<th>Learning Experiences</th>
<th>Overarching Vision for Lesson</th>
</tr>
</thead>
</table>
| Data - Climate Patterns over the last several decades | Students will ask questions about the causes of climate change pattern increases over the last several years. | ● Build curiosity  
● Analyze data and patterns  
● Organize questions based on cause and effect. | Using data on climate patterns for their current area over the last several decades, have students analyze data, search for patterns, and ask questions in the realm of cause and effect. |
| Data - Climate Patterns over the last several decades | Students will create a model that demonstrates how and why climate change could occur. (Systems) | ● Develop a model (systems)  
● Individual whiteboarding  
● Classroom consensus model | Using data on climate patterns for their current area over the last several decades, have students use their analyzed data to produce a model that would explain why climate change would occur. Take time to explain the concept of systems and system models. |
| Earth’s Changing Climate                           | Students will build on their understanding of the collection of climate data as they conduct an investigation using online simulations (Cause and Effect, Patterns) | ● Use online simulations to conduct investigations  
● Construct explanations from data analysis | Students will use online simulations to conduct an investigation to explore and critically analyze real-world data, make claims about data and determine their own level of certainty with regards to their claims. |
| Ice Cores                                           | Students will conduct an investigation that explores how ice core formation can give us information about Earth’s climate past (Patterns) | ● Model ice core formation  
● Construct explanations | Students make their own "ice cores" using information from a hypothetical scenario and share their cores with classmates. Then students will construct explanations as to the types of information ice cores could provide us in regard to Earth’s climate past. |
| Ice Cores                                           | Students will analyze and interpret data from ice cores on climate change (Cause and Effect) | ● Conducting an investigation  
● Analyzing and interpreting data | Students will be given data on ice cores and must analyze that data to construct an explanation that describes the relationship between carbon dioxide levels in ice cores and... |
Students will conduct an investigation using an online simulation to explore how Earth's surface and greenhouse gases interact with radiation. (Stability and Change)

- Explain what happens when solar radiation interacts with Earth's surface
- Explain how greenhouse gases cause Earth's temperature to warm
- Explore data about changes in atmospheric CO2 levels.

Students use computational models to explore how Earth's surface and greenhouse gases interact with radiation. Students will then explore how solar radiation interacts with Earth's surface and atmosphere by using interactive computational models. Then they interpret real-world changes in atmospheric carbon dioxide over varying time frames.

Students will conduct an investigation with different Earth surface materials to determine how reflective they are.

- Use a model to explore reflectivity of certain Earth surface materials.

Students explore the heating and cooling rate of different Earth materials in order to answer the question "How does the surface type and moisture content affect the surface temperature?"

Students will conduct a research investigation on how the cooling effect of snow, ice and clouds affects Earth climate.

- Explain the albedo effect
- Describe positive and negative feedback loop
- Identify the uncertainty about feedback loops and scientist's ability to predict future climate conditions

By using interactive computational models from the Concord Consortium (University of California & National Geographic Society, 2017) students explore how surfaces such as snow, ice, and some clouds have a chilling effect on Earth. Then they will use real world data to examine the positive feedback loop between ice coverage and temperature.

Students will model how the expansion of water from heat causes sea level rise on a global scale. (Cause and Effect)

- Determine the relationship between heat and the expansion of water
- Represent graphically how water expands as it is heated
- Connect this information to what is happening on a global scale

Students will use a mathematical model to generate data about a phenomenon in a natural system, looking at the inputs and outputs in the system, and relating this to a much larger scale model, Earth's oceans.
<table>
<thead>
<tr>
<th>Human Impact on Resources</th>
<th>Students will conduct a research investigation on how humans affect resources through our actions. (Cause and Effect)</th>
<th>● Determine relationship between human activity and climate change over time.</th>
<th>Students will explore how humans affect climate change through research, with a focus on cause and effect outcomes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Amazon Forest Loss</td>
<td>Students will gather and communicate information through research on how humans affect resources through our actions. (Cause and Effect)</td>
<td>● Explore human interactions within the biosphere.</td>
<td>Students will continue to explore how human activity affects climate change, and also how it affects the biosphere with a focus on cause and effect outcomes.</td>
</tr>
</tbody>
</table>
| Human Impact on Climate   | Students will design a solution to mitigate humans affect resources through our actions. (Cause and Effect) | ● Design solutions or method to minimize the impact of humans on the environment.  
● Model system interactions and cause and effect interactions  
● Communicate information to individuals | Using their knowledge of science as the final lesson, students will design a solution to mitigate human cause climate change using the concepts and investigations over the last two years. |
# Chapter 5: Performance Assessments

## Short Performance Assessment: MS-LS1-1

<table>
<thead>
<tr>
<th>Title</th>
<th>Meat Maggots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>Science 7</td>
</tr>
</tbody>
</table>

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**Performance Expectation**

MS-LS1-1: Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.

**Clarification Statement**: Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or many and varied cells.

**Assessment Boundary**: none

**Science and Engineering Practice**

Planning and Carrying Out Investigations

- Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation.

**Disciplinary Core Ideas**

LS1.A: Structure and Function

- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).

**Crosscutting Concept**

Scale, Proportion, and Quantity

- Phenomena that can be observed at one scale may not be observable at another scale.

**Student Performance**

1. Identifying the phenomenon under investigation
2. Identifying the evidence to address the purpose of the investigation
3. Planning the investigation
4. Collecting the data
An experiment was conducted where meat was placed in 3 separate jars over an 8-day period of time. Figure 1 (OpenStax, n.d.) below shows the results of this experiment. The open jar allows air and any other substances in, closed jar is airtight, and the netted jar allows only air in.

![Figure 1](image)

1. The cell theory makes the claim that cells can only come from other living cells. Find evidence in the diagrams above to support this claim. Connect your evidence to the claim using reasoning.

________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

2. Explain what further evidence you would need to gather to prove that maggots are living things and how you would collect such evidence.

________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________
<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student identifies evidence related to the concept but does not clearly explain the connection to the claim proposed by the student.</td>
<td>Student identifies evidence seen from the diagram and has an unclear but present connection to the claim.</td>
<td>Student identifies evidence seen from the diagram and has a clear connection to the claim. Some reasoning is used but needs improvement.</td>
<td>Student identifies evidence seen from the diagram and has a clear connection to the claim and supports it with accurate reasoning.</td>
<td></td>
</tr>
<tr>
<td>Question 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student proposes evidence to collect but does not explain an accurate way to collect such evidence.</td>
<td>Student proposes evidence to collect and explains how they would collect such evidence but does not reference tools to use in the investigation.</td>
<td>Student proposes evidence to collect and explains how they would collect such evidence and an accurate investigation that could be used with reference to tools.</td>
<td>Student proposes multiple lines of evidence to collect and accurate methods to collect such evidence using proper tools.</td>
<td></td>
</tr>
</tbody>
</table>
Title: Salt and Slugs

<table>
<thead>
<tr>
<th>Designed by Kelly Russo</th>
<th>Course(s)</th>
<th>7th</th>
</tr>
</thead>
</table>

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### Performance Expectation

MS-LS1-2: Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.

Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.

Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their relationship to the whole cell. Assessment does not include the biochemical function of cells or cell parts.

### Science and Engineering Practice

- Developing and Using Models
  - Develop and use a model to describe phenomena.

### Disciplinary Core Ideas

- LS1.A: Structure and Function
  - Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.

### Crosscutting Concept

- Structure and Function
  - Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

### Student Performance

1. Components of the model
2. Relationships
3. Connections
Rachel and Jon are two students that were shown what happens when salt is dropped on a slug. The slug shrunk as more salt was added as shown below.

1. Construct a model of the cell that includes the direction of particle movement across the cell membrane that would cause this to happen to the slug. In your model, please include:
   - Labeled cell membrane
   - Salt concentrations
   - Direction of movement
2. Construct an explanation of what is happening to the cells of the slug as salt is added to it.

__________________________________________________________________________________________

__________________________________________________________________________________________

__________________________________________________________________________________________

__________________________________________________________________________________________

3. How would the slug change if it were placed in rainwater?

__________________________________________________________________________________________

__________________________________________________________________________________________

__________________________________________________________________________________________

__________________________________________________________________________________________
## Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student includes only one of the requirements for the model.</td>
<td>Students includes the components of the model but labeling and direction of movement is unclear.</td>
<td>Students includes the components of the model but labeling or direction of movement is unclear.</td>
<td>Students includes the components of the model with clear labeling of the cell membrane, water direction.</td>
<td></td>
</tr>
</tbody>
</table>

## Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student does not explain that the water moves towards the outside of the cell to an area of lower concentration.</td>
<td>Students mentions osmosis/diffusion but gives an unclear explanation.</td>
<td>Student simply connects diffusion and osmosis but does not use evidence from the model.</td>
<td>Student connects diffusion and osmosis to what is happening to the slug using evidence from the graph.</td>
<td></td>
</tr>
</tbody>
</table>

## Assessment Rubric - Question 3

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student does not explain that the water moves towards the inside of the cell to an area of lower concentration.</td>
<td>Students mentions osmosis/diffusion but gives an unclear explanation.</td>
<td>Student notes that because water is being added outside of the cells, the water will move inward towards the cell, but now how the cell would directly change.</td>
<td>Student notes that because water is being added outside of the cells, the water will move inward towards the cell, increasing their size.</td>
<td></td>
</tr>
</tbody>
</table>


# Short Performance Assessment: MS-LS1-3

<table>
<thead>
<tr>
<th>Title</th>
<th>Muscular Dystrophy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td><em>Kelly Russo</em></td>
</tr>
<tr>
<td>Course(s)</td>
<td>7th</td>
</tr>
</tbody>
</table>

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### Performance Expectation

**MS-LS1-3**: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

**Clarification Statement**: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.

**Assessment Boundary**: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.

### Science and Engineering Practice

**Engaging in Argument from Evidence**
- Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.

### Disciplinary Core Ideas

**LS1.A: Structure and Function**
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.

### Crosscutting Concept

**Systems and System Models**
- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.

### Student Performance

1. Supporting claims
2. Identifying scientific evidence
3. Evaluating and critiquing the evidence
4. Reasoning and synthesis
Muscular dystrophy is a group of diseases that cause weakness and a progressive loss of muscle mass.

Duchenne type muscular dystrophy is the most common form of muscular dystrophy, and includes the following symptoms:

- Frequent falls
- Difficulty rising from a lying or sitting up position
- Trouble running and jumping
- Waddling gait
- Walking on the toes
- Large calf muscles
- Muscle pain and stiffness
- Learning disabilities

Alicia states that all organisms are made of cells, and that these cells work together to form tissues, organs, organ systems and organisms. She has gathered evidence from investigations of cells using microscopes, as well as research on the levels of organization. After learning about Duchenne muscular dystrophy (DMD), Alicia claims that issues with the cells and tissues of one body system can affect other body systems. Using the information above as evidence, highlight evidence present and reasoning that would support Alicia’s claim.

<table>
<thead>
<tr>
<th>Claim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence</td>
</tr>
<tr>
<td>Reasoning</td>
</tr>
<tr>
<td>Description of performance</td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
# Short Performance Assessment: MS-LS1-4

<table>
<thead>
<tr>
<th>Title</th>
<th>Bowerbirds and Sexual Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>7th Grade</td>
</tr>
</tbody>
</table>

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**Performance Expectation**

**MS-LS1-4**: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

**Clarification Statement**: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.

**Assessment Boundary**: none

**Science and Engineering Practice**

**Engaging in Argument from Evidence**
- Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

**Disciplinary Core Ideas**

**LS1.B: Growth and Development of Organisms**
- Animals engage in characteristic behaviors that increase the odds of reproduction.
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.

**Crosscutting Concept**

**Cause and Effect**
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

<table>
<thead>
<tr>
<th>Student Performance</th>
<th>1. Supporting claims</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Identifying scientific evidence</td>
</tr>
<tr>
<td></td>
<td>3. Evaluating and critiquing the evidence</td>
</tr>
<tr>
<td></td>
<td>4. Reasoning and synthesis</td>
</tr>
</tbody>
</table>
A male bowerbird woos his chosen one by building a fanciful "bower" that serves as a stage for his elaborate courtship ritual. A successful performance will attract a female to mate with him. Every one of the 20 different species of bowerbird build a slightly different bower, image below, and puts on a faintly different performance. However, all bowerbird species have some version of this mating ritual. Evidence has shown it is a behavior trait inherited from a common ancestor who also used this sort of mating ritual (University of California of Paleontology, n.d.).

1. Based on the information and image shown, identify the relationship between successful bower making and dancing performing and the probability of successful reproduction.
<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student makes a vague cause and effect claim.</td>
<td>Student makes a vague claim that supports the cause and effect relationships but does not clearly explain the relationship between animal behaviors and the probability of successful reproduction.</td>
<td>Student makes a claim that supports the cause and effect relationships but does not clearly explain the relationship between animal behaviors and the probability of successful reproduction.</td>
<td>Student makes a claim that supports the cause and effect relationships between animal behaviors and the probability of successful reproduction.</td>
<td></td>
</tr>
</tbody>
</table>
Title: Wheat Growth in Different Environments

<table>
<thead>
<tr>
<th>Designed by</th>
<th>Kelly Russo</th>
<th>Course(s)</th>
<th>7</th>
</tr>
</thead>
</table>

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Performance Expectation

MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds. Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.

Science and Engineering Practice

Constructing Explanations

• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

• Genetic factors as well as local conditions affect the growth of the adult plant.

Crosscutting Concept

Cause and Effect

• Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Student Performance

1. Articulating the explanation of phenomena
2. Evidence
3. Reasoning
A student wanted to know the effect on different environments on the growth and development of a species of plant. The student opted to treat plants in drought, cold, saline, and heat conditions and measured the plant height, number of leaves, and the color of leaves at the end of two weeks. This data is shown below.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant Leaves</th>
<th>Height</th>
<th>Leaf Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>1</td>
<td>2 cm</td>
<td>Yellow</td>
</tr>
<tr>
<td>Cold</td>
<td>1</td>
<td>1 cm</td>
<td>Brown</td>
</tr>
<tr>
<td>Saline</td>
<td>2</td>
<td>3 cm</td>
<td>Pale Green</td>
</tr>
<tr>
<td>Heat</td>
<td>2</td>
<td>2.5 cm</td>
<td>Green</td>
</tr>
<tr>
<td>Control</td>
<td>4</td>
<td>4 cm</td>
<td>Green</td>
</tr>
</tbody>
</table>

1. The strength of a plant is directly correlated with its ability to flower and to produce seeds. If crops such as wheat and rice are forced to grow in areas that are affected by environmental changes such as increased heat, cold, or drought, what will happen to the production of seeds and other plant parts for human and animal use? Use evidence and reasoning to support your answer.
<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students writes a statement that doesn’t relate the given phenomenon to the idea that both environmental and genetic factors influence the growth of organisms, but rather to something else.</td>
<td>Students writes a statement that relates the given phenomenon to the idea that both environmental and genetic factors influence the growth of organisms but doesn’t use evidence and reasoning to construct their scientific explanation.</td>
</tr>
<tr>
<td>Students writes a statement that relates the given phenomenon to the idea that both environmental and genetic factors influence the growth of organisms but uses vague evidence and reasoning to construct their scientific explanation.</td>
<td>Students writes a statement that relates the given phenomenon to the idea that both environmental and genetic factors influence the growth of organisms and uses clear evidence and reasoning to construct their scientific explanation.</td>
</tr>
</tbody>
</table>
# Short Performance Assessment: MS-LS1-6

<table>
<thead>
<tr>
<th>Title</th>
<th>Cycling of Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>7th</td>
</tr>
</tbody>
</table>

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### Performance Expectation

**MS-LS1-6:** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.  
**Clarification Statement:** Emphasis is on tracing movement of matter and flow of energy.  
**Assessment Boundary:** Assessment does not include the biochemical mechanisms of photosynthesis.

### Science and Engineering Practice

**Constructing Explanations**  
- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

### Disciplinary Core Ideas

**LS1.C: Organization for Matter and Energy Flow in Organisms**  
- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

**PS3.D: Energy in Chemical Processes and Everyday Life**  
- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary)

### Crosscutting Concept

**Energy and Matter**  
- Within a natural system, the transfer of energy drives the motion and/or cycling of matter.

### Student Performance

1. Articulating the explanation of phenomena  
2. Evidence  
3. Reasoning
Background:

A biosphere, Figure 1 (Ecotechnics Staff, 2011), is a sealed container that contains people and a limited supply of air. There are three things that must happen in order to keep air in a submarine breathable:

- Oxygen has to be replenished as it is consumed. If the percentage of oxygen in the air falls too low, a person suffocates.
- Carbon dioxide must be removed from the air. As the concentration of carbon dioxide rises, it becomes a toxin.
- The moisture that we exhale in our breath must be removed.

You have been hired as a botanist that will select species of plants to include in the biosphere that will have the greatest benefit to allow people to survive in the biosphere for five years. Below is data on the species of plants you have access to. Use the evidence from the graph, information provided below, and your knowledge of matter cycling and energy flow to construct a scientific explanation describing the following:
1-3. Which plant species would most affect the rate of matter cycling and energy flow that is beneficial to the crew? Use Claim - Evidence - Reasoning to organize your answer.

1. Claim:

2. Evidence:

3. Reasoning:
### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student writes a claim that is somewhat related to the phenomenon but does not reference the idea that photosynthesis results in the cycling of matter and energy into and out of organisms.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student writes a claim that is related to the phenomena but does not clearly reference the idea that photosynthesis results in the cycling of matter and energy into and out of organisms.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student writes a claim that is related to the phenomena and clearly references the idea that photosynthesis results in the cycling of matter or energy into and out of organisms, but not both.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student writes a claim that is related to the phenomena and clearly references the idea that photosynthesis results in the cycling of matter and energy into and out of organisms.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student uses vague general evidence trends to construct a scientific explanation like “the graph goes up,” or other similar responses.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student uses clearer general evidence trends to construct a scientific explanation like “the data for ___ goes up,” or other similar responses.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student uses general evidence trends to construct a scientific explanation for the phenomenon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student uses specific evidence to construct a scientific explanation for the phenomenon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 3

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student uses vague general reasoning to construct a scientific explanation that does not accurately use scientific terms learned through own investigations and research.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student uses clearer general reasoning to construct a scientific explanation that somewhat uses scientific terms learned through own investigations and research. Reasoning is not connected to the evidence.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student uses clear general reasoning to construct a scientific explanation that uses scientific terms learned through own investigations and research. Reasoning is somewhat connected to the evidence.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student uses clear general reasoning to construct a scientific explanation that uses scientific terms learned through own investigations and research. Reasoning is clearly connected to the evidence.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Short Performance Assessment: MS-LS1-7

<table>
<thead>
<tr>
<th>Title</th>
<th>Tomato Torture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
</tbody>
</table>

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### Performance Expectation

**MS-LS1-7**: Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

**Clarification Statement**: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.

**Assessment Boundary**: Assessment does not include details of the chemical reactions for photosynthesis or respiration.

### Science and Engineering Practice

**Developing and Using Models**
- Develop a model to describe unobservable mechanisms.

### Disciplinary Core Ideas

**LS1.C: Organization for Matter and Energy Flow in Organisms**
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.

**PS3.D: Energy in Chemical Processes and Everyday Life**
- Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary)

### Crosscutting Concept

**Energy and Matter**
- Matter is conserved because atoms are conserved in physical and chemical processes.

### Student Performance

1. Components of the model
2. Relationships
3. Connections
Vincent was upset that several insects were eating his tomato garden. Since his love for tomatoes always came first in his life, he opted to research the effect of pesticides on insects. After doing a bit of research, he came up with the two models, Figure 1 (NGSA Project, n.d.) shown below to help her understand what adding a pesticide could do to the water, carbon dioxide and energy generation from the insects that would have eaten the tomatoes.

Using the models, describe what will happen to the water, carbon dioxide, and energy outputs of the insects when the pesticide is used. Be sure to include:

- What you know what the breakdown and rearrangement of matter within the insect’s body.
- What you know about how energy is transferred.

__________________________________________________________________________________________
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### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using the model, the student is somewhat able to reference the rearrangement of matter but doesn’t reference how food molecules are broken down, and/or that the food molecules are rearranged, and energy is released to support life processes.</td>
<td>Using the model, the student is vaguely able to reference the rearrangement of matter but doesn’t reference how food molecules are broken down, and/or that the food molecules are rearranged, and energy is released to support life processes.</td>
<td>Using the model, the student is able to reference the rearrangement of matter but doesn’t reference how food molecules are broken down, and/or that the food molecules are rearranged, and energy is released to support life processes.</td>
<td>Using the model, the student is able to reference the rearrangement of matter, how food molecules are broken down, and that the food molecules are rearranged, and energy is released to support life processes.</td>
<td></td>
</tr>
</tbody>
</table>
### Short Performance Assessment: MS-LS1-8

<table>
<thead>
<tr>
<th>Title</th>
<th>Bat Echolocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>7</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>MS-LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarification Statement</td>
<td>none</td>
</tr>
<tr>
<td>Assessment Boundary</td>
<td>Assessment does not include mechanisms for the transmission of this information.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science and Engineering Practice</th>
<th>Obtaining, Evaluating, and Communicating Information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>LS1.D: Information Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crosscutting Concept</th>
<th>Cause and Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Cause and effect relationships may be used to predict phenomena in natural systems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student Performance</th>
<th>1. Obtaining information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Evaluating information</td>
</tr>
</tbody>
</table>
Many bats use an acoustic behavior called echolocation to perceive the world around them. During echolocation, bats emit ultrasonic sound waves and analyze the echoes returned when those sound waves bounce off of another object, such as a moth. The bat can then interpret this feedback to gauge distance and adjust its physical movements to capture the moth. During prey capture, bats emit echolocation signals at a variable rate. Before they detect prey, they are in “search” phase and emit signals infrequently. After they detect prey, they enter the “approach” phase and emit signals at an increased rate. The final phase is the “terminal buzz” in which signals are emitted in a rapid sequence to receive information frequently. In many species of bats, the terminal buzz consists of two distinct subphases: buzz I and buzz II.

When signals are emitted slowly, bats have time to process each echo before sending the next signal, but the short interval between calls in the buzz likely does not leave enough time for the bat to process and react to information. Some scientists have argued that the buzz is not used to help during the current capture attempt but rather to help analyze what went wrong when prey escapes. In this study, researchers tested whether bats change their behavior during the buzz phase based on feedback. If so, the result would support the notion that the terminal buzz is used to respond to changes during prey capture rather than for evaluating failed captures afterward. In the control trials (Figure A), bats were recorded by audio and video as they were allowed to catch their prey. In the experimental trial shown in Figure D, researchers removed the prey early in the buzz I phase.


Caption: Spectrograms and corresponding video snapshots (indicated by numbers) show the physical and acoustic behaviors of bats as they attempt to capture prey. Figure A shows a bat successfully capturing prey, while Figure D shows the bat’s behavior when the prey is removed early in the hunt, indicated by the solid black vertical line. The echolocation signals emitted by the bat appear as near-vertical lines on the spectrogram. When these occur in quick succession as a bat approaches its prey, it is called a buzz. Three points during the buzz sequence are labeled: (a) start of buzz I, (b) end of buzz I/start of buzz II, and (c) end of buzz II. In Figure D, where the prey is removed, the bat does not emit a buzz II sequence.
1. It takes a human about 230-400 milliseconds to respond to a visual cue (e.g., raising your hand when you see your instructor raising their hand). How does this reaction time compare to a bat’s reaction time?

__________________________________________________________________________________________

__________________________________________________________________________________________

__________________________________________________________________________________________

__________________________________________________________________________________________

2. The researchers used this experiment to test whether bats use the buzz sequence to gather information and react during prey capture. Based on the results in Figure D, what conclusions can you draw? Provide evidence.

__________________________________________________________________________________________

__________________________________________________________________________________________

__________________________________________________________________________________________

__________________________________________________________________________________________
### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student can synthesize information but does not provide evidence that illustrates the causal relationships between information received by sensory receptors and behavior, both immediate and over longer time scales.</td>
<td>Student can synthesize information to provide evidence that illustrates the causal relationships between information received by sensory receptors and behavior, both immediate and over longer time scales but is unclear overall.</td>
<td>Student can synthesize information to provide evidence that illustrates the causal relationships between information received by sensory receptors and behavior, both immediate and over longer time scales but is unclear overall.</td>
<td>Student can synthesize information to provide evidence that illustrates the causal relationships between information received by sensory receptors and behavior, both immediate and over longer time scales.</td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student cannot use the information provided to predict the response of an organism to different stimuli based on cause and effect relationships between the responses of sensory receptors and behavioral responses.</td>
<td>Student can use the information provided to predict the response of an organism to different stimuli only.</td>
<td>Student can use the information provided to predict the response of an organism to different stimuli based on cause and effect relationships between the responses of sensory receptors and behavioral responses somewhat vaguely</td>
<td>Student can use the information provided to predict the response of an organism to different stimuli based on cause and effect relationships between the responses of sensory receptors and behavioral responses.</td>
<td></td>
</tr>
</tbody>
</table>
# Short Performance Assessment: MS-LS2-1

<table>
<thead>
<tr>
<th>Title</th>
<th>Bird Populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>7th</td>
</tr>
</tbody>
</table>
| Performance Expectation | MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.  
**Clarification Statement:** Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.  
**Assessment Boundary:** none |
| Science and Engineering Practice | Analyzing and Interpreting Data  
• Analyze and interpret data to provide evidence for phenomena. |
| Disciplinary Core Ideas | LS2.A: Interdependent Relationships in Ecosystems  
• Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.  
• In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.  
• Growth of organisms and population increases are limited by access to resources. |
| Crosscutting Concept | **Cause and Effect**  
• Cause and effect relationships may be used to predict phenomena in natural or designed |
| Student Performance | 1. Organizing data  
2. Identifying relationships  
3. Interpreting data |
Students were keeping track of the local cat populations and their impact on birds in the local area that they go
to. They collected data all throughout their time at the high school. The data below regarding the population size of the cats and the birds is an example of what they collected.

Data Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Feral Cat Population</th>
<th>Bird Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>17</td>
<td>124</td>
</tr>
<tr>
<td>2011</td>
<td>8</td>
<td>225</td>
</tr>
<tr>
<td>2012</td>
<td>15</td>
<td>?</td>
</tr>
<tr>
<td>2013</td>
<td>5</td>
<td>205</td>
</tr>
</tbody>
</table>

Prompt.

1. Analyze the data above to estimate (to the nearest hundred) the population size of the birds in 2012. Provide evidence about the phenomena from the data you interpreted to support your prediction.
2. Fill in the graphic organizer below. Begin by providing the effect that you determined from the data provided to you in the question above about the phenomena of the population size of the birds. What is the cause of the phenomena observed in the data table? What process connects the cause to the effect?
<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student can organize and analyze data to interpret relationships between resource availability and population sizes of various organisms but is vague in analysis.</td>
<td>Student can organize and analyze data to interpret relationships between resource availability and population sizes of various organisms but does not have a clear prediction and lacks information that includes changes in the amount and availability of a given resource (e.g., less food) may result in changes in the population of an organism</td>
<td>Student can organize and analyze data to interpret relationships between resource availability and population sizes of various organisms and makes a prediction based on evidence but lacks key information that includes changes in the amount and availability of a given resource (e.g., less food) may result in changes in the population of an organism</td>
<td>Student can organize and analyze data to interpret relationships between resource availability and population sizes of various organisms to make a prediction based on evidence that includes changes in the amount and availability of a given resource (e.g., less food) may result in changes in the population of an organism</td>
<td></td>
</tr>
</tbody>
</table>
## Short Performance Assessment: MS-LS2-2

<table>
<thead>
<tr>
<th>Title</th>
<th>Grain, Birds, Cats Oh My!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>Middle School</td>
</tr>
</tbody>
</table>
| **Performance Expectation** | **MS-LS2-2**: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.  
**Clarification Statement**: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.  
**Assessment Boundary**: none |
| **Science and Engineering Practice** | **Construct Explanations**  
• Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena. |
| **Disciplinary Core Ideas** | **LS2.A: Interdependent Relationships in Ecosystems**  
• Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. |
| **Crosscutting Concept** | **Patterns**  
• Patterns can be used to identify cause and effect relationships |
| **Student Performance** | 1. Articulating the explanation of phenomena  
2. Evidence  
3. Reasoning |
For the past 5 years, the amount of grain, the population of birds, and the population of cats have been recorded on the Eaton Family Farm in Cincinnatus. The data is summarized below.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain (Acres)</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Birds (Amount)</td>
<td>200</td>
<td>300</td>
<td>150</td>
<td>70</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Cats (Amount)</td>
<td>60</td>
<td>60</td>
<td>80</td>
<td>40</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

1. Explain the relationship between the grain, birds and cats from 2014 to 2018.

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

2. Predict what will happen to the population of birds and cats in 2019. Use evidence from the table to support your reasoning.

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

3. Predict what would happen to the interactions in the ecosystem if snakes were introduced to the farm in 2018. Use evidence form the table to support your reasoning.

_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
<table>
<thead>
<tr>
<th>Assessment Rubric - Question 1</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emerging</td>
<td>Student is unable to effectively analyze the data to accurately interpret the relationships between resource availability and populations</td>
<td>Student is able to analyze the data to accurately interpret the relationships between resource availability and populations, but does so vaguely</td>
<td>Student is able to effectively analyze the data to accurately interpret the relationships between resource availability and populations</td>
<td>Student is unable to effectively analyze the data to accurately interpret the relationships between resource availability and populations and references specific data points.</td>
</tr>
<tr>
<td>Developing</td>
<td>Student is able to analyze the data to accurately interpret the relationships between resource availability and populations</td>
<td>Student is able to effectively analyze the data to accurately interpret the relationships between resource availability and populations, but does so vaguely</td>
<td>Student is able to effectively analyze the data to accurately interpret the relationships between resource availability and populations</td>
<td>Student is unable to effectively analyze the data to accurately interpret the relationships between resource availability and populations and references specific data points.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment Rubric - Question 2</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emerging</td>
<td>Student uses data to predict future outcomes in population and ecosystem interactions, but data predictions are incorrect.</td>
<td>Student uses data to predict future outcomes in population and ecosystem interactions, but data predictions are not clear.</td>
<td>Student uses data to predict future outcomes in population and ecosystem interactions that are correct.</td>
<td>Student can use the data to predict future outcomes and uses sound reasoning to do so.</td>
</tr>
<tr>
<td>Developing</td>
<td>Student uses data to predict future outcomes in population and ecosystem interactions, but data predictions are not clear.</td>
<td>Student uses data to predict future outcomes in population and ecosystem interactions that are correct.</td>
<td>Student can use the data to predict future outcomes and uses sound reasoning to do so.</td>
<td>Student can use the data to predict future outcomes and uses sound reasoning to do so.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment Rubric - Question 3</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emerging</td>
<td>Student uses data to predict how competition and food webs will be affected but gives an incorrect prediction.</td>
<td>Student uses data to predict how competition and food webs will be affected but gives an incorrect prediction.</td>
<td>Student uses data to predict how competition and food webs will be affected and gives a correct prediction but doesn’t highlight the changes in the amount and availability of resources and what will happen to populations.</td>
<td>Student uses data to predict how competition and food webs will be affected and gives a correct prediction that highlights the changes in the amount and availability of resources and what will happen to populations.</td>
</tr>
<tr>
<td>Developing</td>
<td>Student uses data to predict how competition and food webs will be affected but gives an incorrect prediction.</td>
<td>Student uses data to predict how competition and food webs will be affected and gives a correct prediction but doesn’t highlight the changes in the amount and availability of resources and what will happen to populations.</td>
<td>Student uses data to predict how competition and food webs will be affected and gives a correct prediction that highlights the changes in the amount and availability of resources and what will happen to populations.</td>
<td>Student uses data to predict how competition and food webs will be affected and gives a correct prediction that highlights the changes in the amount and availability of resources and what will happen to populations.</td>
</tr>
</tbody>
</table>
### Short Performance Assessment: MS-LS2-3

<table>
<thead>
<tr>
<th>Title</th>
<th>Bottled Biosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>7th</td>
</tr>
</tbody>
</table>

**Performance Expectation**

MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

**Clarification Statement**: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.

**Assessment Boundary**: Assessment does not include the use of chemical reactions to describe the processes.

**Science and Engineering Practice**

**Developing and Using Models**

- Develop a model to describe phenomena.

**Disciplinary Core Ideas**

**LS2.B: Cycle of Matter and Energy Transfer in Ecosystems**

- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem.
- Transfers of matter into and out of the physical environment occur at every level.
- Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

**Crosscutting Concept**

**Energy and Matter**

- The transfer of energy can be tracked as energy flows through a natural system.

**Student Performance**

1. Components of model
2. Relationships
3. Connections
The cordyceps fungi has a fascinating life cycle. Spores from the fungi are ingested by an insect (like an ant). The fungi take over the insect causing it to climb to a high branch and hold tight with its mandibles. A fruiting body then emerges from the head of the insect and spreads more spores that infect more insects. Different species of cordyceps infect different species of insects. Click the link to watch a video that demonstrates this phenomenon.

Using the information in this video, the summary above, and your knowledge of science develop a model to illustrate the flow of energy in this ecosystem.
<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student develops a model in which they have identified organisms, but they cannot be classified as producers, consumers and/or decomposers and lacks the nonliving parts of the ecosystem and/or the flow of energy in their model.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student develops a model in which they have identified organisms that can be classified as producers, consumers and/or decomposers but lacks the nonliving parts of the ecosystem and the flow of energy in their model.</td>
<td>Student develops a model in which they have identified organisms that can be classified as producers, consumers and/or decomposers but lacks the nonliving parts of the ecosystem and the flow of energy in their model.</td>
<td>Student develops a model in which they have identified organisms that can be classified as producers, consumers and/or decomposers, the nonliving parts of the ecosystem, and the flow of energy in their model.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Won’t You Be My Urchin?</td>
<td></td>
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<td></td>
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<tr>
<td>-------</td>
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</tr>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course(s)</td>
<td>7th</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarification Statement</td>
<td>Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.</td>
</tr>
<tr>
<td>Assessment Boundary</td>
<td>none</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science and Engineering Practice</th>
<th>Engaging in Argument from Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crosscutting Concept</th>
<th>Stability and Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Small changes in one part of a system might cause large changes in another part.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Supporting claims</td>
</tr>
<tr>
<td>2. Identifying scientific evidence</td>
</tr>
<tr>
<td>3. Evaluating and critiquing the evidence</td>
</tr>
<tr>
<td>4. Reasoning and synthesis</td>
</tr>
</tbody>
</table>

Name __________________________________________
Imagine you are snorkeling on a coral reef where you can see many species living together. Some animals, like sharks, are predators that eat other animals. Other species, like anemones and the fish that live in them, are mutualists and protect each other from predators. There are also herbivores, like urchins, that eat plants and algae on the reef. All of these species, and many more, need the coral reef to survive.

Corals are the animals that build coral reefs. They are very sensitive and can be hurt by human activity, like boating and pollution. Corals reef ecosystems are also in danger from warming waters due to climate change. Sadly, today many coral reefs around the world are dying because the places they grow are changing.

Sarah is a marine biologist who is determined to figure out ways to save coral reefs. Sarah wants to understand how to help the dying corals so they can keep building the important and diverse coral reef habitats.

Corals compete with large types of algae, like seaweed, for space to grow on the reef. Corals are picky and only like to live in certain places. If there is too much algae, corals will have no place to attach and grow. Sea urchins are important herbivores and one of the species that like to eat algae. Sarah thought that when urchins are present on the reef, corals will have less competition from algae for space, and thus more room to grow. Maybe adding urchins to a coral reef is a way to help corals.

To test her idea Sarah set up an experiment. She set 8 bins out on the reef. Into half of the bins, Sarah added urchins. Into the other half she left without urchins as a control. Sarah put tiles into all of the bins. Tiles gave an empty space for coral and algae to compete and grow. After a few months, Sarah looked at the tiles. She counted how many corals were growing on each tile. Sarah predicted that more corals would grow on the tiles in bins with sea urchins compared to the control bins with no sea urchins. Her data is shown below.

<table>
<thead>
<tr>
<th>Treatment in the bin</th>
<th>Bin #</th>
<th>Number of corals on tile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea urchins present</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Sea urchins present</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Sea urchins present</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Sea urchins present</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>No sea urchins</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>No sea urchins</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>No sea urchins</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>No sea urchins</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>

1. Based on the information in the passage, produce a food web that shows the interactions of the named organisms within the ecosystem.
2. Sarah wanted to know how the presence of urchins affected coral. Make a claim based on the data shown above. Support your claim with evidence from the data table.

___________________________________________________________________________________
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___________________________________________________________________________________
### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student cannot effectively make a food web based on the given information provided.</td>
<td>Student can make a food web based on the given information provided with a number of mistakes.</td>
<td>Student can make a food web based on the given information provided with few mistakes.</td>
<td>Student can effectively make a food web based on the given information provided.</td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students make an unrelated claim to be supported about a given explanation or model for a phenomenon. In their claim, students do not include the idea that changes to physical or biological components of an ecosystem can affect the populations living there. Student does not identify and describe the evidence needed to support the claim.</td>
<td>Students make a claim to be supported about a given explanation or model for a phenomenon. In their claim, students include the idea that changes to physical or biological components of an ecosystem can affect the populations living there. Student does not identify and describe the evidence needed to support the claim.</td>
<td>Students make a claim to be supported about a given explanation or model for a phenomenon. In their claim, students somewhat include the idea that changes to physical or biological components of an ecosystem can affect the populations living there. Student also identifies and describes the evidence needed to support the claim.</td>
<td>Students make a claim to be supported about a given explanation or model for a phenomenon. In their claim, students include the idea that changes to physical or biological components of an ecosystem can affect the populations living there. Student also identifies and describes the evidence needed to support the claim.</td>
<td></td>
</tr>
<tr>
<td><strong>Title</strong></td>
<td>Salmon Cannon</td>
<td></td>
<td></td>
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<tr>
<td>-----------</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Designed by</strong></td>
<td>Kelly Russo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Course(s)</strong></td>
<td>7th</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th><strong>Performance Expectation</strong></th>
<th>MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statement</strong>: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.</td>
<td></td>
</tr>
<tr>
<td><strong>Assessment Boundary</strong>: none</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Science and Engineering Practice</strong></th>
<th>Engaging in Argument from Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Disciplinary Core Ideas</strong></th>
<th>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of its health.</td>
<td></td>
</tr>
<tr>
<td>LS4.D: Biodiversity and Humans</td>
<td></td>
</tr>
<tr>
<td>• Changes in biodiversity can influence humans’ resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.(secondary)</td>
<td></td>
</tr>
<tr>
<td>ETS1.B: Developing Possible Solutions</td>
<td></td>
</tr>
<tr>
<td>• There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (secondary)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Crosscutting Concept</strong></th>
<th>Stability and Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Small changes in one part of a system might cause large changes in another part.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Student Performance</strong></th>
<th>1. Identifying the given design solution and supporting evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Identifying any potential additional evidence that is relevant to the evaluation</td>
</tr>
<tr>
<td></td>
<td>3. Evaluating and critiquing the design solution</td>
</tr>
</tbody>
</table>
Ever since rivers have been dammed, destroying the migration routes of salmon, humans have worked to create ways to help the fish return to their spawning grounds. The salmon cannon is a device developed to alleviate the issues that have arisen from human intervention in waterway formation due to the creation of dams. An image of this cannon is shown below. The salmon cannon works exactly as you might imagine, minus the actual cannon bit mind you. Salmon are caught and placed into a long tube that brings the salmon up and over any potential waterway issues through the use of pressure. The salmon are quickly, and safely (not launched like cannon projectiles) into the next water space where they may begin to procreate.

Figure 1: Salmon being loaded into a cannon (Francovich, 2019).

Below is a graph that shows the salmon population effect following the implementation of the salmon cannon in early 2017.
1. Based on the information shown, write a claim supported by evidence and reasoning that highlights the effect of the salmon cannon on maintaining biodiversity in river ecosystems.

Claim:

Evidence:

Reasoning:

<table>
<thead>
<tr>
<th>Description of performance</th>
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<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Student shows difficulty identifying and describing how the salmon cannon is solving the given biodiversity issue, referencing accurate evidence, and using sound reasoning.</td>
<td>Students are able to identify and describe how the salmon cannon is solving the given biodiversity issue, references accurate evidence from the graph but does not give specific details, and doesn’t provide sound reasoning.</td>
<td>Students are able to identify and describe how the salmon cannon is solving the given biodiversity issue, references accurate evidence from the graph and the reading, but doesn’t provide sound reasoning.</td>
<td>Students are able to identify and describe how the salmon cannon is solving the given biodiversity issue, references accurate evidence from the graph and the reading, and provides sound reasoning.</td>
</tr>
<tr>
<td>Title</td>
<td>Mutation in the Cave Ecosystem</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-------</td>
<td>--------------------------------</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Designed by</td>
<td>Paul Andersen (2017, 3-D performance Assessment), adjusted by Kelly Russo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course(s)</td>
<td>7th Grade</td>
<td></td>
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</tbody>
</table>

**Performance Expectation**

**MS-LS3-1:** Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

**Clarification Statement:** Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.

**Assessment Boundary:** Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.

<table>
<thead>
<tr>
<th>Science and Engineering Practice</th>
<th>Developing and Using Models</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Develop and use a model to describe phenomena.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>LS3.A: Inheritance of Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LS3.B: Variation of Traits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crosscutting Concept</th>
<th>Structure and Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student Performance</th>
<th>1. Components of the model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Relationships</td>
</tr>
<tr>
<td></td>
<td>3. Connections</td>
</tr>
</tbody>
</table>
Like something out of a horror film, during your latest expedition to the Mexican cave system, you have found a blind cave fish, blind whiptail scorpions, and other odd creatures that look noticeably different from their surface counterparts. The fish lack eyes, have thin, translucent skin, and are relatively small (7-10 cm). The whiptail scorpion has long legs (15 cm), has extremely small eyes that could not be eyes at all, and walks as if feeling around with its legs. Why do these organisms have such different characteristics?

According to James Owen (2015) of National Geographic, these fish may have lost their eyes in order to preserve energy in an environment that is often poor in food and in oxygen. Natural selection favors individuals, in this case, who have reduced visual capacity due to the high need for energy in photoreceptive cells and neurons. To compensate for this lack of vision, these fish have a more sensitivity to vibrational changes in water using an organ known as the lateral line (Denver Zoo, n.d.). Below is an image of these fish.

**Figure 1:** Photograph of Astyanax mexicanus, surface form with eyes (top) and cave form without eyes (bottom) swimming together. (Castranova, 2018).
Prompt

Develop a model to describe why structural changes to genes (mutations) on chromosomes may affect proteins and may result in beneficial effects to the structure and function of the fish.

<table>
<thead>
<tr>
<th>Structure</th>
<th>How Structure and Function is Affected by Mutations in Blind Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes</td>
<td></td>
</tr>
<tr>
<td>Scales</td>
<td></td>
</tr>
<tr>
<td>Lateral Line</td>
<td></td>
</tr>
</tbody>
</table>

My model of what I think is causing these changes… (flow map: the change, to the cause, to the effect)

Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
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<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student develops a model in which they identify the related parts for making sense of the given phenomena but lack the relationship between gene structure and proteins and relationship of proteins to observable organism traits.</td>
<td>Student develops a model in which they identify the related parts for making sense of the given phenomena but lack the relationship between gene structure and proteins or relationship of proteins to observable organism traits.</td>
<td>Student develops a model in which they identify the related parts for making sense of the given phenomena, and in their model, they are able to describe the relationship between gene structure and proteins but lack the relationship of proteins to observable organism traits.</td>
<td>Student develops a model in which they identify the related parts for making sense of the given phenomena, and in their model, they are able to describe the relationship between gene structure and proteins, as well as the relationship of proteins to observable organism traits.</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Ancient Fossils</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
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</tr>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course(s)</td>
<td>8th Grade</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Performance Expectation</td>
<td>MS-LS4-1: Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science and Engineering Practice</td>
<td>Analyzing and Interpreting Data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Analyze and interpret data to determine similarities and differences in findings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crosscutting Concept</td>
<td>Patterns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Graphs, charts, and images can be used to identify patterns in data.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Student Performance</td>
<td>1. Organizing data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Identifying relationships</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Interpreting data</td>
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</tbody>
</table>
You are a paleontologist working at the Smithsonian Museum of Natural History. A family of farmers from NY have brought you some samples of what they believe to be horse bones that they found while digging up a large section of their field. They marked the depth of each of the bones, which you turned into the data table below. Following the use of your vast library of resources, you were able to identify the type of horses at each interval.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Depth Found</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.5 Meter</td>
<td>Modern Horse</td>
</tr>
<tr>
<td>B</td>
<td>2.5 Meters</td>
<td>Merychippus</td>
</tr>
<tr>
<td>C</td>
<td>6.7 Meters</td>
<td>Mesohippus</td>
</tr>
<tr>
<td>D</td>
<td>15 Meters</td>
<td>Hyracotherium</td>
</tr>
</tbody>
</table>

A farmer from Cortland, NY brings you a tooth and leg bone he found when getting rid of rocks from a field. You believe these bones are from an extinct species that is an ancestor of the horse. He did not record the depth that he took the bones from.

Here are the pictures of the fossils the farmer found (not to scale):

[Images of fossils]
1. Based on the image of the horse’s ancestors, what are two patterns of traits that can be seen through the horse’s evolution?
   a. ________________________________________________________________
   b. ________________________________________________________________

2. Based on the evidence above, where on a timeline might you put the age of the Mystery Horse? Explain using evidence from the data given.
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

3. What is the relationship between depth of a fossil and age?
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assessment Rubric - Question 1</strong></td>
<td>Student identifies a pattern but does not align with the data.</td>
<td>Student is somewhat able to organize the given data to identify a pattern but does not do so clearly.</td>
<td>Student is able to organize the given data to identify a pattern in fossils or horse development.</td>
<td>Student is able to organize the given data to identify a pattern in fossils and horse development.</td>
</tr>
<tr>
<td><strong>Assessment Rubric - Question 2</strong></td>
<td>Student unable to analyze and interpret the data to determine when organisms or types of organisms emerged, went extinct, or evolved; they simply guess.</td>
<td>Student analyzes and interprets the data to determine when organisms or types of organisms emerged, went extinct, or evolved but places organisms incorrectly</td>
<td>Students analyze and interpret the data to determine when organisms or types of organisms emerged, went extinct, or evolved.</td>
<td>Student analyzes and interprets the data to determine when organisms or types of organisms emerged, went extinct, or evolved and references the similarities and difference to provide such evidence.</td>
</tr>
<tr>
<td><strong>Assessment Rubric - Question 3</strong></td>
<td>Student is unable to explain the Law of Superposition</td>
<td></td>
<td></td>
<td>Student is able to explain the Law of Superposition</td>
</tr>
</tbody>
</table>
## Short Performance Assessment: MS-LS4-2

<table>
<thead>
<tr>
<th>Title</th>
<th>Evidence of Common Ancestry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
</tbody>
</table>
| Performance Expectation | **MS-LS4-2**: Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.  
**Clarification Statement**: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.  
**Assessment Boundary**: none | |
| Science and Engineering Practice | **Constructing Explanations**  
• Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events. | |
| Disciplinary Core Ideas | **LS4.A: Evidence of Common Ancestry and Diversity**  
• Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. | |
| Crosscutting Concept | **Patterns**  
• Patterns can be used to identify cause and effect relationships. | |

| Student Performance | 1. Articulating the explanation of phenomena  
2. Evidence  
3. Reasoning |
### Assessment Rubric - Question 1 - Claim

<table>
<thead>
<tr>
<th>Description of Performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student is unable to clearly make a statement that relates anatomical similarities and differences among organisms to infer evolutionary relationships between modern organisms and fossils.</td>
<td>Student vaguely articulates a statement that relates anatomical similarities and differences among organisms to infer evolutionary relationships between modern organisms and fossils.</td>
<td>Student somewhat articulates a statement that relates anatomical similarities and differences among organisms to infer evolutionary relationships between modern organisms and fossils.</td>
<td>Student articulates a statement that relates anatomical similarities and differences among organisms to infer evolutionary relationships between modern organisms and fossils.</td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2 - Evidence

<table>
<thead>
<tr>
<th>Description of Performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student identifies evidence that is not present.</td>
<td>Student identifies but does not describe evidence from presented images.</td>
<td>Student identifies but does not completely describe evidence from presented images.</td>
<td>Student identifies and describes evidence from presented images.</td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 3 - Reasoning

<table>
<thead>
<tr>
<th>Description of Performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students use reasoning to connect the evidence, but reasoning is flawed and unclear</td>
<td>Students use reasoning to connect the evidence but does not give a chain of reasoning.</td>
<td>Students use reasoning to connect the evidence but does not give a completely clear chain of reasoning.</td>
<td>Students use reasoning to connect the evidence and gives a chain of reasoning for the explanation.</td>
<td></td>
</tr>
</tbody>
</table>
Below you will find images of two organisms, *Homo sapiens* and *Homo neandertalensis*. Using the images, make a claim about the evolutionary relationship of these two species. Use the idea of comparative anatomy to support your claim. Use the Claim-Evidence-Reasoning method to construct your argument.

<table>
<thead>
<tr>
<th><strong>Homo sapiens</strong></th>
<th><strong>Homo neandertalensis</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1: Skeleton, 6 Feet Tall (Dénes, 2018)</td>
<td>Figure 4: Skeleton, 5 Feet Tall (Smithsonian Institute, 2018)</td>
</tr>
<tr>
<td>Figure 2: Skull (Monto, 2017)</td>
<td></td>
</tr>
<tr>
<td>Figure 3: Skull (Luna04, 2006)</td>
<td></td>
</tr>
<tr>
<td>Figure 6: Male Head (Le Pape, 2015)</td>
<td>Figure 5: Reconstructed Male Head (Evans, 2012)</td>
</tr>
</tbody>
</table>
**Question:**
What is the relationship between the two species shown?

<table>
<thead>
<tr>
<th>Evidence:</th>
<th>Claim:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Reasoning:**

## Short Performance Assessment: MS-LS4-3

<table>
<thead>
<tr>
<th>Title</th>
<th>Embryo Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>8th Grade</td>
</tr>
</tbody>
</table>

### Performance Expectation
- **MS-LS4-3**: Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.

**Clarification Statement**: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.

**Assessment Boundary**: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.

### Science and Engineering Practice
- **Analyzing and Interpreting Data**
  - Analyze displays of data to identify linear and nonlinear relationships.

### Disciplinary Core Ideas
- **LS4.A: Evidence of Common Ancestry and Diversity**
  - Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.

### Crosscutting Concept
- **Patterns**
  - Graphs, charts, and images can be used to identify patterns in data.

### Student Performance
- 1. Organizing data
- 2. Identifying relationships
- 3. Interpreting data
As an evolutionary embryologist, your job is to study how organisms develop from embryos to organisms. You have been presented with a few images of embryos from different species. These are shown below in Figure 1 (CK-12, n.d.)

1. Identify two similarities between all of the species at various stages of development.
   a. ____________________________________________
   b. ____________________________________________

2. Identify two differences between all of the species at various stages of development.
Based on the diagram and information you recorded from questions 1 and 2, what is a claim that you could make about the evolutionary relationship between these organisms? Use Claim-Evidence-Reasoning to support your answer.

<table>
<thead>
<tr>
<th>Question:</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the evolutionary relationship between the organisms shown?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evidence:</th>
<th>Claim:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reasoning:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student cannot organize the given pictures to identify two similarities in embryos across species.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student can organize the given pictures to identify one similarity in embryos across species but is not clear in answer.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student can organize the given pictures to identify one similarity in embryos across species.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student can organize the given pictures to identify two similarities in embryos across species.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student cannot organize the given pictures to identify two changes of development in embryos across species.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student can organize the given pictures to identify one change of development in embryos across species but is not clear in answer.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student can organize the given pictures to identify one change of development in embryos across species.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student can organize the given pictures to identify two changes of development in embryos across species.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 3

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students is unable to use patterns of similarities and changes in embryo development to describe evidence for relatedness among apparently diverse species and doesn’t include similarities that are not evident in the fully formed anatomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students use patterns of similarities or changes in embryo development to describe evidence for relatedness among apparently diverse species but doesn’t include similarities that are not evident in the fully formed anatomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students use patterns of similarities and changes in embryo development to describe evidence for relatedness among apparently diverse species but doesn’t include similarities that are not evident in the fully formed anatomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students use patterns of similarities and changes in embryo development to describe evidence for relatedness among apparently diverse species, including similarities that are not evident in the fully formed anatomy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Short Performance Assessment: MS-ESS2-1

<table>
<thead>
<tr>
<th>Title</th>
<th>Rock Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>8th Grade</td>
</tr>
</tbody>
</table>

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## Performance Expectation

**MS-ESS2-1**: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

**Clarification Statement**: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth’s materials.

**Assessment Boundary**: Assessment does not include the identification and naming of minerals.

## Science and Engineering Practice

**Developing and Using Models**

- Develop and use a model to describe phenomena.

## Disciplinary Core Ideas

**ESS2.A: Earth’s Materials and Systems**

- All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms.

## Crosscutting Concept

**Stability and Change**

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.

## Student Performance

1. Components of the model
2. Relationships
3. Connections
A geology student discovered a local rock formation in Central New York that consisted of metamorphic rocks exposed from years of weathering and deformation. Using the partial model below, complete the model using arrows and labels to show the formation of this metamorphic rock from sedimentary rock. Begin with magma, then number each process as you continue to work through each step.
Using your rock cycle model from above, develop a model of how **two** of the processes from the rock cycle happen. Include information as to whether it happens above or below ground, and how energy is part of the model.

<table>
<thead>
<tr>
<th>Process</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student is unable to complete the rock cycle with any appropriate labels.</td>
<td>Student is able to complete the rock cycle with some appropriate labels.</td>
<td>Student is able to complete the rock cycle with most of the appropriate labels.</td>
<td>Student is able to complete the rock cycle with all appropriate labels.</td>
<td></td>
</tr>
</tbody>
</table>

## Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the student’s model, they lack details in the relationships between different earth processes, and/or the movement of energy from Earth’s hot interior.</td>
<td>In the student’s model, they describe the relationships between different earth processes, or the movement of energy from Earth’s hot interior.</td>
<td>In the student’s model, they describe the relationships between different earth processes, but lack detail on movement of energy from Earth’s hot interior.</td>
<td>In the student’s model, they describe the relationships between different earth processes, the movement of energy from Earth’s hot interior.</td>
<td></td>
</tr>
</tbody>
</table>
**Short Performance Assessment: MS-ESS2-4**

<table>
<thead>
<tr>
<th>Title</th>
<th>Water Cycle Modeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>8th</td>
</tr>
</tbody>
</table>

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**Performance Expectation**

**MS-ESS2-4**: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

**Clarification Statement**: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.

**Assessment Boundary**: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.

**Science and Engineering Practice**

**Developing and Using Models**
- Develop a model to describe unobservable mechanisms.

**Disciplinary Core Ideas**

**ESS2.C: The Roles of Water in Earth's Surface Processes**
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- Global movements of water and its changes in form are propelled by sunlight and gravity.

**Crosscutting Concept**

**Energy and Matter**
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

**Student Performance**
- 1. Components of the model
- 2. Relationships
- 3. Connections
Over the last 38 years, scientists have observed changes in the local landscape. This year (2018), terrestrial vegetation was observed in the lake. Using the average annual rainfall and temperature data with the models provided, develop a model to predict the cycle of water into and out of the system for 2020.

1. Draw the predicted water table for 2020
   a. Draw and label the following terms on the 1980 and 2020 model:
   b. Transpiration, evaporation, precipitation, infiltration, and runoff
   c. Adjust the size of the arrows to represent the changes in the 2020 model.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall (inches)</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>41.8</td>
<td>48.8</td>
</tr>
<tr>
<td>1980</td>
<td>41</td>
<td>50.3</td>
</tr>
<tr>
<td>1990</td>
<td>39.2</td>
<td>51.7</td>
</tr>
<tr>
<td>2000</td>
<td>38</td>
<td>53</td>
</tr>
<tr>
<td>2010</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Why are scientists concerned with the changing landscape?

_______________________________________________________________________________________
_________________________________________________________________________________________
_________________________________________________________________________________________
_________________________________________________________________________________________
_________________________________________________________________________________________

Assessment Rubric - Question 1
<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emerging</strong></td>
<td>Student needs work to develop a model that identifies the necessary components of the water cycle, and do not use evidence to adjust the location of the water table and the location is not correct.</td>
<td>Student is vaguely to develop a model that identifies the necessary components of the water cycle, and uses evidence to adjust the location of the water table but the location is not correct.</td>
<td>Student is able to develop a model that identifies the necessary components of the water cycle and uses evidence to adjust the location of the water table, but the location is not correct.</td>
<td>Student is able to develop a model that identifies the necessary components of the water cycle and uses evidence to adjust the location of the water table.</td>
</tr>
</tbody>
</table>

**Assessment Rubric* - Question 2**

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emerging</strong></td>
<td>Using their model, students describes an inaccurate relationship between the parts of the model in reference to changing landscape.</td>
<td>Using their model, students vaguely describes the relationship between the parts of the model in reference to changing landscapes and does not use evidence in their answer.</td>
<td>Using their model, students describes the relationship between the parts of the model in reference to changing landscapes in a clear and concise manner but doesn’t use evidence in their answer.</td>
<td>Using their model, students describes the relationship between the parts of the model in reference to changing landscapes in a clear and concise manner, using evidence in their answer.</td>
</tr>
</tbody>
</table>
Short Performance Assessment: MS-ESS2-5

<table>
<thead>
<tr>
<th>Title</th>
<th>Treman Falls Weather Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>8th</td>
</tr>
</tbody>
</table>

**Performance Expectation**

MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

**Clarification Statement**: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).

**Assessment Boundary**: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.

**Science and Engineering Practice**

- **Planning and Carrying Out Investigations**
  - Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

**Disciplinary Core Ideas**

- **ESS2.C: The Roles of Water in Earth's Surface Processes**
  - The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

- **ESS2.D: Weather and Climate**
  - Because these patterns are so complex, weather can only be predicted probabilistically.

**Crosscutting Concept**

- **Cause and Effect**
  - Cause and effect relationships may be used to predict phenomena in natural or designed systems.

**Student Performance**

1. Identifying the phenomenon under investigation
2. Identifying the evidence to address the purpose of the investigation
3. Planning the investigation
4. Collecting the data
Your class is planning a trip to Treman Falls State Parks in Ithaca next week. You have one week to prepare for this and must announce to the class what to bring based on the weather patterns shown below.

Historical Data for the Treman Falls region
1. Describe the relationship between air masses and local weather.

<table>
<thead>
<tr>
<th></th>
<th>General Temperature</th>
<th>Cloud Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Pressure</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. What will the weather likely be in Treman Falls next week?
3. Where will the air mass be the day before it passes over Treman Falls next week?
### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student can identify the general temperatures of high- and low-pressure systems only.</td>
<td>Student can identify one the general temperatures of high- or low-pressure systems and the amount of cloud cover.</td>
<td>Student can identify both the general temperatures of high- and low-pressure systems or the amount of cloud cover.</td>
<td>Student can identify both the general temperatures of high- and low-pressure systems and the amount of cloud cover.</td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student cannot use the data to accurately predict the most likely weather trend, but guesses.</td>
<td>Student can use the data to vaguely predict the most likely weather trend.</td>
<td>Student can use the data to accurately predict the most likely weather trend.</td>
<td>Student can use the data to accurately predict the most likely weather trend.</td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 3

<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student guesses the air mass movement direction.</td>
<td></td>
<td></td>
<td></td>
<td>Student can use the data to predict air mass movement.</td>
</tr>
</tbody>
</table>
Short Performance Assessment: MS-ESS2-6

Title | Jolly Jerry in England and Jenny from Haven

Designed by | Kelly Russo | Course(s) | 8th

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Performance Expectation | MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.

Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.

Science and Engineering Practice | Developing and Using Models
• Develop and use a model to describe phenomena.

Disciplinary Core Ideas | ESS2.C: The Roles of Water in Earth's Surface Processes
• Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

ESS2.D: Weather and Climate
• Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
• The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

Crosscutting Concept | Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Student Performance
1. Components of the model
2. Relationships
3. Connections
Jerry lives in England, and the climate is warmer on average than Jenny who lives in Haven, Maine (a coastal town). Based on the image of Earth below, draw arrows to model the path of ocean currents that occur in the Atlantic Ocean.

2. Explain the reasoning behind the climate differences experienced by Jerry and Jenny.
### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th></th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description of performance</strong></td>
<td>Student draws circles to show ocean circulation but lacks labels or any other indication of knowledge on the topic.</td>
<td>Student is able to develop a model that shows the movement of ocean circulations but doesn’t use the Atlantic Ocean.</td>
<td>Student is able to develop a model that shows the movement of ocean circulations somewhat accurately in the Atlantic Ocean.</td>
<td>Student is able to develop a model that shows the movement of ocean circulations accurately in the Atlantic Ocean.</td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th></th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description of performance</strong></td>
<td>Student does not use the model or explain the relationship of water movement.</td>
<td>Students reasoning hints at the role of water movement but does not reference the model in their answer.</td>
<td>Student is able to use the model to describe the regional patterns of climate (e.g., temperature or moisture) related to a specific pattern of water or air circulation, but does not include the role of water movement from areas of high temperature, density, and/or salinity to areas of low temperature, density, and/or salinity.</td>
<td>Student is able to use the model to describe the regional patterns of climate (e.g., temperature or moisture) related to a specific pattern of water or air circulation, including the role of water movement from areas of high temperature, density, and/or salinity to areas of low temperature, density, and/or salinity.</td>
</tr>
</tbody>
</table>
### Short Performance Assessment: MS-ESS3-2

<table>
<thead>
<tr>
<th>Title</th>
<th>Natural Hazard Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarification Statement</td>
<td>Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).</td>
</tr>
<tr>
<td>Assessment Boundary</td>
<td>none</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science and Engineering Practice</th>
<th>Analyzing and Interpreting Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Analyze and interpret data to determine similarities and differences in findings.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>ESS3.B: Natural Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crosscutting Concept</th>
<th>Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Graphs, charts, and images can be used to identify patterns in data.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student Performance</th>
<th>1. Organizing data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Identifying relationships</td>
</tr>
<tr>
<td></td>
<td>3. Interpreting data</td>
</tr>
</tbody>
</table>
Dean Winchester is a newly elected official in charge of natural hazards program for Wichita, Kansas. As his assistant, you have been tasked with developing a natural hazard response program to the natural disasters that have the greatest percent chance of occurring based on historical data. Dean has provided the data for you, found below.
Your city needs to create an emergency plan for natural hazards. An emergency plan describes what a city will do to prepare for the impacts of natural hazards. Use the data (NOAA, 2014) to help.

1. Come up with a research-based hazards plan for your town, include in your plan:
   o Basic country information (location, population, major cities, major land areas, etc.)
   o Explain the natural disaster risks that your nation faces.
     i. What kind of natural disaster?
     ii. How severe
     iii. How often
     iv. Where (regions)

2. Create a map that includes all of the above information.

3. Research and think creatively to create a disaster plan to mitigate the effects of the natural disasters researched. Include:

   **Before disaster:** What should people do in order to be prepared for the disaster? How will you warn them that the disaster could happen soon? Who will be in charge of this?

   **During:** What should people do during the disaster? Where will people go if their homes are unsafe for the event? How will they get there? How will they be taken care of when they get there? What happens if someone gets hurt/sick/dies?

   **After:** What problems might arise after the disaster? How will medical supplies, food, water, temporary shelter, etc. be delivered after the disaster? What if people can’t return to their homes immediately?
<table>
<thead>
<tr>
<th>Description of performance</th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students organize given data that represent the type of natural hazard event and features associated with that type of event, none of the following: location, magnitude, frequency, and any associated precursor event or geologic forces</td>
<td>Students organize given data that represent the type of natural hazard event and features associated with that type of event, including one of the following: location, magnitude, frequency, and any associated precursor event or geologic forces</td>
<td>Students organize given data that represent the type of natural hazard event and features associated with that type of event, including some of the following: location, magnitude, frequency, and any associated precursor event or geologic forces</td>
<td>Students organize given data that represent the type of natural hazard event and features associated with that type of event, including the location, magnitude, frequency, and any associated precursor event or geologic forces</td>
<td></td>
</tr>
</tbody>
</table>
# Short Performance Assessment: MS-ESS3-5

<table>
<thead>
<tr>
<th>Title</th>
<th>Carbon Dioxide Graph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed by</td>
<td>Kelly Russo</td>
</tr>
<tr>
<td>Course(s)</td>
<td>8th</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>MS-ESS3-5: Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clarification Statement:</strong></td>
<td>Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.</td>
</tr>
<tr>
<td><strong>Assessment Boundary:</strong></td>
<td>none</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science and Engineering Practice</th>
<th>Asking Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Ask questions to identify and clarify evidence of an argument.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disciplinary Core Ideas</th>
<th>ESS3.D: Global Climate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth’s mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crosscutting Concept</th>
<th>Stability and Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Stability might be disturbed either by sudden events or gradual changes that accumulate over time.</td>
</tr>
</tbody>
</table>

| Student Performance | 1. Addressing phenomena of the natural world 2. Identifying the scientific nature of the question |
Marissa came across a graph that shows the changes in global temperature and carbon dioxide concentrations on Earth. The graph is shown below.

1. Explain recent changes on Earth that would cause the data seen on the graph.

__________________________________________________________________________________________
__________________________________________________________________________________________

2. Describe 2 human activities that may help to reverse the pattern seen.

__________________________________________________________________________________________
__________________________________________________________________________________________

3. Construct a model of an experiment that would produce evidence of the relationship between carbon dioxide concentration and global temperatures.

### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th></th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of performance</td>
<td>Student asks a question rather than making a claim.</td>
<td>Student makes a claim not based on evidence.</td>
<td>Student makes a claim loosely based on evidence that is relevant to the data shown.</td>
<td>Student makes a claim based on evidence that is relevant to the data shown.</td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th></th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of performance</td>
<td>Student identifies one activity.</td>
<td>Student identifies two activities but doesn’t explain why.</td>
<td>Student only identifies two activities but explains one of them.</td>
<td>Student is able to identify 2 activities that may have caused this and explains why.</td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 3

<table>
<thead>
<tr>
<th></th>
<th>Emerging</th>
<th>Developing</th>
<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of performance</td>
<td>Student only identifies a question and attempts a model but is missing a lot of key information.</td>
<td>Student identifies a question that can be asked and develops an almost accurate model of an experiment in which evidence can be collected to examine patterns of data related to the phenomena.</td>
<td>Student identifies a question that can be asked and develops an accurate model of an experiment in which evidence can be collected to examine patterns of data related to the phenomena but lacks some key details in the model.</td>
<td>Student identifies a question that can be asked and develops an accurate model of an experiment in which evidence can be collected to examine patterns of data related to the phenomena.</td>
</tr>
</tbody>
</table>
### Performance Expectation

**MS-PS4-1:** Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

**Clarification Statement:** Emphasis is on describing waves with both qualitative and quantitative thinking.

**Assessment Boundary:** Assessment does not include electromagnetic waves and is limited to standard repeating waves.

### Science and Engineering Practice

**Using Mathematics and Computational Thinking**
- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

### Disciplinary Core Ideas

**PS4.A: Wave Properties**
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

### Crosscutting Concept

**Patterns**
- Graphs and charts can be used to identify patterns in data.

### Student Performance

1. Representation
2. Mathematical modeling
3. Analysis

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A student experiences a wave pool for the first time in their life. In the wave pool, the student is pushed by two different waves, one of which is stronger than the other. The weak wave raises the student 3 feet above the bottom of the pool, and the strong wave raises the student 6 feet above the bottom of the pool. Draw a mathematical model of the wave that represents this information below.

Based on the models you drew, why is the wave that rose the student 6 feet stronger than the one that rose him 3 feet?
### Assessment Rubric - Question 1

<table>
<thead>
<tr>
<th>Description of performance</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Student draws one model that looks like a wave but lacks any of the characteristics of the wave.</td>
<td>Student draws a model and labels the waves with qualitatively different amplitudes.</td>
<td>Student draws both waves in the model that shows amplitude but doesn’t include a proper axis of measurement.</td>
<td>Students identify the characteristics of a simple mathematical wave model that includes amplitude, as the maximum extent of the repeating quantity from equilibrium</td>
<td></td>
</tr>
</tbody>
</table>

### Assessment Rubric - Question 2

<table>
<thead>
<tr>
<th>Description of performance</th>
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<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student relates a different characteristic of waves instead of energy and amplitude.</td>
<td>Student explains that one wave has more energy than the other.</td>
<td>Student explains that one wave is stronger than the other but does not clearly relate energy to the phenomena.</td>
<td>Student explains the change in energy of the wave that allows for the difference in height the student was raised in the pool.</td>
<td></td>
</tr>
<tr>
<td>Performance Expectation</td>
<td>MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.</td>
<td></td>
<td></td>
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<tr>
<td>-------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarification Statement</td>
<td>Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment Boundary</td>
<td>Assessment is limited to qualitative applications pertaining to light and mechanical waves.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Science and Engineering Practice | Developing and Using Models  
  • Develop and use a model to describe phenomena. |
| Disciplinary Core Ideas | PS4.A: Wave Properties  
  • A sound wave needs a medium through which it is transmitted.  

**PS4.B: Electromagnetic Radiation**  
• When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light.  
• The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.  
• A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.  
• However, because light can travel through space, it cannot be a matter wave, like sound or water waves. |
| Crosscutting Concept | Structure and Function  
  • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. |
| Student Performance | 1. Components of the model  
  2. Relationships  
  3. Connections |
Have you ever seen how bright the sun is when it's reflected off of snow? That would be because snow has a high albedo. **Albedo** is a measure of how much light is reflected back from a body. It usually refers to planetary bodies like Earth and the amount of sunlight that is reflected back into space. Earth's average albedo is .3 to .35, which means 30% to 35% of the sunlight is reflected back into space.

What happens to the sunlight that is not reflected? The other 65% to 70% of the sunlight gets absorbed by the earth. Dark ocean water, trees, and dark soil absorb a lot of the sun's energy, and that's what keeps us warm. Imagine the difference between leaving a bicycle with a black seat or a white seat in the sun. The black seat will absorb a lot more energy from the sun, which you would feel as heat; ouch! That's an effect of albedo.

1. Based on this information, develop a model to explain how energy from the sun is reflected back into the atmosphere in the arctic that causes a colder climate.
<table>
<thead>
<tr>
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<th>Approaching Proficiency</th>
<th>Excelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student develops a model showing either refraction or diffraction, but not reflection.</td>
<td>Student develops a model showing a wave reflection but lacks the information that the wave is a light wave.</td>
<td>Student develops a model that shows a light wave being reflected off a light-colored surface to represent the Arctic that doesn’t include the cold temperatures present in the area due to the effect.</td>
<td>Student develops a model that shows a light wave being reflected off a light-colored surface to represent the Arctic that also includes the cold temperatures present in the area due to the effect.</td>
<td></td>
</tr>
</tbody>
</table>
References


Andersen, P. (n.d.). MS-LS1-3 3D Performance Assessment. Retrieved from https://docs.google.com/document/d/1cbiEZU0hiNvBrBNgIynIPxqVasQpvS9Ypmd9pXi6Zc/edit.


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