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Incorporating Socio-Scientific Issues into the 5E Model for Learning: Engaging Students in Science through Emotional Connection, Kinesthetic Movement and Real World Phenomenon.

Alexis Lodico
alodi1@brockport.edu

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By:
Alexis D. Lodico

SUNY College at Brockport
Advised by: Dr. Peter Veronesi

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To all of the teachers who have taught me the magic and wisdom of life; my parents, my sisters, my family, my friends, each and every one of my teachers, and of course mother nature, because of you I know how beautiful this life really is. You have inspired me to be compassionate, curious, and good. Thank you all for everything. I will do my best to pass the same wisdom on to my students.

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Learning through STEM-rich tinkering: findings from a jointly negotiated research project taken up in practice.

In an effort to find ways to engage students in science, technology, engineering and math content and increase content comprehension, a plethora of theories have been developed. Among them, kinesthetic learning theory, real world phenomenon based learning, inquiry based learning, design based learning, explorative learning and museum-based learning. In an attempt to utilize all of these theories, "the maker movement" arose around 2010. This movement is about learners being given the opportunity to "tinker" with tools and materials in order to make something or produce a result. This movement supports inquiry and design based learning by asking students to utilize materials at hand to create a working solution to a real world problem. The maker movement is intended to foster creativity, excitement, and innovation. This learning theory is important it because it further explores ways in which educators can engage and motivate students in science learning.

Bevan, Gutwill, Petrich, & Wilkinson (2015) conduct a joint research study between educators and museum scientists to study the effects of "tinkering" on learning. Students were asked to participate voluntarily in an after school program. This was conducted by observing 14 afterschool STEM programs for 2 years. The afterschool programs brought students to a local museum where they explored concepts through tinkering & movement theory. Students were offered the choice between exploring making marble machines, wind tunnels, or circuit boards. The choice was intended to promote autonomy and motivate learning through interest. Students were free to explore, learn and build at their own pace. Student activity was recorded by video and audio, and examined later for data collection. 56 videos of learning were ultimately collected

and coded for data collection to determine which learning dimensions were being explored and improved through this method of learning.

The results of this data analysis were qualitative. After examining all 56 videos multiple times, student behavior indicators were coded into categories. These categories demonstrated four forms of learning and development among students. Results show students were highly engaged in the content, showed high rates of initiative and intentionality, developed high levels of social scaffolding, and demonstrated development of understanding. Through observation, it was apparent that students were completely engaged in the topic, never appearing to get bored or off topic. Since students were free to work alone or in groups in congruence with their own flow, they were able to improve social scaffolding skills by moving in and out of groups to get help or help when necessary. Students made explicitly observed statements that demonstrated intentionality behind their actions and choices during exploration. Since students each eventually succeed in completing their tasks they were able to clearly demonstrate development of understanding from beginning to end.

Bevan, Gutwill, Petrich & Wilkinson (2015) conclude that hands on exploration is engaging for learners. The ability to make choices during learning drives initiative and intentionality, dynamic play and problem solving and increases social skills, and that understanding develops as learners move through the steps of problem solving through making or tinkering. This research itself lead to the creation of the "Tinkering Learning Dimensions Framework" which is a publicly accessible database of videos with various tinkering design projects for learners and educators to utilize. The implication is big for educators because it means a framework for learning in this fashion already exists. Educators can publically access

this framework to pull lesson plan ideas and to explore new ways of engaging students and building skills.

A cool controversy.

The BSCS 5E model is a science learning theory that asks students to engage, explore, explain, elaborate, and evaluate. As an engagement piece, recent research has suggested the use of socio-scientific issues. Socio-scientific issues are real world issues we experience in the modern world that are both social and scientific in nature and are also usually controversial. The controversial nature and real world relation of socio-scientific issues make them emotionally invoking, motivational, and curiosity driving. In this article by Biddy (2015), he suggests that historical controversies can also be used in the 5E model to increase motivation to learn and interest in scientific concepts. When using historical controversies, Biddy suggest the teacher presents historical theories that were once an attempt at explaining a phenomenon and allowing students to use inquiry to discover where the misconceptions lie in these historical theories to uncover the most recent scientific theory explaining the phenomenon. In this article, the author outlines a full lesson plan on glaciers, from engagement to evaluation, that details where to use the historical controversy in the 5E cycle for optimal motivation to learn.

In this example using glaciers, Biddy suggests several creative ways to use historical controversies to elaborate the students learning. First, the author suggests using an image of fossils to engage students and asks students to fill out a claim, evidence, and reasoning statement. Next, students explore glaciers through the creation and observation of a polymer Gak model of glacier flow. Biddy (2015) suggests ending this section of the lesson by watching a real time-lapse video of a glacier and make comparisons between their model and the real glacier.

Following the exploration, students explain what they have learned by labeling a diagram of a glacier with related vocabulary terms. In the fourth phase, the elaborate phase, the teacher asks the students to dive deeper into the content and apply what they have learned in new ways. This is where the author suggests using historical controversies to engage learners. Similar to many activities surrounding socio-scientific issues, this activity begins with role-play to get students fully involved and immersed in the story line. During this activity students begin by reading historical background information on two prevalent theories on glaciers from the 1800's along side the current glacial theory. Students then use old maps and images to go on an "expedition" to explore and study glaciers at various stations and collect evidence. Students will then organize this evidence to create a claim for or against glacial theory in order to finally evaluate student learning.

This lesson plan was a good model for the 5E science learning model and found a creative way to teach students historical context with modern theory embedded in a larger lesson. Biddy (2015) implies that historical content does not have to be boring in context but instead can be exciting, active and engaging. Here we see how role-play can be used for historical content and similarly it can be used for socio-scientific issues. Further this lesson demonstrates the diversity in learning styles that can be achieved through the 5E model.

The BSCS 5E instructional model: personal reflections and contemporary implications.

The 5E instructional model has roots in educational theories over 30 years old. Created by Roger Bybee, the BSCS 5E model was adapted from 1962's SCIS learning cycle. Since its creation years ago, the 5E model has been widely used and adapted. In this article, Bybee takes the time to re-explain the foundation and basic principles of the 5E model. Further, Bybee dives

into the contemporary applications of the 5E model in conjunction with the new Next Generation Science Standards. This model was made from the constructivist view of learning. The constructivist view of learning states that students must have experiences that challenge their current views followed by inquiry and exploratory time and activities to reconstruct their knowledge on a topic. The 5E's, which are engage, explore, explain, elaborate, and evaluate, were developed to create a learning sequence in order to express coherence within lessons. (Bybee, 2014)

Although this article is not comprised of formal research, it is a review of a popular science education theory by its creator. The major findings are the details of each part of the cycle of the learning theory (Bybee, 2014). As stated before, the cycle starts flows from engage, to explore, explain, elaborate, and ends with evaluate. The first phase is to engage learners in the content. This phase is the beginning of the lesson and does not need to be an entire lesson. The engagement piece should be an activity or a strategy that demonstrates a phenomenon or poses a question that address students' prior knowledge, draws out misconceptions, and leaves the students curious for more information. The second phase of this learning cycle has students exploring phenomenon. In this lesson students will participate in activities that allow them to explore the questions from the engage phase, make connections to prior knowledge, and begin to resolve their misconceptions. This phase is similar to guided inquiry learning. The third phase in the learning cycle is explaining phenomenon. During this phase, educators should first be asking students to explain what they have learned about the phenomenon at hand. Following this, the teacher should provide direct feedback to students about their explanations by providing a clear and concise explanation in response. In relation to NGSS, this is where the teacher outwardly explains the disciplinary core ideas. The fourth phase of the cycle is elaborating scientific

concepts and abilities. During this phase students are involved in activities that enrich and elaborate on the concepts developed in the prior phases. This phase is intended to solidify concepts into working memory, so that they are transferable to new experiences, thus deepening the learning experience of the students. This is a good time to challenge high achievers and offer aid to struggling students. The last phase of the cycle is to evaluate student learning. This phase concludes the lesson and is intended to provide evidence of student learning. This could be an informal or formal assessment but should evaluate the skills and conceptual understandings presented throughout the cycle and should involve teacher feedback to students.

Bybee (2014) explains the implications of his learning theory. The research that was used as a basis for the development of this learning cycle implies that student achievement is at its highest when the cycle is followed out in full and in order. This is not intended to be completed in one lesson, but rather over the course of a unit, in order to obtain an understanding of an over arching theme or a key idea and the skills that go with it. This model flows well with modern learning and the new Next Generation Science Standards. The 5E model offers the opportunity to engage learners using relevant techniques and then offers the opportunity to use inquiry learning, explain the core disciplinary ideas, elaborate on those ideas with cross cutting concepts and multidimensionality, as well as to evaluate student learning. These are key ideas of both the 5E model and the NGSS. This model has practical value, is supported by research, is clear and easy to use and conforms to the natural flow of science learning.

Science in the garden: a qualitative analysis of school-based agricultural educators' strategies.

As modern science teachers search for new ways to engage students in real world related content, several educational theories have emerged as a part of a resolution. Place-based learning

asks educators to put students directly in the field for first hand immersive learning. Socio-scientific issues based instruction asks educators to present students with real world issues to develop opinions and values on the phenomenon. One new education practice that utilizes place-based learning and socio-scientific issues based instruction is the use of school gardens. School gardens teach students agricultural and biological content and skills through immersive hands-on experience. Further, it is a doorway to the introduction of many relevant real world socio-scientific issues, such as, the use of genetically modified organisms, organic foods, land use, and climate change just to name a few. Cross & Kahn (2018), aim to determine if and how the use of school gardens in science education use socio-scientific issues with in their instruction.

School teachers utilizing school gardens in their science instruction were questioned in interviews for this study to collect qualitative data. Data was then analyzed using the constant comparative method. There were 3 main findings of this research (Cross & Kahn, 2018). First, students found it engaging to do the hands on work in the school garden. Second, that socio-scientific issues were discussed but they were not the frameworks for learning. Third, the teachers found it difficult to embed the science curriculum standards into the school garden setting.

Cross & Kahn (2018) indicate that place-based learning in school gardens can be a useful tool for engaging learners and should not be left unused simply because of the difficulty with the application of the curriculum standards. This implies that educators might need to use creativity and ingenuity to adapt the use of the school garden to both the science curriculum standards, as well as the socio- scientific issues based instruction method.

Theoretical inquiry-based learning insights on natural science education: from the source to 5E model.

Theoretical inquiry-based learning is a science learning theory built from the constructivist learning theory. The constructivist learning theory states that knowledge is built off of what is previously understood through natural and objective experiences. Inquiry based learning functions similarly in that it allows students to ask questions and guide their own research/learning to ask questions and find answers to build off of their prior knowledge. There are four learning principles on which most learning theory is built. These are, learning is constructive and is built on science knowledge, knowledge is transferred through conscious and unconscious perception; how knowledge will be acquired and used should be stated in the beginning of the lesson; and lastly, knowledge should be constructed reliably for use in the future. Understanding these basic principles, Dagys (2017) developed this study to answer the following questions; What is inquiry learning and how is it actualized? How does it differ from usual learning methods?

Using survey results to create qualitative analysis, inquiry based learning and the BSCS 5E model of science learning proposed by Roger Bybee are analyzed and compared. Basic principles are developed for each learning theory based on data analysis that can be used in comparison to the common learning principles of most learning theories as stated above. The results of the study determined three principles of the inquiry based learning model. (Dagys, 2017) The first principle is to motivate, to create a need for knowledge and a curiosity. The second principle is to construct an experience through observation of phenomenon and an opportunity to introduce new learning constructs to explain the phenomenon. The third principle

is to improve, giving students room to apply their new knowledge and a chance to summarize and reflect on their knowledge. Lastly, the results show that the 5E model includes five simple principles of engage, explore, explain, elaborate, and evaluate.

Dagys (2017) showed that inquiry based learning and the 5E-learning models are not based on principles that are exclusive of each other. Both the 5E model and inquiry based learning are based on the five common principles of all learning theories and most importantly, both are based on constructivist views that knowledge is built upon itself through experiences. Both inquiry based learning and the 5E model present more clearly organized principles to follow. The 5E model presents the simplest organization and flow of principles to follow. However, these learning theories are not mutually exclusive. Both begin with motivation or engagement. Both include exploring and explaining an observed phenomenon. Both offer the opportunity to elaborate by applying new knowledge and both offer the chance to reflect and summarize ones understanding of new concepts. In conclusion, the 5E model can include inquiry based learning theory and is built on the same basic principles of learning.

Hook, line, & sinker.

Teachers are always looking for new ways to engage students and new activities to disperse content. Some research has suggested the use of role-playing, even in the unexpected discipline of science. Role-playing comes in many forms. Role-playing can mean reading a script, like a play, in which students take specific character roles and have pre-mandated lines. This can be an informative extension of students' knowledge and has the power to improve conceptual understanding, argumentative skills, and scientific literacy by providing students with

the vocabulary and discourse necessary. The problem with this type of role-playing is that is can be non-scientific in nature and can get a little dry because it is so structured.

The next type of role-play is role-playing games. Role-playing games tend to be a bit more engaging as they offer students the opportunity to play as specific characters or as teams and to act out a scenario with a bit more freedom and improvisation. Although this activity is still guided by the teacher, it is not as structured as the previously mentioned scripted role-play.

In this article, Ehrlick & Cronin (2013) discuss a third form of role-play. This last form of role-play is considered more of a debate or a vote. In this interactive role-play, students are offered, roles, jobs, positions, or characteristics in which they are asked to take a side on a controversial phenomenon. This type of role-play is engaging as it asks students to consider opposing sides of already controversially engaging topics and use their prior knowledge to create their own defenses and reasoning. During this activity, the teacher should be sure to guide student discussion to be accurate and appropriate discourse. With these guidelines, the students can develop science literacy and argumentative skills through this activity. The role-play can be developed further, to ask students to come to an agreement on the controversial matter even though they have taken opposing roles. This offers students the opportunity to develop cooperative skills.

Ehrlick & Cronin (2013) outline the use of this role-playing activity to discuss the issue of declining global fisheries and their conservation. They suggest a few key aspects to include in the activity. First, set the stage by introducing the activity and providing background information. Second, provide role cards with descriptions and answer student questions about character. Third, make it real by creating a realistic and creative setting and structure for the role-

play, this works best with place-based activities. Lastly, have the students act out the activity, and find your own way to evaluate learning.

This activity has multiple positive implications for the classroom. In the science classroom we often use hands on, exploratory activities, but this activity is a "minds on" activity and allows students to explore the theoretical, social, and conceptual aspects of science. Hands on and minds on manipulation and practice are equally as important for science learners. This activity is a great way to teach students about real world, socio-scientific issues. These are engaging because of their controversial nature but also motivating because of their connection to the real world. Lastly, this activity is great for use in many parts of the widely used BSCS 5E model. This activity can be adapted to be used at any phase of the 5E model, engage, explore, explain, elaborate, and evaluate.

Student's social interaction in inquiry-based science education: how experiences of flow can increase motivation and achievement.

Inquiry based science instruction is a relatively new science education theory that has been making waves in the science education community. Inquiry based instruction functions on the idea that students have increased motivation and achievement when learning is centered on their own ideas, thoughts, and inquiry. It is the idea that students are asking their own questions and taking action and doing research to discover their own answers. This type of learning is in opposition to the standard approach of teacher says, student does and offers more autonomy to the students in their learning process. This study by Ellwood & Abrams (2018) compares 2 different approaches to inquiry science to determine how students socialize and interact during this type of instruction and how such socialization informs motivation and achievement.

This study was a qualitative comparative case study, meaning there were two case studies that were compared using qualitative data. Each case study was comprised of a group of 8 middle school girls. Data was collected through interviews, journals, student work samples, & observations. All of the data collected was transcribed and coded to discover emerging themes. Both groups investigated bird behavior during an inquiry lab. One group was taught in a normal classroom "on campus" and the other group was taught "off campus" in an immersive sight, a local nature reserve.

The general results of this study show that off campus students out performed their on-campus piers on 46% of the assignments. On the other 54% of the assignments students performed close to equally. Results also show that off campus students reported higher rates of "flow state" (Ellwood & Abrams, 2018). For the purposes of this study, we define flow state as positive emotions and actions, content related conversation lasting more than 3 minutes, behaviors "acting like a scientist" and student identification and resolution of problems. Lastly, results of observation showed that students in the classroom doing individual work looked at the clock an average of 11 times, while students in the classroom doing group work looked at the clock an average of 4 times, and students off campus did not inquire about the time at all.

The most significant of the findings by Ellwood & Abrams (2018) implies that students who conduct inquiry based lessons off campus and in the field find themselves in a greater "flow state" than students on campus. The flow state is a hyper concentrated state of focus in which students are fully immersed in the work, focused, and thinking creatively. Flow states are proven to increase achievement because it is your peak of work ability; they have clear rules, immediate feedback, are self-motivated and have increased concentration. It has been identified that the greatest achieving artists and scientist credit their work to high functioning flow states. This is

significant because it indicates that we need to either do a better job immersing students in content and creating flow states or we need to immerse students in real context and place-based learning. These results imply that off campus or place based learning can better accommodate flow theory practices. In other words, students are able to own the creative process & create their own work-flow, which is motivating and immersive. Further, when students are more deeply immersed in content and inquiry there is a lack of boredom, which increases concentration. This study even implies that working in groups even with in the classroom can create higher rates of immersion based on data of the number of times students looked at the clocks.

Advantages and disadvantages of socio-scientific issue-based instruction in science classrooms.

As global living conditions have changed, individual responsibility as citizens has increased. Much of this responsibility surrounds socio-scientific issues (SSI) such as alternative energy, recycling, GMOs, etc. We face many problems globally and the majority of them are scientific in nature. Educating students to be scientifically literate, critical thinking, problem solvers, is a prerequisite to having a strong progressive global community with competent self-advocating members. One contemporary educational theory suggests that the best way to prepare students with the skills, understanding, and motivation to handle these real world problems is to introduce them into the classroom. This theory is called socio-scientific issues based learning or socio-scientific issues based instruction. Such instruction calls for the introduction of socio-scientific issues as motivation and engagement in the related content. The idea here is that the real world content and the controversial nature of socio-scientific issues will serve as connection and motivation for students.

This study by Evren (2018) describes a case study using qualitative research measures. Its aim is to discover the explicit advantages and disadvantages of socio-scientific issue based instruction in the classroom. During this study, socio-scientific issues based instruction was employed on an undergraduate class of 40 perspective teachers. The idea here being that in order to prepare students for learning about socio-scientific issues we must first prepare teachers. The data collected was from journals and interviews of perspective teachers who were engaged in learning through socio-scientific issues based learning. Pre-assessment data was collected to determine that none of the pre-service teachers were familiar with socio-scientific issues based instruction.

Evren (2018) outlines the socio-scientific issues based instruction model as combining the chosen socio-scientific issues content with an intentional teaching approach for integration as a lesson. This is the first research that explicitly suggests that socio-scientific issues based instruction should be integrated as a part of a larger lesson.

The study collected qualitative data from journals and interviews of those engaged in socio-scientific issues based learning. Analysis of this qualitative data was done to find the general themes. 8 general themes of advantages of SSI based instruction emerged from this data analysis. These 8 “subthemes” include; meaningful learning, social awareness, opinion development, vocational development, character development, science literacy and up-skilling (Evren, 2018). The subtheme of up-skilling is comprehensive in nature, meaning the upward movement of skills. The skills referred to for this study include increased research skills, critical thinking, skills problem solving skills, communication skills, reflection skills, and questioning skills. Further, after data analysis, this study found four general disadvantages of socio-scientific issues based instruction categorized into sub-themes. The disadvantages for the use of socio-

scientific issues based instruction are categorized as follows; responsibility of teacher to obtain background knowledge, misconception among students, shortage of time in curriculum, lack of resources.

Evren (2018) determines that there are far more advantages to using SSI-based instruction than disadvantages, and that those disadvantages are ones that we can work to overcome. Nonetheless, the advantages categorized into the subthemes listed above are critical skills that are the overarching themes and goals of education in general. The list of critical skills of this study implies that students have the ability to gain through socio-scientific issues based learning is long and full of key skills already highlighted as main skills to learn in the science curriculum. This implies that the use of SSI based learning has far reaching educational power. Due to these far reaching advantages, is seems worth it for teachers to try to overcome the apparent disadvantages of using socio-scientific issues based instruction. Further, this study suggests that socio-scientific issues based instruction should be implemented as an integrated part of a whole lesson, not as the whole lesson itself. Understanding that the basis of the socio-scientific issues based instruction model is to build connection to students and create motivation to learn, it would seem that socio-scientific issues might be fitting to be the engagement or introductory piece in a larger lesson.

Hiding in plain sight: how to identify and use trade books to support the 5E instructional model.

The BSCS 5E instructional model is commonly use in the adolescent science classroom as a reliable learning theory. It is based on the constructivist theory of learning, which states that learning is built upon prior knowledge by having new and objective experiences. The 5E model is comprised of 5 stages, which are, engage, explore, explain, elaborate, and evaluate. There is a

question of what these stages look like at the adolescent stage but in general they include observing some phenomenon, having a laboratory setting to explore the phenomenon and then further explain the phenomenon, using the laboratory setting to be able to apply the learned knowledge in new ways and then having some form of evaluation to assess student learning.

How does the 5E model look for childhood learners however? Does the 5E model work for younger learners and if so, what should each of the phases of learning look like? In this study, Forsythe, Jackson, & Conteras (2018) propose the use of trade books to support the 5E model for younger learners.

Forsythe, Jackson, & Conteras argue that reading can deepen learning, and although the use of books in the 5E model is not intended to teach the skill of reading, it has been found that reading to teach can support teaching to read.

For the engage phase of the 5E model, authors suggest using quick reads that pose questions or capture the students' attention. For example, poems or riddles can be used during the engagement phase.

During the explore phase, students should be involved in hands on activities that allow them to observe phenomenon and to begin to find explanations. Here, they suggest using an interactive read aloud with hands on activities placed throughout the reading. This allows students to explore a phenomenon through texts paired with hands on activities (Forsythe, Jackson, & Conteras, 2018).

The third phase of the 5E model is explain, during this phase students are offered the opportunity to explain their understanding, as well as having formal explanations explained to them for comparison. At this phase, authors suggest an informational text shared through an

interactive read aloud which is paused at predetermined moments in order to ask students questions to ensure they understand and can explain the concepts.

The fourth stage of the 5E model is elaborate; this phase allows students to apply the concepts they've learned to new situations. Here Forsythe, Jackson, & Contreras (2018), suggests reading, writing, and evaluating claim, evidence and reasoning statements.

The last phase of the 5E model is to evaluate student learning. For this last phase, they suggest a few different options for evaluating student learning that take advantage of texts. Such as, two truths ans a lie, identifying errors and making corrections in a text, or an interactive read aloud where students stop to answer questions, make predictions, or complete an idea.

Although most people consider hands on activities and laboratories to be the basis for inquiry learning and the 5E model, Forsythe, Jackson & Contreras (2018) indicate that there are reading strategies that can be used at each stage of the 5E model to deepen learning. Further, these reading strategies pair well with hands on activities. Lastly, these reading strategies can be applied to the 5E model for both childhood learners and adolescent learners.

A historical journey in science education through role-playing.

Classrooms can sometimes become routine and monotonous. To combat this, teachers are often looking for ways to fully engage students. In this study by Guha (2013), they suggest the use of role-playing activities to revitalize the classroom and engage students. Role-playing incorporates multiple senses, is fun and active, and can be full of informative content that students can directly interact with. Role-play fully immerses students in a novel experience, develops communication and scientific literacy through communication, and allows students to

be creative within their character as well as in the classroom. There are multiple angles of role-play, which motivate and engage learners.

Guha (2013) presents a 30-minute play that goes along with a lesson on temperature, boiling point, melting point, and freezing point. The author suggests using the role-playing activity after an experiment on the same content. In accordance with the 5E-learning model, the temperature experiment would be a part of the students' exploratory phase on the topic. After the students are allowed to explore different aspects of temperature, surely they will be left with questions and misconceptions about the observed phenomenon. Here the author suggests using the role-playing activity as an opportunity to explain further the observed phenomenon on temperature.

Guha (2013) delivers explicit explanations and works for this phase of the 5E process because it was a structured play with direct lines guided by the teacher. Although role-play has the opportunity to be fully engaging, this type of role-play that is scripted can also be dry unless heavily planned to be other wise. While it does ask students to further develop conceptualization and scientific literacy, it is not as free flowing and engaging as the alternative, role-playing games. Another dilemma with scripted role-play is creating roles for an entire class of students so that all students remain engaged. The rigid structure of a mandated role-playing script can work in opposition to the engagement aspect.

Taking an attention-grabbing 'headlines first!' approach to engage students in a lecture setting.

The BSCS 5E instructional model is a cycle of learning often used in science classes. The 5E cycle begins with engaging students through a motivation and question inducing activity and is followed by the phases explore, explain, elaborate and evaluate.

Finding a truly attention grabbing activity to motivate and engage students for science topics can be difficult. During a lecture it is especially true that it can be hard to captivate your audience of learners. Creating more active and dynamic lessons could ease this issue of engagement but this particular study aims to find ways to make lectures more engaging. Harris, Stevenson, & Joyner (2015) suggest that using the 'headlines first!' approach can be attention grabbing and engaging for students during a lecture.

The headlines first approach is a story telling approach that is exciting, engaging, and entertaining (Harris, Stevenson, & Joyner, 2015). Some types of stories that are good for this type of setting can be personal anecdotes, narratives, fiction, and how it's made stories. The purpose of using stories like these is to create an emotional response to create engagement and heightened interest. Traditional science literature functions to provide logical and clear explanations from abstract to conclusion. These texts typically and purposefully lack emotion, as they are based on rationality. In contrast, headlines of other articles and newspapers have attention grabbing, emotion invoking titles. These titles are exciting and drive the readers' curiosity and inquiry to read more.

Harris, Stevenson, & Joyner (2015) conclude that reading science literature can be interesting and emotion driving while still providing fact filled, intellectual content. Students' attention spans are getting shorter over time; lectures and readings need to be adapted to cater to

the students' attention and abilities. By using attention-grabbing headlines, educators can entice curiosity from students and invite them to dive deeper into a text or a lecture on their own accord. The emotional response of students drives their own motivation to learn.

Students' environmental NOS views, compassion, intent, and action: impact of place-based socio-scientific issues instruction.

With the goal of functional science literacy and scientific skills, recent research suggests employing socio-scientific issues (SSI) based instruction in the classroom. Socio-scientific issues based instruction centers around the idea that students will find connection to content and therefore motivation to learn when they are introduced to content through real world socio-scientific issues. These socio-scientific issues investigations should inherently include education of scientific processes, the nature of science (NOS) and diverse sociocultural perspectives (Herman, 2018). This study suggests that most socio-scientific issues approaches fail to really engage students fully in socio-scientific issues. In this literature, Herman (2018) employs a mixed methods investigation into discovering the current shortcomings of socio-scientific issues-based instruction and how to overcome them. There are three main issues Herman (2018) sees within the current research on socio-scientific issues based instruction. First, the socio-scientific issues presented in the classroom tend not to have a clearly indicated alignment with concepts of the nature of science. When we speak of the nature of science we mean the general themes that constitute the culture of science, which in simple terms is to explain natural phenomenon through a collective analysis of evidence. Second, that most socio-scientific issues are presented in "laboratory" settings and not real life settings, which changes the context. Leading to the third

issue, that most decision-making around socio-scientific issues in the classroom does not truly reflect how one would make decisions around socio-scientific issues in real life.

Herman (2018) looked at a place-based SSI instruction in an attempt to fix these issues. For this purpose, 62 students were taken on a field trip to Yellowstone National Park where they experienced placed based SSI-instruction on the reintroduction of wolves (Herman, 2018). This focus class consisted of a range of students from 7th grade -11th grade from Missouri. This place-based SSI instruction took the general format as follows; introduction to the topic through documentaries and wolf watching, hiking to observe the land and make abstract contextualizations about its characteristics in relation to NOS, students talked to experts in the field and last, students shared their ideas in group discussions in multiple settings.

For data collection on this instructional method, researchers developed and employed the socio-scientific and ecological dimensions survey II (SEEDS II), (Herman, 2018). This survey was given before and after instruction to all students and assesses, quantitatively and qualitatively, social issues engagement. Data was collected on 3 categories reflecting the three main issues discussed earlier; accuracy of NOS views, compassion towards others, and pro-environmental intent (Herman, 2018). Data analysis here aims to answer two questions; (1) did the scores significantly change after place-based SSI instruction? (2) Were the scores significantly different between students who wanted to donate to the cause and students who did not?

Results show that scores dramatically increased from pre-test to post test in all subjects, and especially in those who did not want to donate initially. This indicates that place-based instruction strongly improves student understanding of the nature of science, compassion toward

others, and their desire to do good in the world. These results also indicate increased motivation to learn and participate in science through socio-scientific issues.

Herman (2018) concludes that place-based SSI investigations are a successful method of increasing student engagement, improving conceptual understanding of content, improving conceptual understanding of NOS, developing compassion for others, and increasing intent to help others and the environment. These are powerful tools for knowing how to implement SSI properly. Further, this study implies that socio-scientific issues based instruction did in fact increase motivation to participate in science. One can see this evident in the fact that students who began with a disinterest to donate to socio-scientific causes had an increased desire to donate to such causes by the end of the lesson.

Challenging a "why should I care" attitude by incorporating societal issues in the classroom.

Often students ask why should I care, why do I need to know this, or when will this ever be useful to me? These are hard but serious questions. The knowledge we teach our students, especially in the science classroom should be useful. If the information and skills we teach our students is useless we are probably not doing our job. We make our content useful by giving it meaning in the lives of students, by giving it connections to the real world. In this article by Hoban and Romero-Severson (2011), they explore the use of incorporating societal issues in the classroom to combat the why should I care attitude. These societal issues have recently been classified as socio-scientific issues by educational theorist. These issues are real world issues that are both scientific and social in natures. Based on the use of these issues, curriculums have been developed under the title of socio-scientific issues based instruction. Further, the uses of this type

of instruction does not just aim to engage students but also to create life long learners who are prepared to problem solve and make rational decisions.

Hoban & Romero-Severson (2011) outlines an activity for engaging students in societal issues. This activity asks students to write a letter to a state official about a real world issue that is affecting people, local wildlife, or the environment. Students are to research an issue, understand how and why it has a negative impact and possible solutions. Students are then to use their science discourse, content knowledge, and science literacy skills to write the letter including all of these aspects surrounding the issue with their suggestion of possible solutions. 40 students participated in this learning activity. All were able to complete all aspects of the assignment. Although grades and effort varied, many students reported this being the most memorable aspect of the learning year. Students reported feelings of doing something meaningful. This type of meaningful activity is empowering for student learning as well as engaging.

This was just one suggestion for a type of socio-scientific issue to use in the classroom. Results indicate that it is a positive and useful activity for engaging learning and creating care about the content (Hoban & Romero-Severson, 2011). This type of activity develops science discourse, literacy, reasoning and argumentative skills, and content knowledge, but does not develop crucial scientific skills that are learning through hand-on activities. Therefore, socio-scientific issues based instruction such as presented here should be used in congruence with other types of activities to complete lessons.

A science for citizenship model: assessing the effects of benefits, risks, and trust in predicting students' interest in and understanding of science related content.

Science can be defined as the systematic study of the natural world. We, as humans, survive off of the natural world, it moves us and we move it. It is in our vested interest to understand this world and our impact on it, some would argue now more than ever. To better develop our relationship to the natural world, it may be beneficial to teach science education to students through inquiry into real world phenomenon. This type of science investigation benefits both the community and the student learner. Jack, et al. (2017) proposes a "science for citizenship model" that addresses this education theme. Jack, et al. (2017), supported by other educational research theory, suggests student motivation to learn can be directly related to student self awareness of conceptual relation and importance to their lives.

Jack, et al. (2017) propose the Science for Citizenship Model (SCM) as a conceptual model for measuring student interest based on the "students self evaluated awareness of the benefits, risk, and trustworthiness of science" (Jack, et al., 2017). Using a pool of 301 Taiwanese students, ages 15-18, from 3 traditional Taiwanese high schools, this study aims to answer two research questions: (1) what are the relationships between Taiwanese students' trust in scientists, their perceptions of learning the benefits and risks associates with science, and their levels of interest in learning its context, (2) can a 50-minute instructional presentation contextualized to Taiwanese students' knowledge of the natural world and society affect measurable change in their perceptions of the benefits and risks associated with the concept, their trust in scientists, their understanding of the concept, and their triggered interest in learning science.

For the purpose of this study, the science concept that will be addressed is emerging nanotechnology. Data was collected through a 25 minute pre-test administered before a 50

minute lesson on nanotechnology as well as a 25 minute post-test administered after. The 50-minute lesson was comprised of an adapted, college level reading outlining an explanation of the scientific concept, examples of real world phenomenon in connection to students' prior knowledge, benefits of the technology and risks of the technology. The pre- and post-test were comprised of the following: 10 Likert-type scale questions assessing students' self-evaluated attitudes of trust ([4] highly trust- [1] highly distrust), five Likert-type scale questions measuring self-evaluated perceptions of benefits & five measuring self-evaluated perceptions of risks ([4] strongly agree-[1] strongly disagree), six Likert-type scale questions assessing students interest in learning science ([4] strongly agree- [1] strongly disagree), and a total of 26 multiple choice questions were used to assess students conceptual understanding of nanotechnology (Jack, et al. 2017).

T-tests were run to find correlations of statistical significance between variables. The results of these tests show a statistically significant correlation between benefits and risks, benefits and trust, benefits with interest, and trust with interest. These positive correlations indicate, "that as the value of one variable increased, the value of the other variable also increased" (Jack, et al., 2017). Interestingly, risk and interest only had a statistically significant correlation on the post-test and risk and trust had a statistically significant but negative correlation on the pre-test. A detailed look at the results indicates that students' trust in nanotechnology provides a predictive effect on interest in nanotechnology, benefits of nanotechnology understood post-lesson provide predictive effect on interest, and the combined awareness of all three variables was a greater predictor of interest after the 50 minute lesson.

Ultimately, these findings show that a lesson demonstrating the benefits and risk and gaining students trust on a science topic can lead to increased interest in learning (Jack, et al.,

2017). The discovered answer to the second question of this study, suggest that presenting students with an understanding of the phenomenon that is coherent with their real life understanding deepens their interest and creates a stronger basis for gaining a deeper understanding in later lessons. This study supports the idea that connecting science phenomenon directly to the students life through teaching the benefits, risks, and trustworthiness that students interest, and therefore motivation to learn, increases. Further, the more motivated students are too learn, the better they actually learn, making for citizens who are highly informed and self motivated to participate in the decisions that affect and advance society.

Elements of design-based science activities that affect students' motivation.

As science educators we want students to be interested in the content and motivated to learn. It can be quite disheartening to have a classroom full of unmotivated, bored, disinterested students. Not only does student motivation help content retention, it also helps classroom moral, and application of knowledge to real world problems. Further, we need students to be interested in science for the future of our work force. We are no longer a society of hunters and gatherers or industrial factory workers. We have advanced into an intellectually based, science and technology based society. This is iterated by our current job climate, which relies heavily on science, technology, engineering, and medicine. This societal need should be reflected in the classrooms of young students, as it is our duty as educators to prepare students for the real world and to develop adults who will contribute to societal growth. Therefore, it is apparent that the education force needs teaching strategies that motivates students to learn content that will be applicable to their lives in the real world. Jones, et al. (2015) determined the effectiveness of design-based science activities on student motivation.

Jones, et al. (2015) utilized a 12 week after school STEM program for middle school students, in which students were given real world problems and asked to use hands-on, design-based problem solving related to science, technology and engineering ideas. 14 students were enrolled in this afterschool program. The design principles of this program were an interdisciplinary curriculum, active and inquiry based learning through design activities and real world problems, informal learning arrangements which allowed creativity, exploration, & problem solving, use of internet to expand learning, and workforce development.

This was a qualitative study that used triangulation to ensure valid results. The researchers utilized questionnaires, structured interviews, & observations structured through the proven "MUSIC" theory of motivation for data collection. The "MUSIC" motivation theory tests for 5 categories: empowerment, usefulness, success, interest, and caring.

The results of the questionnaire measured that 70% of students felt empowered by this learning, 82% felt the content was useful, 84% felt successful in completing activities, 78% felt interested in the content, & 77% felt cared for during the learning. Interviews were conducted at the beginning, middle, and end of the program and at each point students were asked 5 questions, one pertaining to each "MUSIC" category. The results of the interviews determined that students felt "very empowered", that the information was "not very useful now", that the information was "very useful for the future", that they felt "very successful" & "very interested", they felt the facilitators were "very caring" and that they put in "a lot of effort". Lastly, trained observers that denoted behaviors made observations; the results supported the results of the questionnaires and the interviews.

So how did this STEM program effect engagement & motivation? Jones, et al. (2015) imply but do not prove that this hands on, design based learning was motivating for middle

school students. These results have 3 major implications, these are the 3 major ways this program increased motivation that can be transferred into the science classroom. First, students felt empowered by the feeling that facilitators were caring and helpful. Second, students felt increased engagement by activities that were hands on & exploratory. Third, students felt empowered by the ability to make their own choices. Lastly, The results showed that students felt that this information was useful for their future but not useful right now. This implies that although the students were engaged, they felt this information was not relatable to their lives at the moment. This indicates that perhaps younger students need to be taught with content that is more relatable to their lives at the moment.

Case studies of science teachers designing socio-scientific issues- based instruction.

Socio-scientific issues (SSI) based instruction teaches science content through the introduction of socio-scientific issues. Socio-scientific issues are issues that are complex problems without one clear solution that occur in the social context of the world and are embedded within scientific content. Socio-scientific issues have been discussed frequently in recent literature as a part of movement towards creating scientific, technological, socially literate citizens. Much of the current research on socio-scientific issues discusses its impact on students, such as motivation, increased ability to partake in public discourse, enriched science literacy and skills, and more. However, as research mounts to support the idea that socio-scientific issues based instruction improves student engagement and motivation to learn, more studies are beginning to emerge that discuss the techniques in which socio-scientific issues based instruction are implemented. Here, Karahan & Roerhig (2019) aim to discuss the impact of teachers' views on how they teach socio-scientific issues.

Karahan and Roerhig (2019) employ a multiple case study to answer the following questions: (1) How do science teachers design and implement socio-scientific issues-based instruction? (2) How do contextual factors influence teachers' design and implementation of socio-scientific issues based instruction? The case studies follow 3 high school science teachers (two male and one female). Data was collected and triangulated through observations, interviews, and teacher journals. Qualitative thematic analysis of data was done to identify and categorize patterns in teachers' beliefs and classroom practices.

When teachers are asked to teach the same socio-scientific issues content, the results of the study showed that each of the teachers used different approaches based on their life experiences. For example, two of the teachers approached the SSI content based only on scientific evidence. Another teacher, who had firsthand experience with the socio-scientific issues, believed that since biases influenced the issue, that value based biases and ethics should be discussed in the class. On a deeper level, two of the teachers believed scientific data was enough to make critical decisions but one of the teachers, believed students should be skeptical and critical to form real opinions on socio-scientific issues. Karahan & Roerhig (2019) show that most teaching comes with some form of a bias. For some, this is a bias towards hard evidence in support of arguments. For others this means taking the time to develop well-rounded opinions that include multiple variables.

The impact of this study demonstrates that although we are coming to a collective consensus on the idea of using socio-scientific issues in the classroom for critical student development, there is not a singular way of doing so (Karahan & Roerhig, 2019). Further, individual teacher perspectives have great influence on how SSIs are taught. However, this brings up a deeper implication, which is that all classrooms are taught with a little bit of bias

based on the teachers' opinions and experiences. This truth is impossible to escape. Perhaps, students need to be faced with socio-scientific issues in a way that develops both logical and factual reasoning as well as their own opinions, values and beliefs so that they are prepared to solve problems with either focus in mind.

Use of socio-scientific contexts for promoting student agency in environmental science classroom.

There are an array of socio-scientific issues (SSI) and real world phenomena we face today. Now more than ever we need citizens who are knowledgeable, empowered, and prepared to make decisions concerning such issues. School should prepare students for life in this manner and science can be a key component in teaching students this type of critical thinking. This study by Karahan & Roerhig (2016) investigates how a socio-scientific issue based curriculum aids in the agency and individual power of the student in their decision-making. It is argued by other research that students in a tradition classroom are "passive receivers" of information, which trains them to be passive members of society; this is not what we want. Karahan and Roerhig (2016) propose that socio-scientific issue based learning can teach students how to be active learners and therefore active members of a democratic scientific society.

Karahan & Roerhig (2016) set up case study using qualitative measurements of the effects of an SSI based course co-taught by a science teacher and a social studies teacher to produce positive student agency. This study took place in a culturally diverse, suburban, high school, environmental classroom in the Midwest, USA. The student sample population was a total of 31 students. Qualitative data was collected through observations, interviews, and

informal discussion. Research backed thematic analysis of collected data responses was employed for pattern finding in data analysis.

The class was set up in two parts; the first half of the year students used their own personal inquiry to determine a socio-scientific issue research topic of interest to them, followed by the second half of the year in which students completed a project to effect change about this issue in their community. The direct results of this classroom framework are creating students who are both active agents in their own learning and active agents of change within their community. This curriculum combines student based/inquiry learning models with a science for citizenship model (SCM). Further, this method produced emotional connections to content, which increased motivation for learning, as well as producing positive attitudes towards science which increased the ability to confidently think critically when problem solving for real world phenomenon (Karahan & Roerhig, 2016).

Karahan & Roerhig (2016) demonstrate the necessity and also the ability to create interested learners who are effective agents of change. Classroom learning must reflect the type of knowledge and issues students are expected to encounter as active adult citizens. Using socio-scientific issues as a lens proves to provide emotional connection, intrinsic motivation to learn and be active, critical thinking skills, decision-making skills and an understanding of real work phenomenon.

Emotional intelligence among auditory, reading, and kinesthetic learning styles of elementary school students in Ambon-Indonesia.

In recent years there has been a big push in education research to reinvigorate the science classroom and improve student motivation and achievement. In much of the recently published research on forms of learning that drive motivation, such as, design based learning, socio-

scientific issues based learning, project based learning, etc., there seem to be a couple characteristics in common. All of these new forms of learning and motivation theory center on real world phenomenon or real world connections and kinesthetic learning. Kinesthetic learning theory suggests students learn best when they have tactile activities and get to move their whole bodies. To date, there is not much literature that exists on kinesthetic learning especially in the science classroom. Further, most of the research that exists on kinesthetic learning theory is for elementary learners. This begs the question, does the desire to learn kinesthetically decrease as we age, or is hands-on learning always motivating for human beings?

Of the little research on this topic that exists, this research by Leasy, Corembima, Ibrohim, & Suwono (2017) compares various forms of learning, including kinesthetic learning. In this self-dubbed quasi-experimental research, researchers compare the emotional intelligence of students using reading, auditory, and kinesthetic learning styles. This comparative study surveyed 12 elementary classes, totaling 210 students. The classes were divided into two learning styles and were taught with that learning style for 26 classes over four months. Since students, and human beings in general, have preferred methods of learning, researchers wanted to ensure that the method of learning in some classes was not in opposition to majority student preference while in some classes it was matched with the majority preferred learning style. A mistake like that would have created bias. Before implementation, researchers polled classrooms to find the majority preferred learning styles, and assigned each classroom for the study accordingly. In this study, some classes learned through reading, some classes learned through auditory lessons or lectures, and others learned through kinesthetic lessons. Emotional intelligence was measured by the VARK model of learning questionnaire. This questionnaire measured understanding of context, ability to relay information, self-reliance, and decision-

making skills. All student participants were given both a pre- test and post- test. Score growth was measured and then averaged per learning group.

The results of the emotional intelligence survey showed that kinesthetic learners had the highest scores on the post survey (Leasy, Corembima, Ibrohim, & Suwono, 2017). The kinesthetic learners mean emotional intelligence score was 69.5, the reading learners mean emotional intelligence score was 65.68 and the auditory learners emotional intelligence score was 64.14. Kinesthetic learner scores were 8.35 % higher than auditory learners and 6.11% higher than reading learners.

These findings do however; imply that kinesthetic learning can be a useful tool for learners. Leasy, Corembima, Ibrohim, & Suwono (2017) demonstrate that kinesthetic learners might develop greater understanding of context, ability to relay information, self-reliance, and decision-making skills. This is important to the science classroom because these are all key science skills and any tool that might improve them could be useful to educators. Emotional intelligence is just one form of learning but it is one that can help students become learners of life. Leasy, Corembima, Ibrohim, & Suwono (2017) show us that kinesthetic learning can breed multifaceted growth because it has a sense of learning by doing which is always multifaceted. Kinesthetic learning appears to be highly stimulating and creates a rich environment with a lot of variance and opportunity. The conclusion from this study is that learning paired with movement is important for diversity in growth and learning in students.

Science teachers taking their first steps toward teaching socio-scientific issues through collaborative action research.

The use of socio-scientific issues (SSI) as a method for teaching science is fairly new. While the research emerging on the subject suggests it helps motivate and engage students, many

also argue that it is important for creating scientifically literate democratic citizens, which is crucial at this time in society. All the research on the subject is just beginning to emerge within the last few years, and that's exciting. That also means, there will be resistance, and it will need teachers open to change to be practiced in the classroom. This study collected data on implementing socio-scientific based lessons in three parts. First it surveyed teachers on whether they would implement socio-scientific issues based instruction and then categorized their answers. Second, two teachers attempted to implement socio-scientific issues based instruction in their collaborative classroom and collected data on and categorized the challenges they faced. Lastly, they assessed the use of action research, which is another newer concept to education, as a way to introduce socio-scientific issues based instruction into the classroom and work through the challenges.

For the first part of this study, 20 teachers were surveyed on their attitudes towards SSIs. Results show five main reasons that teachers might be apprehensive about introducing SSIs. These resulting reasons are categorized as follows according to Lee & Yang (2019); lack of content knowledge, lack of skills and techniques for teaching such content, lack of support from the school and community, insufficient funds, or lack of curriculum flexibility. For the second part of the study, two science teachers volunteered to design and collaboratively teach a socio-scientific issue based unit with two graduate assistants and a research scientist to help create the units and collect data. This research group met every week. The lessons were taught to an 8th grade class in Korea. The cycle of action research was use to plan, implement, collect data, reflect, make changes, and re-implement every week. The primary data sources were videos of classroom instruction, video interviews of teachers reflecting after instruction, videos of student discourse, and student work samples. Data was analyzed to categorize the challenges. According

to Lee and Yang (2019), there were four main challenges when implementing SSI. According to this research teachers found it challenging to restructure the classical classroom, engaging students in the socio-scientific issue, handling student values, and finding where socio-scientific issues fit into the curriculum. Lastly, teachers reported positive effects of the cycle of action research in implementing the new SSI content. They reported feeling more comfortable with each cycle, and students becoming more engaged.

While the sample is small, the implications are pretty remarkable. What this study demonstrates is that many teachers are resistant to changes in teaching style and content, but that action research, especially collaborative, can provide a way for teachers to learn, grow, and adapt (Lee & Yang, 2019). This study exemplifies that teachers may need explicit guidance and support to introduce SSI based instruction. Further, it shows that initially teachers hold the belief that teaching SSIs is somehow in opposition to the nature of science but that after having experience with teaching SSIs come to learn that it is not. Lee and Yang (2019) show that SSIs do no oppose the teaching of standard science concepts, principles, laws and inquiry but rather is a way of teaching standard science concepts, principles, laws and inquiry. This demonstrates that in order for teachers to see the value of using SSI based instruction, there may need to be deep restructuring or a paradigm shift. Lastly, data collected from videos of student discourse shows that SSI based instruction promotes engagement and student motivation. This last implication has been supported by other research as well.

Bringing science to life: using social learning to make real-world connections in science.

As new education theories emerge to help bring science to life in the modern world, educators are competing for the attention span and interest of the youth. Even with new learning

theories like place-based learning and socio-scientific issues, and even in a hands on exploratory classroom like the science classroom, its hard to compete with the instant gratification and connection to interests that social media has provided young students. But as the old saying goes, if you cant beat them, join them. If students are so immersed in social media, why not use that to our advantage as educators. When we think along these lines, the question then becomes, how? This is not an easy question to answer. Maine, et al. (2018) develop and propose the use of a website called MySciLife to combine the world of social media with the world of science learning for the benefit of students and educators alike.

The use of MySciLife was studied on middle school students, as this is a crucial age for determining student interest and future pathways. MySciLife merged science content with a social media platform. Its modules include; atoms, cells, chemical reactions, earth, ecology, force motion & energy, genetics, human body systems, moon phases and seasons, universe and weather. When students open a module, they take on an identity associated with the learning lessons; for example, in the cells module one student may take on the identity of a nucleus. Essentially, this is online role-play. Students complete learning modules and are then guided to discussion boards. Here teachers are able to guide student learning by entering prompts to guide social media sharing. Students are then required to follow the prompts and post back and forth on the social media page as their designated characters interacting with one another. This provides an immersive, social, and technology driven learning experience (Maine, et al., 2018).

While it takes a bit of training to use MySciLife on the teachers end, it is a free platform that engages students in a way that they are used to interacting (Maine, et al., 2018). This makes it relatable to the real world for them, and therefore, more engaging. This could not and should not be used as the entire basis for learning in a classroom but it would be motivating for student

learning to integrate into the learning environment. This website uses constructivist learning to build on what students already know, both socially and conceptually.

The role of a museum based science education program in promoting content knowledge and motivation.

Recently there have been rising concerns over the decline in science achievement and participation in science related programs by the youth, specifically in western nations. According to studies, the decline in attitudes towards science begins around age 10. This is a problem because a decline in STEM interest in kids results in a decline in STEM as a profession. In order to progress as a nation we must continue to have an intellectual STEM driven work force. It's no surprise that science achievement in school is linked to science jobs. With that in mind, it is important that we try to reshape the science classroom to improve motivation and engagement. Kids are bored in the classroom and they are struggling to find meaning in lessons. We need a creative, reimagined focus on science. Some of the ideas coming to the surface in relevant research include place based learning and real world emersion. Both place based learning and real world emersion are theories that lend way to the idea that students learn better when they can have the fullest experience, that is, through experiencing learning in the most authentic and immersive way. The most prominent way to fully emerge students is too put them in the place in which the real world phenomenon might occur. If this cannot be achieved, it has been suggested that museums can often create a close to realistic immersive experience for learners. This study by Martin, et al. (2016) introduces the idea of museum based learning that is both place based and real world. It also includes theories of kinesthetic learning and guided discovery learning, both of which are proven to increase motivation and achievement.

Martin, et al. (2016) assessed the role of self-paced science education in a museum in enhancing students' content knowledge, self-efficacy, motivation and aspiration. 167 upper elementary students, ages 10-16 were offered multiple 10-day programs during their vacation times to complete a museum based education program. The program was 10 days and included 10 stations in which the students could complete in any order, with the idea of allowing students to choose the order of learning to promote self-efficacy and motivation. The museum was a health and medical science museum and learning was in the form of guided discovery learning. Students were administered two pre and post test, one was a content quiz & the other a likert-scale test measuring self efficacy, motivation, values, and aspirations. Data was collected from the scores of these tests and the data was cross-referenced.

The results of this study showed that museum based learning increased students content knowledge by an average of 2%. Further results show ~0.10% increase on self-efficacy, values, motivation, and aspiration (Martin, et al, 2016). All of these were measured to be statistically reliable. Over all these results demonstrate that museum based learning is a good tool for both motivation and achievement.

The results align with similar studies that show improved motivation and achievement in science through multiple modes of instruction, kinesthetic learning and place based learning. What this study and others like it mentioned here imply is that students want to do more than sit in a traditional classroom and read or be lectured to. Students want to move, think, problem solve, interact with the real world, and have first hand experiences. These opportunities enhance engagement, motivation, and learning. More specifically, Martin, et al. (2016) shows that museum based learning is a good tool for improving science education. When students can't get

out of the classroom, this study suggest that using multiple modes of learning, choices in how they learn, and purposeful themes can improve motivation in a conventional setting.

Effects of teaching materials based on 5E model removed pre-service teachers' misconceptions about acids-bases.

The BSCS 5E model is a constructivist model for learning proposed by Roger Bybee some 20 years ago. The 5E model has been widely used in science classes since that time and is comprised of a cycle that includes the phases; engage, explore, explain, elaborate, evaluate. In this study, Metin (2011) aims to determine the effectiveness of the 5E model at reducing science misconceptions and increasing student conceptual understanding. This study was done on a class of 25 university students, who were also pre-service science teachers. The class was a laboratory techniques class studying a unit on acids and bases. Students were given a pre-test and a post-test and were taught a lesson on acids and bases using the 5E model in between. The pre-test and post-test were used and analyzed comparatively to determine the effectiveness of the 5E model on removing misconceptions and improving conceptual understanding of acids and bases.

The results of the pre-test showed that less than 24% of students showed sound understanding of concepts of acids and bases, while the rest of the students showed partial understanding with major misconceptions or no understanding at all (Metin, 2011). The post-test results showed that 96% of teachers had a sound understanding of concepts of acids and bases. These results show that the 5E lesson plan on acids and bases had done a statistically significant job at remediating misconceptions and increasing conceptual understanding of acids and bases.

Metin (2011) indicates that the BSCS 5E model is an effective method for teaching science concepts. More specifically, the 5E model is an effective tool for addressing student

misconceptions, offering remediation, and increasing students' conceptual understanding. Further, this study demonstrated that the 5E model can be effective even in the course of a single lesson, as opposed to over the course of a whole unit, as previously suggested by its author Roger Bybee.

Development of arguementation skills through socio-scientific issues in a science course: a collaborative action research.

Science itself is about formulating ideas (hypotheses) and finding evidence to support that claim. This is the same structure as a good argument. On this basis, one could say that good argumentative skills are good scientific reasoning skills. Further, developing these skills is crucial to navigating society in adulthood. Skilled humans can form opinions based on logical and critical thinking and can clearly communicate these opinions or ideas. This is especially important in the complex, high tech, advanced society we live in today. The issues we face as a society are often socio-scientific in nature (that is both social and scientific), such as global warming & pollution, and are critical issues that require popular opinions and actions and are best solved with collective, critical thinking and scientific reasoning.

Ozturk & Doganay (2019) aim to discover how the use of socio-scientific issues (SSI) based instruction in the classroom helps to develop these crucial argumentative skills that are key to both science and life. This study aimed to answer the following questions: How can arguementation skills be developed through SSIs in a science course for 8th graders? What problems can be encountered during the implementation process? How can these problems be resolved? (Ozturk & Doganay, 2019) This study was done through a process of action research, implemented by a teacher with a class of 26 students over the course of 27 weeks. This class was

chosen because they were struggling to develop arguementation skills, this action plan was developed collaboratively to resolve this issue. Data was collected through student written work samples, observation, and teacher and student journals. Data was analyzed by qualitative content analysis. Good arguementation skills were measured as the ability to effectively communicate a claim, warrant, evidence, counter-claim, counter-warrant and rebuttal.

Pre-assessment data shows that most students started this research with only the ability to propose an initial claim. This study covered 22 different socio-scientific issues and aimed to develop arguementation skills in three parts; ability to generate claim + warrant + evidence, ability to generate counter claim + counter warrant, ability to generate rebuttal (Ozturk & Doganay, 2019). Video observation and student work samples demonstrated whether students met their goals weekly and at the end of each stage. Stage one took place over the course of eight weeks and covered eight SSIs (one per week). Data shows that in the beginning of this stage none of the students were able to produce claim, warrant and evidence. In fact, 22/26 students could only propose a claim. By the end of the 8-week stage, all 26 students could produce cohesive claim, warrant, and evidence. The data for stage two and stage three followed the same pattern. The concluding data analysis showing that all 26 students were able to create a full argument (claim, warrant, evidence, counter-claim, counter-warrant, rebuttal) by the end of the 22 weeks and three stages. Further, analysis revealed some major problems in argumentative development in students and implementation of SSI based instruction by teachers. These problems are as follows; student inability to understand the necessity to provide evidence of support, student misunderstanding of a rebuttal, student difficulty differentiating warrant and evidence, student use of objective opinions and beliefs, teacher biases on SSIs, teacher difficulty

asking the right questions for further development of argument and teacher lack of SSI research skills (Ozturk & Doganay, 2019)

Ozturk & Doganay (2019) demonstrate an extremely strong relationship between socio-scientific issues based instruction and the development of complete argumentative skills by students. Further, it shows that socio-scientific issues may be a topic of motivation for students to do more research and understand more about certain content. It also shows that SSI can be used to rehabilitate students who are behind in development of scientific reasoning, communication, and arguementation. Ozturk & Doganay (2019) also suggests that one of the main problems is that students don't understand the components of a good argument, and need real life examples to demonstrate and develop these understandings. Lastly, this study implies that action research is a great tool for teachers to reflect and overcome their own problems in teaching arguementation and/or socio-scientific issues.

Using kinesthetic activities to teach Ptolemaic and Copernican retrograde motion.

Education is looking for new ways to reinvigorate the classroom. As times have changed, student motivation and interests have shifted as well. The push to increase motivation has been particularly strained in science classrooms as inventive educators theorize how we can create more scientifically literate, intrinsically motivated students. Much of the current research on motivation implies that both real world connection and hands on learning are two major motivating factors in the science classroom. This is reflected in much of the recent published research on forms of learning that drive motivation, such as, design based learning, socio-scientific issues based learning, project based learning, etc. These theories use common terms like inquiry learning, real world phenomenon, and kinesthetic learning. Kinesthetic learning is a

term that describes a form of learning that is hands on and requires whole body involvement. Research on the effects of kinesthetic learning is hard to come by. Even harder to come by is statistically significant data on the topic, especially for learners at the secondary education stage.

Ted Richards, a university science teacher, occasionally used kinesthetic learning activities in class to teach concepts. Retrospectively, he wanted to determine the effects of this type of learning. Richards (2012) outlines a retrospective comparative case study of his use of kinesthetic learning activities. Specifically he had a class that he taught the concepts of planetary motion through kinesthetic learning activities in which students were up and moving, demonstrating planetary motion by "being" the planets. In subsequent years he did not teach planetary motion this way. The following years consisted of lectures and class discussion only. By doing a retroactive study, Richards (2012) was able to compare test scores from students who were taught using kinesthetic learning activities to students who were taught with out kinesthetic learning activities. Students who did not experience the kinesthetic learning activities were the control group and students who experienced the kinesthetic learning activities were the test group. Six questions pertaining to planetary motion from the students' final examination were used for statistical analysis. A 2-tailed p-test was done as a comparison between class scores.

Results of the 2-tailed p-test determined that the test group performed better than the control group on each of the six relevant questions. These results showed a statistical confidence interval of 95% (Richards, 2012). This is largely statistically significant and shows significant correlation between the use of kinesthetic learning activities and increased test scores.

Richards (2012) concludes kinesthetic learning activities can be an effective method of teaching. The discussion followed offered the consideration that breaking classroom routine aids in creating novel memories & that body movement increases conceptual understanding. These

ideas are not novel; they follow the same concepts as designed based learning and inquiry based learning, along with other similar learning theories. All of these theories imply that students are more motivated to learn and actually learn better when they have more active involvement than listening to lectures. This study is significant however, because it indicates that even older and more mature learners still need movement and real world connection to find further engagement in learning.

Socio-scientific issues-based instruction: an investigation of agriscience students' content knowledge based on student variables.

In the modern world, we face many dilemmas as a society and global community. These issues are often in regard to the science and technology that governs our world and are, most of the time, social in nature, meaning they involve or affect everyone and require a collective solution. It is the job of the education system to prepare students to deal with, live with, understand, and help solve these socio-scientific issues. More specifically, since it is concerning science, it is the job of science to prepare students with the skills necessary to properly assess and manage such socio-scientific issues. Because of this modern day necessity, education theory has proposed the use of socio-scientific issues based instruction as a way to introduce students to real world phenomenon and issues, teach them the necessary discourse and skills to handle these issues, and allow them to develop a logical understanding and rational opinion on such matters. In this study by Shoulders (2013), the effectiveness of socio-scientific issues-based instruction is measured.

While many studies have reported improved scientific literacy and motivation from the use of socio-scientific issues based instruction, this study aims to determine its effectiveness at

improving content knowledge. This study used a 6-week unit on agricultural science for students to test the socio-scientific issues based instruction. The study used a pre-test and post-test to collect data on student content knowledge. Results from pre-test to post-test did show significant increase in students' content knowledge (Shoulders, 2013).

This study implicates the usefulness of socio-scientific issues in implementing effective lesson plans and increasing students' content knowledge through such (Shoulders, 2013). However, due to inherent flaws in the design of the study it is hard to make informative generalizations from this data. The increase in student content knowledge could have been from general learning and different teaching methods may have been equally as effective. This study does definitively show that socio-scientific issues based instruction is not ineffective.

The nature of discourse throughout 5E lessons in a large enrolment college biology course.

The BSCS 5E instructional model is a science-teaching model produced by Roger Bybee that suggests educators should teach through the cycle of engage, explore, explain, elaborate, and evaluate. In traditional science classes and laboratories this model is easy to implement and follow. However, in university, its common to find large-scale introductory science lectures, that according to their usual format would find it hard to incorporate the 5E model. These traditional university lectures usually consist of one teacher lecturing a narrative to sometimes hundreds of students with out much engagement or interaction. In this research by Sickel (2013), he studies the nature of a large enrolment introductory university biology course, which usually functions with the traditional discourse of lecture and listen. However, for this study 5E instructional model was used to design and implement four lessons in this course. These lessons following the 5E model included opportunities for teacher-student and student-student interaction.

Data was collected from this study by means of video and audio recordings of both whole-class and small-group discussions. Sickel (2013) analyzed this data to answer this guiding question; what is the nature of discourse through out 5E lessons in a large enrollment college biology course? The nature of discourse could be one of four ways; interactive/dialogic, interactive/authoritative, non-interactive/dialogic, non-interactive/authoritative. Data analysis was qualitative in nature and shows that the nature of discourse shifted from interactive/dialogic to non-interactive/authoritative. More specifically, it was found that the engage and explore phases were mainly dialogic, the explain and elaborate phases were a combination of dialogic and authoritative, and the evaluation phase was found to be authoritative.

Sickel (2013) demonstrates the diversification of lesson styles through the introduction of the 5E model. Prior to the 5E model these large lectures consisted of only authoritative/non-interactive communication. After the introduction of the 5E model the communication and interaction became diversified and followed a flow from open, to guided, to structured. This flow pairs well with the 5E model flow and it useful in creating a more dynamic classroom even in large lecture settings.

The science of storytelling: middle schoolers engaging with socio-scientific issues through multimodal science.

Socio-scientific issues (SSI) are issues that global citizens face daily. They are impactful and we as humans and citizens must collectively make decisions on them. Examples include global warming, genetic modification, nuclear power, global pandemics, vaccinations, and more. As individuals in a society, we need scientific literacy and critical thinking skills to solve these issues. Recent education literature has suggested that introducing socio-scientific issues into the

secondary science classroom not only directly develops such skills, it prepares students for the real world and increases motivation to learn through real life relevancy. Much of the emerging research supports the use of socio-scientific issues based-instruction in the classroom but does not explore how such topics should be introduced. Even more specifically of concern is how young these topics should be introduced. Can a 12 year old grasp global issues? Will they find these issues relevant and motivating? How can we bring these adult issues to young learners in a way that is engaging?

Smith & Shiyan (2019) aims to answer these questions by exploring the use of science fictional story telling to introduce socio-scientific issues into the middle school science classroom. To do so, this study developed a curriculum called "Project IF" (Smith & Shiyan, 2019) as an afterschool program for students, grades 5-8 that focused on socio-scientific issues. This after school program culminated in a final project in which students demonstrated their knowledge through the creation of a multimodal science fiction narrative that addresses real socio-scientific issues. Leading up the final project, this curriculum scaffolds instruction into five parts (closely following the 5E model). First, students' experienced disciplinary sessions to learn about various socio-scientific issues through web based lessons, hands on activities, and field trips. Second, students were asked to read and analyze science fiction texts and works. Third, students experienced session in which students learned directly from contact with various field experts who were able to share the real world experience. Fourth, students experienced sessions on skill building and how to use relevant technology for producing science fiction content. This is the introduction to the production of a final product in a multi modal format, offering student choice and autonomy. Lastly, students were asked to produce their final product, creating their

own science fiction narrative. Students worked collaboratively as scientist, writers, and designers.

Smith & Shiyan (2019) demonstrate a great way to introduce very serious complex problems to younger learners with out corrupting their youthful minds and playing into their strong imaginations. Through this curriculum it appears that students were able to develop in-depth understandings of various socio-scientific issues but were offered the opportunity to connect these to their young lives and personal interest through the narrative of fictional creativity. Although student created solutions to real issues were often fictional and unrealistic, this curriculum provided students the opportunity to explore real world important issues while also using their imaginations to create solutions that feel relatable to their lives as they are now.

Smith & Shiyan (2019) conclude that the use of narrative and multimodal formats functions well to introduce socio-scientific issues to younger learners and that it can be powerful for developing problem solving skills, collaboration, self identity and expression. This curriculum offered students the opportunity to express themselves creatively while integrating a working knowledge of socio-scientific issues and major science concepts into their prior knowledge. This was a helpful framework missing from current literature on SSI based instruction. Further, this helps bridge the gap between young, naive, playful children and responsible, knowledgeable, functioning adults by introducing socio-scientific issues in a relatable way at the middle school age.

Effects of teaching with 5E model on students' behaviors and their conceptual changes about the subject of heat and temperature.

The BSCS 5E instructional model is a science-teaching model created by Roger Bybee and popularized by educators in the last couple of decades. This model asks instructors to follow the 5E cycle of engage, explore, explain, elaborate, evaluate in order to deepen conceptual learning of science students. In this study by Turgut and Gurbuz (2011), the effectiveness of the 5E model on conceptual understanding and attitudes towards science were tested. 37 students were a part of this study; all students had the same science teacher but were divided between two different science classes. One class was randomly selected to be the control group and was taught using traditional question and answer methods. The other class was randomly selected to be the experimental group and was taught using the 5E model. Students were taught a unit on heat and temperature; misconceptions were addressed to determine if conceptual change was occurring.

Data was collected in two ways. Conceptual change was determined through a heat and temperature misconception test. Attitudes towards science and technology were assessed through an attitude scale for science and technology. Lastly, mean scores and t-tests were done as a part of data analysis to determine the statistical significance of the experimental variables (Turgut & Gurbuz, 2011). The results of the heat and temperature misconception test determined that the mean score of the experimental group was higher than that of the control group with statistical significance. This indicates that the 5E model proves to be better for remediation of misconceptions and conceptual change. The results of the attitude scale for science and technology did not show a statistically significant difference between the experimental and control groups. This indicates that while the 5E model does help students with conceptual understanding it does not bring about better attitudes towards science.

Turgut & Gurbuz (2011) indicate that the 5E model is successful in increasing students conceptual understanding at a greater rate that traditional classroom narrative. However, this study also indicates that the 5E model does not bring about improved attitudes towards science, so other factors must be included in the lesson plan to increase student attitudes towards science learning.

Associations between attitudes towards science and children's evaluation of information about socio-scientific issues.

The issues we face as humans can be phenomena that affect our life in impactful and meaningful ways, for us as individuals, societies, and even globally, so it is the aim of science to prepare students for facing these issues. This study aims to determine the attitudes of learners towards science on how they evaluate information about socio-scientific issues. Socio-scientific issues can be defined as "personal or social issues upon which scientific understandings can be brought to bear to help people make decisions" (Xiao & Sandoval, 2017). In today's emerging-technological world, it is important we develop these "critical scientific understandings" as we are faced with these socio-scientific issues often and increasingly. Understanding the relationship between attitudes and evaluation of socio-scientific issues in children will help to build useful instruction in the science classroom that will prepare students to be informed citizens. The question presented in this study asks, "Do students with varying attitudes towards science evaluate information and make decisions differently?" (Xiao &Sandoval, 2017)

For this study, all of the 6th grade students from a western USA school, totaling 49 students, were surveyed. This survey included both an assessment of attitudes and an assessment of the evaluation of information. The first was assessed through a Likert-style self-assessment

([5] positive attitudes- [1] negative attitudes). The later was assessed by offering an example socio-scientific issue scenario and asking students to describe the most important information for making an informed decision and to describe your reasoning, The reasoning for each choice in pertinent information is categorized (scientific, economic, moral, social, or value) and an assessment of its correlation towards scores on the scale of assessment for attitude is made. (Xiao & Sandoval, 2017)

The results immediately show the correlation between low score on interest in more information and low scoring attitude toward science outside of school as well as future participation in science (Xiao & Sandoval, 2017). Students in total cited 189 statements as important evidence for decision making, with the most high ranking reasoning being scientific at a score of 59, followed by personal value at 50, moral at 37, social at 30, and economic reasons at a low 18. The findings support two major correlations; (1) students who chose science as their major reasoning, also demonstrated positive attitudes towards science and learning, where as students who chose economics as their major reasoning demonstrated more negative attitudes towards science and learning.

Xiao & Sandoval (2017) conclude that there is a positive correlation between positive student attitudes towards science and the tendency to reason scientifically. Xiao & Sandoval (2017) conclude, "If students do not feel that science is important or relevant to their concerns outside of school, they may be less likely to evaluate pertinent information about socio-scientific issues". It is important then, that we aid in students building of positive attitudes towards science so that when they age as members of society faced with real socio-scientific issues, they have a tendency to reason scientifically and utilize important information, rather than shy away from it.

Two fifth grade teachers use of real world situations in science and mathematics lessons.

According to the constructivist learning theory, students learning occurs when content is adjunct to what students already know and their new experiences add to their prior knowledge. In simple terms, new knowledge will stick better when it's connect to what students already know. This could mean their prior knowledge, but this could also mean real world connections. When content has real world connections it becomes more relatable to students and when students feel the content is relatable there is more motivation to learn. In this study, Yanik & Serin (2016) they investigate the types of real world situations used in classrooms and the cognitive levels achieved through this content. This is a comparative study to examine the difference between the use of real world content in mathematics classes and science classes.

Qualitative data was collected through teacher interviews and observations. The use of real world connections has the same purpose in math and science, to help students solve problems in the real world and to improve motivation and attitudes towards science, and creating meaningful learning experiences. There were four types of scientific ways to make real world connections; these are, personal, social, global, and historical (Yanik & Serin, 2016). There were four types of mathematical ways to make real world connections; these are, personal, public, occupational, or scientific. Results showed that in 100 lessons, science relied on real life situations or connections 77 times, while mathematics relied on real life situations or connections five-seven times. Further, 37 of the real life connections in science were personal, while most of the real world connections in mathematics were occupational. However, results showed that mathematic lessons with real world connections had high-level cognitive demands, like solving problems with real world connections. On the other hand, science classes only used this high level cognitive activity for 10 of the real world connection activities. Most of the real world

connections in science (64 of them) were low-level cognitive demands, like simple memorization.

Yanik & Serin (2016) conclude that science uses real world connections in lessons far more often than mathematics, which is likely the reason that kids are often more engaged in science class. Since most of the real world connections are personal or social is creates emotional ties to the content which increases engagement, connection and motivation. However, these real world connections in science are often only demanding low-level cognitive functions. So perhaps science educators can work on increasing the demands of the real world connected problems while still maintaining the personal connection and engagement of students.

Overview of SSI Engagement Lessons

Following are 24 activities, one for each of the 24 Next Generation Science Standards. Each activity introduces students to a socio-scientific issue and acts as an engaging activity to fit with in the 5E model for science learning. Any of these activities can be done at multiple points of the 5E model and can be incorporated into lessons surrounding the standard in many unique ways, but all are intended to be ENGAGING. All activities include a fully engaging, multimodal activity that must be followed up by a class discussion of the issue. These activities are intended to grasp the interest of the students and act as a gateway into the depth and content of the topic. These activities cover the Life Science standards, which include four broad topics broken into 24 standards. There is one SSI for each standard at the high school level totaling 24 activities. These activities are intended for use with 9th and 10th grade living environment students. All socio-scientific issues are applicable at the middle school level or at the 11th/ 12th/ AP levels, content and depth may need to be revised. If the activities presented are not suited for your classroom, you may use this as a reference book for socio-scientific issues related to the Next Generation Science Standards for Life Science. Given the changing nature of education merged with the growth of technology, each activity page is equipped with an online adaptation for remote learning.

It should be noted that all learning goals, such as "construct an explanation", found in the standards are not prompted through these activities. These activities serve as ENGAGING INTRODCUTIONS to the scientific concept. By using these activities as the engagement piece in the 5E model, the goal is to create interested and engaged students who will then follow the rest of the 5E model cycle with interest and focus. The subsequent 5E learning phases; explore,

explain and elaborate, should all lead up to the last phase, evaluation which then meets the action parts of the standard, such as “construct an explanation.” These activities are intended to produce complete engagement in preparation for the learning that will allow them to meet the standard fully by the end of the 5E cycle, and therefore the end of the lesson.

#1	
Topic:	From Molecules to Organisms: Structures and Processes
Course:	High School Life Sciences
NYS Standard:	HS-LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
Disciplinary Core Idea:	All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of the cells.
Socio-scientific issue:	Human Genetic Disorders.
Activity:	"Baked Goods"- - Discovering the essential function of DNA for protein production.
Summary:	Students will compare the results of various baked goods as they engage in a baking activity in which they learn the functions and relationship of DNA and protein in the human body. In this activity, the students will act as enzymes (workers) that are given DNA (baking instructions), which will call for proteins (ingredients), which then undergoes its function (baking), to result in character traits (cakes). Some students instructions will call for the right ingredients and methods of baking a cake, others will bake cupcakes or cookies. These will represent the different characteristics that DNA can create. Other students will have disrupted instructions calling for the wrong ingredients or an improper way of baking and resulting in a "mutation". At the end of activities students will have various baked goods. A small population of the class will have defective baked goods; that is, goods that are either misshaped in some way, lacking proper taste, or that did not bake at all. Students will then vote as a community on whether or not they should throw out the mis-baked cakes or eat them. Mis-baked cakes represent Human Genetic Disorders. How we care for and understand humans with them is a social issue we face today. Following the activity, the teacher will guide the students in a classroom discussion to draw comparisons between the function of DNA and baking a cake.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Prep/Materials: • Good Recipe's (varied: cookies, cakes, and cupcakes) • Mutated Recipe's (good recipes with ingredients or baking instructions altered) • Ingredients

	• Baking Utensils • Access to ovens. (Can be altered to use small convection ovens or easy- bake ovens.) 2) Labels should be placed on each piece of the activity as a reference for student understanding. Students=ENZYMES Recipe= DNA SEQUENCE Ingredients=PROTEINS Baking Instructions= FUNCTION/PROCESS Baked Goods= RESULTING TRAIT OR CHARACTERISTIC. 3) Students follow instructions and bake. 4) Students share their results with each other. 5) Students vote on which goods to eat. 6) Students pass out the "good" desserts. 7) The remaining baked goods (representing mutations) are brought to the front of the classroom. 8) Everyone votes on what to do with the "bad" baked goods. 9) Class Discussion PART 2: DISCUSSION QUESTIONS 1) Why did some of the baked goods turn out bad? What does this represent? 2) Should we study the bad cakes (genetic mutations) to figure out what went wrong? Why or why not 3) Can you think of some human characteristics that might be caused by a mutation from DNA? 4) What are some examples of human genetic disorders that are caused by mutations? 5) Why don't we "throw out" humans with genetic mutations? 6) How does this impact society?
Rationale: (Connection between SSI and standard)	Human babies are formed in the process of sexual reproduction. During this process, DNA is duplicated and then used as an instructional code in the human body for the production of proteins that provide both the structure of the human body and carry out most of the function of its cells. When the DNA code gets altered or mutated, protein production can be disrupted and it can result in improper structure or function in the body. Some mutations have positive effects and lead to evolutionary traits, some are neutral, and other mutations in DNA are classified as Human Genetic Disorders. Human genetic disorders are a scientific issue by nature. Some of the disorders include cystic fibrosis, down syndrome, and hemophiliac disease. In fact, there are roughly 6,000 different human genetic disorders that are known to exist today. These disorders require research, clinical funding, medical treatment and societal consideration, especially when it comes to education. Further, there has been social

	debate over the source of these genetic disorders, which has an even further effect on how we choose to treat or eliminate them. Some people believe that all genetic disorders are random in nature, while others believe they are the result of unnatural substances mixing with the human body, for example, toxic fumes, radiation, vaccines, and modified foods. The first genetic disease was discovered in a human in 1983, which was not so long ago. This fact lends way to the notion that there is something in our modern society, which is causing harmful mutations to the human genome. It is important for our students to understand this socio-scientific issue in order for them to make informed decisions about which foods to eat, what vaccinations to use, were to live, and what jobs to take on. Further, scientifically literate population can keep up with leading research to make informed decisions on current policies.
Relevance to Leading Education Research:	This activity utilizes the practice of tinkering. Tinkering can be described as the act of hands on action utilizing multiple tools in order to create a product. Tinkering allows students to explore and analyze the steps of production. In a study by Bevin, Gutwill, Petrich, and Wilkinson (2015), it was shown that hands on exploration is engaging for learners and drives initiative and intentionality. Further, it was shown that understanding of a subject develops as learners move through the steps of making or tinkering.
Possible Misconceptions:	• Students should understand that mutations could also lead to advantageous traits. Those traits are passed on (like a recipe is reused) to ensure the best results every time.
Recommendations:	• Following this activity, students should have conceptual understanding of how DNA codes for proteins, which carry out a specific function to result in a characteristic or trait. Next, teachers should guide students' exploration of what this looks like in the human body and offer examples of real life characteristics called for by DNA. Further, teachers should address the societal impact of favored genes versus genetic disorders.
Adaptations for online learning:	This activity can be done through online learning. Students will be instructed to bake at home; results can be shared and discussed via online video platform. An online alternative is to have students participate in the website myscilife.org, where students can participate in a blog style role play in which they converse with the various components of the cell that play a role in protein production.

#2 **Topic:**	From Molecules to Organisms: Structures and Processes
Course:	High School Life Science
NYS Standard:	HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions with in multicellular organisms.
Disciplinary Core Idea:	Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.
Socio-scientific issue:	Cancer.
Activity:	"Instructions to grow" - - Create a tower of hierarchical organization.
Summary:	Students will create a model that demonstrates the hierarchical organization of systems with in an organism as well as the effects on the system when there is a failure at one level. In this activity, students will compare the organizational structure of a tower to that of multicellular organism. With blocks representing cells, students will see a representation of cancer, when a cell does not stop dividing. Through the interpretation of hierarchical structure and cancerous cells students will analyze the importance of proper structure and how a problem at one level of the hierarchy (or tower) can cause death (falling over) of the organism. Groups of students will be given a set of blocks and building instructions. Each set of instructions will guide the students towards building a tower. Some students will have instructions that code for a perfect tower, other students will have instructions that will ask them to continuously add blocks (cells) until the tower becomes very unstable or inevitably falls over. Instructions for students with a perfect tower will have a final direction to STOP. Instructions for students with a cancerous tower will not have a STOP instruction. Following the activity, the teacher will guide the students in a classroom discussion to analyze the towers and draw conclusions about the similarities between building a tower and building a multicellular organism.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Prep/Materials: • Sets of blocks (Jenga blocks work well) (Blocks should be labeled as "cells") • Various sets of instructions for building towers [Set A: builds a strong complete tower Set B: builds a tower with a weak bottom Set C: builds a tower with a weak middle Set D: builds never ending tower that eventually falls] 2) Students will follow their unique set of instructions to build towers

	using blocks until instructions tell them to STOP or the tower falls over. [A strong tower=healthy organism Weak tower= organism with ailment Never ending tower= organism with cancer Fallen tower=death] 3) Students will work together in a class discussion to draw conclusions about the organization of multicellular organisms and the consequences of failure at any level of the organization, namely cancer, illness, or death. PART 2: DISCUSSION QUESTIONS 1) What are the consequences of having weak spots in the tower? 2) How do weaknesses appear in the human body? 3) What happened to the towers that died? 4) Why did some towers never stop growing? 5) Were the errors that caused "death" in the structure of blocks them selves or at a different level? Where? 6) Which layers of the tower are crucial for survival of the organism? 7) Which towers represent cancerous cells? 8) How does this activity demonstrate the hierarchical nature of human systems? 9) In what ways is cancer a socio-scientific issue?
Rationale: (Connection between SSI and standard)	Within the structural organization of the body there are multiple systems that function in a hierarchical order. In fact, the human body is one big hierarchy of organization. DNA produces proteins, those proteins produce cells, those cells produce energy and other molecules, which bind to form the organs of the body, and those organs work together to create one complex functioning human. The hierarchical structure has allowed tiny individual bacterial cells to work together to form the grand, intellectual, complex creatures we are today. It is a miracle of nature but also has its down falls. When one of the levels of the hierarchy fails its function, the whole system can fail. One example of this is cancer. Cancer is a disease that is characterized by uncontrollable reproduction of cells that result in one or many tumors. However, cancer does not start or end at the cellular level, it is hierarchical in nature. Cancer starts when there is an issue at the genetic level. When the DNA that codes for cellular reproduction, more specifically for the end of cellular reproduction, has a malfunction, the message never gets related to the proteins of the cell to stop reproduction. The result is that DNA is copied over and over and cells are produced rapidly and unnecessarily in succession. The bulk of over grown cells is called a tumor and is the key characteristic of cancer. Tumors can happen in any part of the body and often have severe effects of that level of function. Tumors can disrupt blood and nutrient flow, deplete energy, add pressure to nerves and organs, and completely obstruct organ function. The end result of cancer,

	with out treatment, is unfortunately, total shut down of the whole bodily system. This disease is scientific in nature but requires problem solving as a society. Like the issue of human genetic disorders, many believe cancer is a natural unavoidable illness, others believe that it is caused by things humans interact with in society. Today, cancer is the leading cause of death in the world, accounting for an estimated 9.6 million deaths in 2018 according to the world health organization. Given that fact, it is our job as a society to fund the research or be a part of the research that will uncover not only how cancer is caused but also the best treatments. It is imperative that we create students and citizens that can make informed decisions about how they interact with the world around them, their health, their families' health, and public funding for scientific and medical research. Students, who understand the hierarchical design of their body systems, should be able to make conscious holistic decisions to maintain health.
Relevance to Leading Education Research:	This activity utilizes multimodal learning. While students will be reading instructions, they will also be manipulating materials tactilely and observing visually the creation of the tower. Kinesthetic activities are those in which the students are manipulating materials. In a classroom study by science teacher T. Richards (2012), it was demonstrated that in a comparison between traditional lecture format and kinesthetic learning format, students learned content better with the kinesthetic learning format. It was concluded from data that breaking classroom routine aids in creating novel memories and that body movement increases conceptual understanding.
Possible Misconceptions:	• Cancer is not the only systemic failure that can lead to death. Students should be informed of other issues in organism function caused by failure at different levels of hierarchical structure. Smaller dis-functions occur are various levels of the human system that can lead to long-term decline in health and possibly death.
Recommendations:	• Following this activity, the concept of hierarchical organization should be explained to students using the towers as a representation. Real life models of hierarchical organization in the human body should be explored further.
Adaptation for remote learning:	Students can be given instructions and materials to build towers at home. Students will each build two towers, one sound structure and one "cancerous" structure. Students will make and share comparisons virtually.

#3 **Topic:**	From Molecules to Organisms: Structures and Processes
Course:	High School Life Science
NYS Standard:	HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
Disciplinary Core Ideas:	Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.
Socio-scientific issue:	Human data collection.
Activity:	"Mechanisms of music" - - Examining the Mechanisms of Feedback Loops
Summary:	Students will examine the information feedback mechanism that exists within a modern music-playing app in order to draw comparisons to the feedback mechanisms that exist with in the human body. Modern music radio playing apps (apple music, Pandora, Spotify, Tidal, etc.) function by receiving feedback from the user. Users music choices dictate new music that is presented to the user. Music platforms offer a "thumbs up" button and a "thumbs down" button to indicate positive or negative feedback about a song. The teacher will start the day by playing a suggested track radio. Students will vote thumbs up or thumbs down for each song, with the majority dictating the outcome for each vote. The class will tally how many songs it takes for the information feedback to train the music to play 7 "liked" songs in a row (=homeostasis). Following the activity, the teacher will guide the students in a classroom discussion to analyze the difference between positive and negative feedback and how both play in important roll in dictating system function.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Computer or phone/ internet • Music playing app (apple music, tidal, spotify, Pandora, etc.) • Paper, poster, or board for keeping tally 2) Have students submit music station suggestions and vote on the most popular 3) Designate each side of the room thumbs up or thumbs down (a sign is helpful) 4) Play the music station: when a song is on, students vote by running to the thumbs up or thumbs down side of the room 5) Teacher or designated student keeps tally of votes and changes

	the song until 7 songs in a row get a thumbs up. 6) Students participate in class discussion about activity PART 2: DISCUSSION QUESTIONS 1) What part of this music app acts as a "feedback mechanism"? 2) How does the feedback mechanism inform the app? 3) Can you infer from this app the difference between negative feedback and positive feedback? 4) What are some mechanisms within the human body that use data from feedback loops? 5) As technology becomes more integrated into our lives what are some positive and negative ways that personal data can be used to inform a system? 6) What are some other current technologies or companies that user feedback to dictate content for that user? 7) How do feedback loops help us to survive? 8) How have the mechanisms of feedback loops been exploited to become a social issue?
Rationale: (Connection between SSI and standard)	Feedback mechanisms relay important information to living systems in order for that system to create a cascade of responses that allow that system to continue living, a mechanism called homeostasis. A simple example of a negative feedback loops is thermoregulation. When the body detects cold temperatures, it begins to shiver, using the muscle movement to create heat in the body and regulate temperature. Similarly, when the body detects warm temperatures, the body begins to sweat to release some of the heat and maintain normal body temperature. On the other hand, an example of a positive feedback loop in the human body is lactation. When a woman is pregnant she produces milk in her breasts, when the milk is used via breastfeeding, it stimulates the production of more milk. It is not until breastfeeding stops that the feedback loop informs the body to stop producing milk. Further, doctors use feedback to diagnose illness, your body uses feedback to tell you when to eat, trees use feedback from light to grow, and animals use feedback from the environment to know when to hibernate and when to hunt. All of these mechanisms help to maintain homeostasis in the human body. The human body itself and other living organisms in nature are comprised of a myriad of perfected feedback loops to help sustain life. In the society we have created, comprised of social interactions, capitalism, politics, economics, and technology, there are also many feedback loops at work. One could consider that society, as a whole is a living organism. With in society there are entities like the government, the economy, or the internet that although are not living the same way that a human is, could be considered living entities. They all thrive on the symbiotic movement of small bodies, which provide feedback to the system to adjust and maintain itself. For the government this means

	protests, lobbying, and amendments to laws. For the economy this means inflation, regulation, and printing of money. For the internet this means technology updates, system interface design, and data analysis. When the internet was first invented in the 1960s it was just a tool to provide information and ease of access to the public. However, as it has developed over the last 60 years, it has grown into an entity of its own. It's comprised of other entities, such as Google, Facebook, Netflix and Twitter, and function on a hierarchical structure just like most other living entities. The code that allows the internet to run is similar to the DNA of humans. Like humans, the entity of the internet wants to live. Facebook, Netflix, Twitter, Instagram and all other platforms are businesses that support living beings and therefore need to survive. In the need to survive, feedback loops have been enforced with in these entities. These systems collect your data, track your searches, monitor the things you like and don't like. They use this data as a feedback loop. The more information they gather on you as a user, the more they tailor your experience to your liking, whether that is by design or content. Today, many people feel they are being psychological manipulated by the businesses and corporations trying to keep their entities alive. In order for their entities to be sustained they need the energy and attention of the people, the users. The popup adds and over run commercials are the tumors of society caused by human data collection. Some of these applications are actually considered addicting because of the high levels of tailoring from the information provided from the feedback loop of human data collection. This is a highly controversial issue at the moment. While human data collection can be useful, it can also be an invasion of privacy and psychological manipulation if utilized improperly. Students should understand how both positive and negative feedback mechanisms inform a system, in order to sustain its vital processes and maintain homeostasis to continue living. Most systems that exist utilize data to create efficient feedback loops. Scientifically literate citizens understand the process of data collection and feedback loops both internally and externally. Citizens should understand how their data can be exploited by corporations and technology using similar feedback loop mechanisms in order to make informed consumer decisions.
Relevance to Leading Education Research:	This activity utilizes the whole classes input. This is not a lecture on the nature of feedback loops; rather this is a whole class interactive exploration. In an observational study of science classrooms, Sickel (2013) documents the non-interactive/authoritative nature of science lectures. Further, Sickel demonstrates the increase in engagement and conceptual mastery from classrooms that engage in interactive/dialogic activities, such as this one, instead.
Possible	• Students should understand the connection between stabilizing

Misconceptions:	the radio station and stabilization in the body as the mechanism we call homeostasis. This connection could be lost in the depth of the topic; the term homeostasis should be repeatedly used. • Students might not understand how their personal data is collected or used by other apps, if so; the teacher should use this opportunity to explain the socio-scientific issue of data collection. Use examples and ask for student's opinion.
Recommendations:	• The initial music station should be chosen by the students by vote in order to ensure the majority votes together. • If the class is divided or hostile, the teacher can pick the station, in which case it should be a completely neutral, non-popular station. • Recommend the teacher tries this experiment at home and see how long it takes them to get to 7 straight likes from a new artist radio station.
Adaptation for remote learning:	Students can be instructed to carry out this activity at home. Music playing apps are free and accessible through phone, computer, or tablet.

#4	
Topic:	From Molecules to Organisms: Structures and Processes
Course:	High School Life Science
NYS Standard:	HS-LS1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.
Disciplinary Core Idea:	In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organisms to grow. The organism begins as a single cell that divides successively to produce many cells, with each parent cell passing identical genetic material to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.
Socio-scientific issue:	Stem cell research/therapy.
Activity:	"Stem cell role play" - - Judge the role of stem cell therapy.
Summary:	In this activity, students will each be assigned a character with a back-story and a need for stem cell therapy. Students will present their character to the class and the class will make a judgment about the appropriateness of the use off stem cell therapy for each character. Judgment votes will be tallied in order to determine the overall ethical stance of the class on the use of stem cells. Before students begin the activity they will need background information on cellular division and differentiation, as well as stem cells. The teacher can choose to present this information verbally, visually (in the form of a diagram), or in a reading (an article or passage). Following the activity, the teacher will guide a class discussion on process of cellular division and differentiation. The benefits and ethical dilemmas of using undifferentiated stem cells from human embryos will be weighed.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Role playing cards (each card should have a different story, each persons story should present a desire or need for stem cell therapy) [EXAMPLES: a) Person A was in a car crash and his lung was pierced. He needs to replace the damaged lung tissue immediately or he will die. b) Person B is experiencing macular degeneration and is losing eyesight, they want to replace the damaged eye cells to restore their vision. c) Person C was burned from a chemical spill. They want to use stem cell therapy to replace the damaged tissue so their skin can go back to normal d) Person D has been a life long alcoholic, their

	kidneys are failing and they need replacements immediately e) Person E is 90 years old, their heart tissue is not strong enough to maintain a consistent heart beat any more, they need a heart transplant to stay alive f) Person F is a new born baby with a heart murmur, they need a heart transplant to stay alive g) Person G is approaching 70 and feels their organs are not working as efficiently as they used to, they have the money and would like to replace their organs one at a time] 2) Students are introduced to cellular division, differentiation and stem cell research. (Ex. Students read a short passage) 3) Students are given role cards. 4) Role cards are read, one at a time, to the class, who acts as a panel of judges. 5) For each character presentation, the panel votes on whether or not stem cell therapy should be used on this patient. 6) Votes are tallied through out the class. 7) Students participate in a class discussion about the ethical use of stem cell research PART 2: DISCUSSION QUESTIONS 1) Why are stem cells applicable to such a wide range of treatments? (Answer should include potential for differentiation) 2) Did the class vote more approval or disapproval for stem cell therapy? Why or why not? 3) What are the benefits of using stem cell therapy? 4) What are the ethical dilemmas that would keep us from using stem cell therapy? 5) If stem cell therapy applicable on a case-to-case basis who should be responsible for making these decisions? 6) Why is stem cell therapy a socio-scientific issue?
Rationale: (Connection between SSI and standard)	The product of reproduction is a single daughter cell containing the genetic information of both of the parent calls, a process called meiosis. From this single cell, an entire complex multicellular organism will form. This first cell is unspecialized. It undergoes the process of cellular division known as mitosis to create more cells, repeatedly creating daughter cells whose genetic material are identical to the parent cell. As more cells are created, the cells differentiate to have functions, making up the different systems of the human body. Once a cell is specialized it creates more cells with the same function as it undergoes mitosis. These specialized cells work together to meet the needs of the whole organism and maintain homeostasis. Stem cells are the undifferentiated cells that exist in the early stages of development of an organism. These cells are undifferentiated and unspecified for a certain role in the body yet. Because of this, stem cells have the potential to develop into any type of specialized cell in

	the body. Scientist first discovered how to derive embryonic stem cells in 1981. This potential of stem cells is valuable for research, science, and medical purposes because they can use these cells to replace any damaged cells in the body. Because stem cells have the potential to become any type of cell, any organ or body part can theoretically be grown via stem cells. For humans with sever illness or bodily impairment, stem cells have the potential to produce limbs or organs to replace those that are damaged. This could relieve the necessity for organ donors. The use of stem cells has even been considered to combat aging, replacing old and damaged cells, organs, or body parts with newly differentiated cells. The issue with using stem cells is that in order to obtain the stem cells, an embryo must be destroyed. Some see the embryo as early life and believe that destroying it is taking a life. Others believe the embryo is not a full life yet and that its use could benefit other already living organisms. This issue is scientific in nature and requires that members of an informed society are able to make a decision on the ethics of the use of stem cells. Today, stem cell use is limited in the medical field. One of the most common uses of stem cells is for tissue transplant after chemotherapy and radiation cancer treatment. Stem cells that are used in human medical treatment come from early embryonic stem cells of unused embryos with donor consent, or adult stem cells found in umbilical cord blood or bone marrow. Most of the controversy surrounding stem cell research concerns the ethics of using human fetuses and thereby destroying their potential for life. It is important that students understand how stem cells function to be able to comprehend the many ways that stem cell research may impact our medical capabilities in the coming years. Scientifically literate citizens should be able to make informed decision about the ethics and practice of stem cell research that either limit or allow the use of stem cell practices.
Relevance to Leading Education Research:	While many science classrooms diversify lessons through hands on activity, this lesson is a "minds on" activity. In this activity, role-play is utilized to increase student's conceptual understanding and to tie concepts to the real world. In an article by Ehrlick and Cronin-Jones (2013), it is highlighted, that role-playing in the form of debate or vote has many positive effects on student learning. Through this type of role-playing, students can develop science literacy, argumentative skills, and cooperative skills. Further, activities of this nature allow students to explore theoretical, social, and conceptual aspects of science. These activities are engaging because of their connection to their controversial nature but also motivating because of their connection to the real world.
Possible	• Students should understand that most research is done

Misconceptions:	on the embryonic cells of animals. However, treatments for humans require human stem cells. Some of these come from adult bone marrow or umbilical cords. Other stem cells do come from embryos from fertility clinics that have been voluntarily donated.
Recommendations:	• Role playing cards should be diverse and controversial. • Students should understand where stem cells for human therapies come from in order to make informed decisions when voting. • The need for strong moral ethics in the science field should be highlighted. This is part of the need for democracy, so power can remain checked by the majority of society. • The lesson that follows this activity should explore the process of division and differentiation in the body.
Adaptation for remote learning:	Role cards, voting, can be done as a class in a virtual meeting space such as zoom, or on a virtual discussion forum.

#5 **Topic:**	From Molecules to Organisms: Structures and Processes
Course:	High School Life Science
NYS Standard:	HS-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
Disciplinary Core Idea:	The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
Socio-scientific issue:	Deforestation.
Activity:	"Graph the Green" - - Analyzing the rates of deforestation.
Summary:	Students will create a graph that demonstrates the rate of deforestation as well as the rate of human population growth. Students will use these graphs to analyze the point at which the population of trees can no longer support all of human life. During their analysis students will have to collaborate to find an equation that determines how many humans a given tree population can support. After this activity, students will participate in a class discussion to analyze the data and uncover why the tree population is so important for human life.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Data on annual deforestation • Data on annual human population growth • Poster paper, markers, rulers • Calculators 2) Students will divide into 2 groups. 3) The first group will use the data on deforestation to create a graph of the rate of deforestation while the second group will use the data on deforestation to create a graph of the rate of human population growth. 4) Both sets of students will then extend the graphs to predict the trends in deforestation and human population grown in the next 100 years. 5) Graphs will be placed at the front of the room 6) Students will participate in a class discussion to analyze the data and find the year in which there are no longer enough trees to sustain the human population and to find an explanation. PART 2: DISCUSSION QUESTIONS 1) What is the world population of trees today? / What is the world population of humans today? (400 billion trees and 7.6 billion humans) 2) Do humans needs trees to live? Why? (Answer should involve oxygen) 3) If each human consumes about 8 trees worth of oxygen annually,

	how many humans can our forests support right now? (50 billion) 4) Create a formula to analyze how many humans a tree population can support. (# of living trees/ 8 trees= # of people that can be supported) 5) Analyze and compare the data from the two graphs. Using the equation just formulated, in what projected year are there not enough trees to support human life? 6) How far away is this from now? 7) What are the consequences of reaching this point? 8) How can we prevent us from reaching this point? 9) What are some other ways that plant life is essential for maintaining life on the planet? 10) Why is deforestation a socio-scientific issue? 11) What are some solutions or alternatives to the practice of deforestation?
Rationale: (Connection between SSI and standard)	Photosynthesis is a beautiful process that plant life endures in their symbiotic relationship with animals. Photosynthesis takes the waste product of animals (CO_2) and water and uses light to produce energy for the plant life in the form of sugar plus oxygen, which it then releases for humans to use. Humans use the oxygen in the atmosphere for respiration, which is necessary to maintain life. The balance of life hinges on these processes. For most of the development of humanity, nature and trees have outpopulated humans. In the 1960's Brazil became the first country to commit the act of deforestation in which they cut or burned down large sections of tree and forest for economic and societal development. From 2000 to 2010 cattle ranching and commercial mono-crop farming caused 75 % of forest loss. Since the 1990's we have lost a total of 80 million hectare of forest. Today, deforestation occurs for land usage for commercial agriculture, housing developments, and other human interests. As we begin to remove large sections of trees, we are also removing photo-synthesizers who process our carbon dioxide and provide us with oxygen. Further we are losing the first level of food for consumers. Without plant life there will be no food for animal life (some animals eat other animals but the first species in that food chain inevitably eats plants). Some believe the economic benefits outweigh the potential danger, others fear that with rising population and decreasing natural land, we may not be able to sustain life for much longer. Protecting the equilibrium of the ecosystem is a scientific issue by nature but it is up to society to make informed decision and vote on how to either use or protect the land that allows us to live. Students should understand the role that plant photosynthesis plays in the overall balance of life on the planet. As citizens, we should be conscious of the various

	activities that cause loss of plant mass on the planet and threaten the equilibrium of the planet.
Relevance to Leading Education Research:	Although much of this project suggests the use of novel experiences and multi-modal learning, research by Forsythe, Jackson, and Conteras (2018) suggest that there are key ways to utilize reading texts to promote student learning and engagement. In their published article, it is suggested that short reads, paired with hands on activities can provide both engagement as well as increased scientific literacy and reading skills. This activity teaches a crucial skill in scientific literacy, which is reading data and creating graphs. The content itself is controversial real world phenomenon, creating an added layer of engagement in the activity itself.
Possible Misconceptions:	• Students should understand that trees also absorb carbon emissions from human respiration as well as human activity. The carbon absorption of trees is in some way more important than their oxygen output because increased carbon emissions are causing global warming, which could cause human extinction faster than loss of oxygen.
Recommendations:	• Students may need help creating graphs depending on age and skill level. • Teachers should use this activity as an introduction into exploring the process of photosynthesis.
Adaptation for remote learning:	Students can be given data and instructions to create a graph on Microsoft excel or by hand. Students can share their graphs and interpretation direct to teachers or to a virtual discussion board.

#6	
Topic:	From Molecules to Organisms: Structures and Processes
Course:	High School Life Science
NYS Standard:	HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules
Disciplinary Core Idea:	As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
Socio-scientific issue:	Nutrient deficiencies in processed foods, food deserts/food oasis.
Activity:	"Living in the desert" - - Comparing the nutritional values of different molecules.
Summary:	Students will role-play living in food deserts with certain food choices vs. living in a food oasis. Students will attempt to grab as much food as possible with in their range of living. Each food will be assigned a point value. The more valuable the food is for your body, the more points they are worth. Value is determined by the type and amount of carbon based molecules and amino acids they can provide for the body. Students will try to categorize and understand why these foods are worth more or less to the body. After the activity, students will participate in a class discussion about nutritional value of various foods and the socio-scientific issue of the availability of these foods in food deserts vs. food oasis.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Various foods labeled with points by nutritional value (higher nutrition = higher point value) • List of nutritional molecules that make up each food. 2) Food will be placed around the room. Lower valued foods will be placed in one part of the room, higher valued points in the other. 3) Students will have 90 seconds to grab as much food as possible with in 10 steps of their seat. 4) Students will add up the value of their foods. Students with less than 10 points will be considered "sick" students with more than 10 points will be considered healthy. 5) As a class, students will evaluate the foods that caused "sick" students in comparison the to foods that caused "healthy students" PART 2: DISCUSSION QUESTIONS 1) What are the nutrients in the healthy foods? 2) What are the nutrients in the unhealthy foods? 3) What are the unhealthy foods made of? 4) What are the similarities and differences between healthy and

	unhealthy foods? 5) Why could only some of you reach the healthy foods? 6) Who in the real world has trouble accessing healthy foods? Why? 7) How can we help resolve this issue?
Rationale: (Connection between SSI and standard)	Carbon, hydrogen, and oxygen are the building blocks of organic life. All living matter is comprised mainly of these molecules, which bind to form larger compounds that make up the human body. In order to keep the body functioning, growing, and repairing, the body needs to take in a certain amount of these compounds in the form of food and water, which gets broken down to form energy and other compounds. The five main carbon based compounds that life relies on are carbohydrates, lipids, proteins, which are made of amino acids, and nucleic acids. Plants create their own matter and energy, aka food, through photosynthesis. Humans and other animals however need to obtain matter and energy by eating food. The highest source of this matter and energy comes from foods, which are either plants or other animals. The lowest source of this matter and energy comes from processed foods. A major issue in the world but specifically in the United States is that there are regions where people live that don't have access to foods that provide these nutrients. These regions do not have easy access to locally grown fresh foods or to grocery stores, in some cases there is no access at all. These regions are called food deserts. These food deserts are mostly found in extreme low populations of the rural or extreme dense populations of urban cities. The alternative for food in these areas is low quality ultra processed food at fast food restaurants, gas stations, and corner stores. The opposite of a food desert is a food oasis. Food oases use innovative and sustainable practices to ensure abundant access to healthy high-energy foods to its residence. This matter is deeply related to social constructs and economics of the area. Food deserts are a sign of poverty, while food oases are a sign of wealth, either financially or intellectually. The necessity for humans to obtain the matter and energy to live through food is biological in nature. However, when the access to healthy foods becomes a permanent social construct plaguing a large part of humanity, it becomes a social issue. Students should be able to consider the biological necessity for healthy foods and make decisions about the distribution of wealth and goods that could allow all humans access to health.
Relevance to Leading Education Research:	Role-playing incorporates multiple senses, is fun and active, and can be full of informative content that students can interact with directly. In an article by Guha (2013), it is demonstrated that not only are role-playing activities engaging ways to learn, but role-playing games are even more engaging. Role playing games are shown to free flowing and

	explorative. The nature of role-playing games is to create student involvement while also inevitably creating student inquiry by the end, with students asking questions about the content uncovered through the game.
Possible Misconceptions:	• The first question asks students to list different nutritional molecules found in healthy foods. These should include amino acids, vitamins, and healthy minerals. The teacher should help guide students to these answers and review their make up. • Students may confuse food deserts with the inability to afford healthy food. It should be explained that poverty often accompanies food deserts but that food deserts are about high density populated areas that lack availability of healthy food options.
Recommendations:	• During the discussion, it could be explained that the places where people cannot access healthy fresh foods are called food deserts (and places where they are abundant are called food oasis). • Teacher should help students understand how processed "unhealthy" foods are made from healthy fresh crops but molecules are recombined in different ways, creating less nutritional value.
Adaptation for remote learning:	Students may be asked to collect foods from around their house. Foods will be assessed by point value system and compared in the same way. Discussion can take place in a virtual meeting space.

#7	
Topic:	From Molecules to Organisms: Structures and Processes
Course:	High School Life Science
NYS Standard:	HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
Disciplinary Core Idea:	As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.
Socio-scientific issue:	Human unhealth and reliance on medicine.
Activity:	"Stay Healthy" - - Exploring the effects of food and exercise, PhET simulation.
Summary:	In this activity, students will run a PhET simulation on food and exercise. In it, they will explore the various ways that food are broken down and utilized in the muscles for energy or stored as fat. Students will feed their simulation and observe the impacts on the body. Students should explore what habits create an unhealthy person and then explore what habits can create health again. Students will participate in a class discussion to share their observation. Students should discuss what behaviors create health for them. Students should also discuss ways in which humans often neglect their health and self-care, as well as ways in which we have become depended on western medical solutions to provide health for us.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Computer/internet • https://phet.colorado.edu/en/simulation/legacy/eating-and-exercise • instructions for PhET simulation • Simulation log worksheet for recording findings 2) Students will long into the PhET simulation and explore the way feeding the simulation different foods affects its weight and health. 3) Students will then explore how different levels of exercise can affect weight and health. 4) Students will then research medical issues caused by unhealthy habits 5) Students will then use the Internet to research leading medical solutions to common health issues.

	PART 2: DISCUSSION QUESTIONS 1) In the simulation, which actions caused BMR to increase? Decrease? 2) In the simulation, which actions caused weight to increase? Decrease? 3) In the simulation, which actions caused lifestyle number to increase? Decrease? 4) In real life, what are the consequences of an unhealthy life style? 5) In real life, what are the effects of a healthy life style? 6) What are the common ways the medical industry treats patients with issues that result from an unhealthy lifestyle? 7) How can the medical industry and individuals better treat patients with issues that result form an unhealthy lifestyle?
Rationale: (Connection between SSI and standard)	The human body functions through an array of chemical reactions that occur through out the body. It is estimated that there are about 37 thousand billion billion chemical reactions occurring every second in the human body! These chemical processes absorb and convert oxygen, digest food, breakdown chemicals, rebuild new chemicals, supply muscles and organs with nutrients, allow complex cognition, build energy, protect the body from invaders, fight illness, replace dying cells, and release waste. The combination of these chemical reactions comprises your metabolism, which functions to keep you alive and moving optimally. Through exploration and experimentation, humans discovered they could utilize the resources around them to enhance their metabolic function. The earliest medicines recorded come from 2112 BC and were likely comprised of local plants and herbs that appeared to have positive effects on the body. For a long time, natural plant medicine served as a way to help the human race survive longer and outsmart some of the natural order. Advances in technology have brought an abundance of medical advances. Since then we have developed thousands of various drugs in the laboratory; some to aid with all types of ailments, some just to enhance human performance, and some for recreational use. As the desire for medical aid increased, pharmaceutical companies capitalized on the opportunity to build a business around supplying chemicals to advance human help. In quest for money, pharmaceutical companies began offering incentives to doctors to push prescriptions to patients. New medicines were approved for human consumption with only short periods of research, leaving long-term side effects to be determined. Opioids, for example, are a class of drug that naturally occurs in poppy plants. Opioids are known for their ability to relax the body and ease pain. Opioids are prescribed medically but are no longer sourced from the poppy plant. Today, opioids are manufactured in a lab. Approximately 191 million Americans are prescribed opioids. In the early 2000's people started abusing opioids, whose adverse effects caused addiction, sickening with drawls and decreased stability in mental health.

	Opioid addiction rapidly rose and approximately 450,000 have died from an overdose. The opioid epidemic affects millions of Americans, requiring swift action by medical practitioners, policy makers, law enforcement and members of society. Today, 66% of all Americans take prescription drugs. Most citizens who take drugs do not understand how these drugs are manufactured, the research supporting its use, or the way these chemicals alter the chemical reactions in the body. Many drugs have unforeseen long-term effects that can be highly damaging. Hundreds of thousands of lawsuits have been raised against pharmaceutical companies for the unknown side effects of drugs. Most of the desired effects of pharmaceutical drugs can be achieved through natural healing with plants and food. Students should be able to understand how food and drugs are broken down in the body through cellular respiration and other processes. As citizens, they should be able to consider the benefits and possible consequences of the use of various pharmaceuticals. Scientifically literate citizens understand the importance of research and have the ability to interpret the results of such studies. Citizens have the knowledge to make informed decisions on their own medical health and policies that govern medical treatment, research, and politics to ensure that medicine always puts human health over economic wealth. Further, students who gain knowledge of the complex chemical reactions that allow the body to function optimally may also be ale to supplement their health naturally.
Relevance to Leading Education Research:	This activity utilizes an online simulation. While the usefulness of simulations in engagement is not discussed in this article, it can be assumed that with children's aptitudes and attitudes towards the use of technology, online interactive will be an engaging platform for student learning. In this activity students explore the direct effects of diet and exercise on the human body. This utilizes the connection to students' real world understanding and builds on their own experience and knowledge. Every student has some relationship with their body and how they manage it so this activity is inherently relatable. It was demonstrated by Yanik & Serin (2016), that when content has real world connections it becomes more relatable to students and when students feel the content is relatable there is more motivation to learn.
Possible Misconceptions:	• This simulation only shows weight increase and lifestyle rating as a consequence of unhealthy life style. Students should be informed of the range of diseases that can arise from an unhealthy life style. • Students should be guided to discover the range of medicines that are offered as solutions to issues from an unhealthy life style. Students should understand that while this can be a useful tool, a change in lifestyle should be the first thing offered.

Recommendations:	• Instructions should guide students on how to use the simulation. There are a lot of ways to manipulate the system and it can get confusing.
Adaptation for remote learning:	This simulation is already an online activity. Instructions can be offered remotely and students can share their findings virtually.

#8	
Topic:	From Molecules to Organisms: Structures and Processes
Course:	High School Life Science
NYS Standard:	HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
Disciplinary Core Idea:	Each ecosystem has a carrying capacity, which is a limit to the number of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease.
Socio-scientific issue:	Over population of the earth.
Activity:	"How much can you carry?" - - Exploring carrying capacity.
Summary:	In this activity students will explore carrying capacity by evaluating their own carrying capacity. Students will go outside (or to the gym) where they will attempt to make it across a long distance carrying backpacks with various weights in them. Each backpack will represent various animal populations on Earth. For example, one backpack will represent the small population of 8,000 cheetahs; this backpack will be light in weight. Another backpack, will be very heavy, and represent the almost 8 billion humans that exist today. Students will take turns attempting to carry the backpacks in a race to the finish line. While 10 students might be racing at once, the other students are observing. After this activity, students will participate in a discussion about how much weight they can carry. Students should begin to make connections about how the environment can also only carry a certain mass of a population, called its carrying capacity. Students should discuss why the bag representing human population weighed the most and what it might mean if the environment of the planet can no longer carry the weight of the human population.
Steps: (example, can be modified)	Part 1: ACTIVITY 1) Materials & Prep: • Various backpacks; weighted with books or weights and labeled. (Backpacks should be labeled with various species populations and their weight should be in accordance with how large their population is.. ex. The species with the largest population on Earth is also the backpack with the most weight.) • A large field or gymnasium 2) Labeled backpacks will be placed on a starting line. When prompted, students will put on the backpacks and race across to the finish line. (Students who are not racing will line up on the sides to observe the race) 3) Students will rotate in and out as races continue until every student has had multiple chances. PART 2: DISCUSSION QUESTIONS:

	1) Which backpack was the heaviest?/ Which backpack was the lightest? 2) Why do you think that is? 3) Why were students struggling to carry the heaviest backpack? 4) Based on this activity, when you hear the term "carrying capacity" what does it sound like it refers too? 5) If a population has exceeded the carrying capacity, what do you think might happen to the environment? 6) Do you think humans have reached their carrying capacity on Earth? 7) What are some of the issues with the human population being so large? 8) What are some ways we can make sure the human population does not exceed the Earth's carrying capacity?
Rationale: (Connection between SSI and standard)	The resources on our planet are finite. We need these resources to sustain life; these include food, water, and materials for shelter. Because resources are finite, there is competition for them. Ecosystems have developed as well balanced regions in which species living together all have access to enough resources to maintain their population's niche in the system. The maximum population of a species that can live off of the resources of a specific ecosystem is known as the carrying capacity of the ecosystem. The Earth is its own large ecosystem and all life we know is a part of this community. As the human population becomes larger we are consuming more of the natural resources. In many of our endeavors to protect, elongate, and ensure our own human species we have caused extinction and endangerment of other populations of species as we take their land, and their sources of food, water and shelter. Some people believe that it is our right to this land as the dominant species, a theory called survival of the fittest. Some believe we have taken our dominance too far and that it is imperative to have a range and abundance of life around us. Humans cannot survive in a world with out biodiversity. It is up to us as a society to make informed decisions on use and preservation of the limited natural resources that we all need. If we run out of resources we will not be able to survive on this planet. If we have science educated citizens, in the future technology could advance us into the production of synthetic resources or we could develop sustainable practices to make our resources last as long as possible.
Relevance to Leading Education Research:	This activity asks students to be completely immersed in the lesson, using their entire body to explore the concept of carrying capacity. When an activity asks students to utilize movement of their whole body, it is considered kinesthetic learning. Kinesthetic learning theory suggests that students learn best when they have tactile activities and get to move their whole bodies. A study by Leasy, Corembima,

	Ibrohim, and Suwono (2017) found that kinesthetic learners might develop a greater understanding of context, ability to relay information, self-reliance, and decision-making skills. Further they conclude the kinesthetic learning has a correlation to increased emotional intelligence. Emotional intelligence is important for developing an understanding and interest in socio-scientific issues. The highly stimulating nature of kinesthetic learning appears to create a rich and engaging learning environment.
Possible Misconceptions:	• It is not the literal weight of a population that determines carrying capacity; it is the ecological weight, like food consumption, waste production, and land usage.
Recommendations:	• All students should have the opportunity to try a couple different backpacks. All students should attempt the "human" backpack once. • Backpacks should not be so heavy that they are harmful to kids! (The human bag should be able to be lifted and carried by few kids, but not light enough that they can run, it should be a struggle to carry.)
Adaptation for remote learning:	Students can do this exercise from their home using textbooks as weight. Discussions can take place online.

#9	
Topic:	From Molecules to Organisms: Structures and Processes
Course:	High School Life Science
NYS Standard:	HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
Disciplinary Core Idea:	A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status, as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
Socio-scientific issue:	Rising sea levels and temperatures.
Activity:	"Playing with Ice"—Investigating rising temperatures and sea levels
Summary:	In this activity, students will investigate how rising temperatures cause rising water levels, which can decrease landmass and habitat availability for various species. Students will start by exploring a flat model of the Earth, in which there are landmasses, bodies of real water, and arctic circles that hold ice. Students will start by placing small human and animal figurines anywhere on land they can and observing the starting sea level. Slowly, the ice will begin to melt; to increase the rate of melting, students will increase temperature, mimicking the real life increasing climate temperature. Once all of the ice has melted students will be able to compare water levels from before and after. Students will then determine if the species they placed on the land in the beginning of the activity have survived the increased temperatures and increased water levels. By the end of the activity, water should be covering or overflowing onto the land. Students should be able to observe how fluctuations in conditions can change the environment and destroy habitats causing loss of population. After the activity, students should participate in a class discussion. Students make connections between human activity causing climate change in the environment and how their own action in the activity also increased the temperature. The environmental effects of such changes should be highlighted, noting that the polar ice caps are melting and causing rising sea levels, causing a loss of both polar habitats, some water species, and certain land masses.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Model of earth with room for real water (this can be an intricate model with flat land and troughs for water, or it can be simple model, using a bowl with cardboard land

	around the rim. This activity will prep a simple model) • Water and ice • Small figurines (humans or animals or both) 2) Set up: • A bowl should be placed on the center of the table. • A cardboard box should be cut so that there is a hole in the center that is the circumference of the bowl • Cut the bottom of the box so that the top of the box (the side with the hole) is the same height as the bowl. • Place the box over the top of the bowl. The bowl represents all of the water of earth and the flat top surface of the box represents the landmass of the earth. • Fill the bowl completely with half water and half ice (the water should be at the rim and the ice should be poking out of the top) • Have the students place the figurines on the land. 3) Have the students make predictions: how long will it take the ice to melt? What will happen if the ice melts? 4) Students will then increase "atmospheric temperatures" by using a hair dryer (or heat lamp) to begin to melt the ice. 5) Students should analyze what happens to the water levels, the landmass, and the population of figurines as they observe the ice melt completely. PART 2: DISCUSSION QUESTIONS 1) What did the water represent? / What did the box represent? / What did the figurines represent? 2) What part of the Earth does the ice represent? 3) Why did the ice melt in the experiment? 4) Why might the ice caps be melting in real life? 5) What happened when the ice melted? 6) How might the polar icecaps melting effects us in the real world? 7) What are some solutions to the problem of melting polar ice caps, rising sea levels, and increasing temperatures?
Rationale: (Connection between SSI and standard)	All of our resources come from the land, sea, or sky around us. Each of these ecosystems contains many of it's own ecosystems. Each of which is working to maintain its stability of all living species over time. When physical disasters strike they alter the land, change the ecosystem, and disturb the equilibrium. Examples of physical disasters might be hurricanes, tornadoes, or forest fires. The Earth is resilient, so most of the damage from a single minor fluctuation in the environment can be healed and replenished by the Earth with new life. Much like a cut will heal with a just Band-Aid. However, the number and strength of crisis's that are happening now is greater than ever before. In the 1900's, after a century of industrialization, carbon levels in the air began to rise and so did the heat in the atmosphere. As

	temperatures gradually increase over time, the entropy has increased in some ecosystems. The sea levels have been rapidly rising on Earth since the early 1900's. Increased global temperatures melt the ice of the arctic polar regions, creating more water on earth in the form of a liquid, which takes up more space than frozen water, increasing sea levels. The increased global temperatures increases the temperature of the oceans, which changes wave patterns, ocean currents and marine life. Coral reefs have lost their color due to chemical differences in the water and many species have lost their habitats. In addition, polluted chemicals cycle through the gaseous atmosphere, dropping in the form of acid rain in the artic regions. The acidic water further increases the rate of arctic environment heating and ice melting. Magical creatures like the polar bear; the narwhal, the beluga whale, and the pacific walrus are all inhabitants of the arctic tundra who are endangered species due to the loss of habitat from climate change. These drastic changes in aquatic and arctic ecosystems when in rapid succession, don't offer the ecosystem enough time to recover from the disturbance and return to equilibrium. On one hand we our lucky that our Earth is so resilient. On the other hand, we don't know the limits from which it cannot return. As citizens of this global society it is our duty to protect the ecosystems and preserve them from reaching these limits. If the Earth is unable to maintain equilibrium there is good chance humanity will not survive. So it is up to us, as the inhabitants of the planet to make informed decision that will attempt to slow and reduce the amount of entropy that brought on by increased temperatures.
Relevance to Leading Education Research:	In this activity, students are presented with a very critical issue that we are facing as a society today, melting ice caps and rising sea level. This controversial topic falls under the category of socio-scientific issues. It is an issue that threatened our society, is scientific in nature, currently has no leading solution, and requires collective attention. When social issues, such as this one are presented in the classroom, it challenges the typical "why should I care" attitude of students. This activity presents the issue in a multi-sensory demonstration of the pressing issue, increasing engagement further. In a study of the incorporation of societal issues in the classroom to challenge the "why should I care attitude", Hoban and Romero-Severson (2011) conclude, the use of this type of instruction (socio-scientific issues based instruction) does not just engage students but also creates life long learners who are prepared to problem solve and make rational decisions. Most importantly, this type of instruction creates learners who care about the content and the relevant issues.
Possible Misconceptions:	• The ice on Earth is not found as one giant mass but rather scattered in the arctic ecosystems of the Earth, mainly, the 2

	poles of the Earth.
Recommendations:	• For this demonstration to work properly the ice needs to be much taller than the bowl it is in and the water needs to be right up to the top of the bowl at the start of the activity.
Adaptation for remote learning:	Students can be given instructions to complete this activity at home independently. Discussion can take place virtually.

#10	
Topic:	Ecosystems: Interactions, Energy, and Dynamics
Course:	High School Life Science
NYS Standard:	HS-LS2-3 Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
Disciplinary Core Idea:	Photosynthesis and cellular respiration provide most of the energy for life processes.
Socio-scientific issue:	Solar death/the search for a new planet.
Activity:	"Where will we live next?" – Evaluating the critical conditions for life.
Summary:	In this activity, students will play out a scenario in which the Earth is no longer habitable, and all humans need to find a planet to move to as fast as possible! In a race to determine where we will live next, students will first evaluate the critical processes of life, photosynthesis and cellular respiration. Given the formulas for cellular respiration and photosynthesis, students will attempt to determine the 4 most important materials (carbon, oxygen, hydrogen, and light) for life. Once students have this information they will begin the exploration for a new planet! Students will explore dozens of planets (placed around the room) in an attempt to find a planet that has all of the materials that provide the energy we need for life. As all of the possible planets will be scattered around the room, students will be free to explore each planet on their own. While at each planet there will be short readings (and sometimes accompanying videos) about the planets characteristics. Students will use this information to determine whether this planet is a viable planet for human life or not by determining if it has the four most important material required for life. The first student to find the most habitable planet saves the human race! (and maybe wins a prize!) After this activity, students will participate in a class discussion about our search for the new planet. Students will review photosynthesis and cellular respiration and why those processes are so crucial to life. Further students will discuss the basic charactertics a planet needs to sustain life and which planets do or do not carry these. Lastly, students will discuss possible reasons humans might really need to look for a new planet and why this is an issue for society.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Equations for photosynthesis and cellular respiration • Representations of planets placed around the room with accompanying readings and videos about the planetary characteristics 2) Students are given a couple minutes to review the equations for photosynthesis and cellular respiration to determine the (write down) four essential materials needed for life. 3) The teacher should check their answers before students move to

	the next part. 4) Once students understand the 4 necessities for life, they can begin exploring the planets around them. Students will move from planet to planet around the room, reading about each, to determine if the planet could sustain life. 5) The first student to find a planet with all of the necessary materials to sustain life saves the human population! PART 2: DISCUSSION QUESTIONS 1) Why are photosynthesis and cellular respiration essential to life? 2) What are the four things that a planet must have in order to sustain new life? 3) Which planet is the closest to being able to sustain human life? 4) Why are some of the other planets uninhabitable? 5) Why might we be searching for a new planet? 6) How many planets would you guess exist that could sustain human life? 7) What would be some problems associated with moving to a new planet? 8) What are some ways we can help save this planet so that we don't have to rely on a new one?
Rationale: (Connection between SSI and standard)	Photosynthesis and cellular respiration are two of the most vital processes that govern all life. These processes provide energy to all living beings. Photosynthesis occurs in plants and uses sunlight to convert water and carbon dioxide into oxygen and sugar. The sugar produced is the food and provides the energy for the plant to perform its biological functions. Photosynthesis allows the plant to make it's own food out of light! Animals on the other hand, cannot produce their own energy in the form of sugar, there fore, they obtain sugars by eating plants or eating animals that eat plants. The process of cellular respiration allows animals to break down the sugars they have ingested by combing the glucose with oxygen to create carbon dioxide, water, energy, and waste. The net result for both photosynthesis and cellular respiration is the energy for life in the form of ATP. All living things need ATP to perform all of your biological functions. Our sun is central to us maintaining life. Our sun provides the light for the plants to undergo photosynthesis. Those plants are the food for the rest of life. Presumably, with out the sun there is no photosynthesis, there is no cellular respiration, and there is no life. According to science, our sun is 4.5 billion years old. The average age of a star falls between 1 billion and 10 billion years. When a star dies, it no longer produces light. Our sun is destined to die at some point, at which all life may cease to exist. Scientists have already begun to explore the options of other planets. Some are attempting to find a local planet we can inhabit safely, like Mars, while others are working on locating a planet similar to Earth and developing the technology to get there.

	Lastly, others are focusing on finding ways to extend the life of this planet. As we educate our students about life we must educate them on their biological origin and the potential dangers of life. Real effort and money and time are going into deciding the future of humanity. We need scientifically literate citizens to participate in the research, creation, and decision making concerning where humanity will live in the future. This is especially true as the population is increasing to its carrying capacity on this planet.
Relevance to Leading Education Research:	In a survey by Dagys (2017), the principles and implications of inquiry-based learning are explored. One of these basic principles is the constructivist theory of learning, which states that knowledge is built of off prior knowledge. This scaffolding of knowledge building is amplified when students are allowed to follow their own inquiry, the basis of inquiry-based learning. In this activity, students are prompted with a basic question, which planet might be inhabitable by humans? Students are then free to explore using self-guided inquiry to uncover the answers that continuously build off of their prior knowledge and inevitably to understand the key components necessary for human life.
Possible Misconceptions:	• Students should understand that sugar (food) and water are necessary materials for life but break down into carbon, oxygen, and hydrogen.
Recommendations:	• The planets around the room should look enticing. Using videos that demonstrate their atmosphere is a good way to make the activity multisensory. • There are a variety of really wild planets! Use those to capture student interest!
Adaptation for remote learning:	Teachers can send students articles to read on each planet or students can do independent research on each of the planets in order to complete this activity independently and remotely. Virtual space can be used for discussion.

#11	
Topic:	Ecosystems: Interactions, Energy, and Dynamics
Course:	High School Life Science
NYS Standard:	HS-LS2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
Disciplinary Core Ideas:	Plants or algae form the lowest level of the food web, only a small fraction of the matter consumed at the lower levels is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that made up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved.
Socio-scientific issue:	Over fishing.
Activity:	"Go Fish" - - Investigating the harmful effects of over fishing on the flow of matter.
Summary:	In this activity, students will investigate the cycle of energy and matter through the marine environment and the human role in this cycle. In the center of the classroom, students will observe a large body of "water" full of fish. Students will act out the fishing trends over time, slowly "fishing" out all of the fish from the body of water to reveal a large algae bloom underneath. Some students will act as fishermen, other will act as birds (consuming fish). Once students have acted out the relationship between humans, fish, bacteria and water that make up the marine environment, they will work together to create a visual representation of the cycle of energy and matter through the marine environment. Lastly, students will be presented with a beaker of algae water to compare to fresh water to create a long lasting impression of the effects of disrupting the natural flow of energy and matter. After this activity, students will participate in a class discussion. Students review the cycle of matter and energy through the aquatic system and discuss how trends in human fishing have negative impacts on the environment. Further students will discuss why this is a human issue and potential solutions.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Data on global fishing trends or fish consumption. (Preferably in a graph that is large enough for students to see, ex. Poster board) • Desks should be moved into a circular formation around

	the edges of the room. (Or a new empty room should be used) • SET UP: o The center of the room should be covered in green paper (representing a fresh water algae bloom) o Paper fish should be made using construction paper, each glued to a BLUE piece of construction paper (blue representing fresh water). o Use the data to determine how many fish should be made; there should enough fish to satisfy the current population of fishermen (ex. The current human consumption rate of fish is 23 kg per person, so there should be 23 fish per person that will be assigned as a fisherman in the class) • Sample of algae filled water • White board, chalk board, or poster paper • T-shirts labeled FISHERMAN or BIRD 2) To begin the activity, students should be assigned either the role of a fisherman or bird, there should only be a hand full of birds. 3) Next, students act out the trends in human fishing. Following the large graph presented to the class, students grab the amount of fish from the center of the classroom that matches the year they are acting out. (E.g. If the graph starts at 1700, and fish consumption was at 1 kg per person, each person will pick up one fish.) 4) After each fisherman has collected their fish, the birds will all grab one fish. 5) Students will observe how many fish are left and how much green algae has been exposed, then they will throw their fish back and start again. 6) Students will repeat steps 3-5 at increments representing various years from the fishing data, up until the present. With each increment, there should be less fish left and more green algae visible. 7) When the present year is reached, fishermen should fish out all fish, the water should be completely green, and the birds should not have any fish to grab (causing them to "die") 8) After all of the marine life has been fished and the birds have died, students may return to their seat for a class discussion PART 2: DISCUSSION QUESTIONS 1) What kinds of animals get their energy by eating fish? 2) Where do fish get their energy? 3) Where does algae get its energy? 4) Can we create a diagram that demonstrate the flow of energy

	and matter through the aquatic system we just acted out? (Use white board) 5) Why have the rates of fishing been going up? 6) What are the consequences of over fishing? 7) If algae blooms get too large, how does this effect the human population? (Or other populations and ecosystems?) 8) What are some sustainable solutions to this problem?
Rationale: (Connection between SSI and standard)	Plants and algae produce their own food through photosynthesis. They are primary producers of energy. Primary producers are eaten by animals called primary consumers, primary consumers are eaten by animals called secondary consumers, and secondary consumers are eaten by animals called tertiary consumers. The movement of energy from plant to multiple animals is called a food chain or food web. As energy travels from the producers, where it is made, to the last consumer, it looses energy. The living environment naturally balances food webs in an attempt for an ecosystem to maintain homeostasis. When a population dies, the consumer above it usually decreases in population while the consumer or producer below it usually becomes over populated. Both processes effecting the biodiversity and balance of the ecosystem. Human impact has led to drastic impacts on various populations. The marine ecosystem is one place where we have had large impacts. The increased temperatures from global warming have increased ocean temperatures, producing an effect called corral bleaching, in which corals lose their color. Over fishing for human consumption has caused a decrease in many fish populations, effecting ecosystems all over. Farm fishing, an alternative to over fishing the open ocean, also effects ocean ecosystems all over. Fish that are farmed are held captive in small areas. Bacteria and disease populations are high in fish farms, whose water gets dispersed into larger bodies of water and can impact or harm other species of aquatic life. Fishing has been a historical part of mans survival and a staple in his source for sustenance. In the 1800's fishing increased drastically when they began to use blubber for oil for lamps. However, recent inclines in population paired with inclines in consumerism and global trade has produce a large need to both catch and farm extremely large quantities of fish. If we continue to catch fish at this rate we could deplete the oceans by 2050 as science currently predicts. It is up to us as scientists and a society to help create a system for sustainable farming, sustainable consumerism, and sustainable life. Students should be able to analyze the source and cost of consuming fish as well as actively participate in societal decisions concerning the preservation of our oceans.
Relevance to Leading Education	This activity uncovers the socio-scientific issue we face of over-fishing. Over fishing is an issue brought on by human choice. It is the

Research:	constant consumer decisions that have led to the issues we are now facing due to over fishing. In a case study by Karahan and Roerhig (2016), they investigate how socio-scientific issues based curriculum aids in the agency and individual power of the student in their decision-making. Based on this study, it is suggested that the use of socio-scientific issues, such as the one posed in this activity, can teach students how to be active learners and therefore active members of a democratic scientific society. The direct results of this classroom framework are creating students who are both active agents in their own learning and active agents of change with in their community.
Possible Misconceptions:	• The teacher should discuss the pros and cons of farm fishing as a solution, as well as the pros and cons of cattle farming and mono crop farming as alternative food sources. • Students should understand that energy flows in the same way from plants on land through food webs of land bound animals. • It should be noted that this activity is a dramatization (we are not currently fishing out all of the fish) BUT it should be highlighted that we are reducing about 25% of the fish biomass and endangering many fish species.
Recommendations:	• Students should be presented with a sample of algae water to smell and observe! • STUDENTS CANNOT DRINK THE ALGAE WATER
Adaptation for remote learning:	This activity is hard to adapt for online learning. Teachers may opt to have students analyze data about fish populations compared to human fish consumption. Discussions can be held virtually online.

#12	
Topic:	Ecosystems: Interactions, Energy, and Dynamics
Course:	High School Life Science
NYS Standard:	HS-LS2-5 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
Disciplinary Core Idea:	Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
Socio-scientific issue:	Pollution/Human Impact
Activity:	"Where does your waste go?" - - Creating a solution for pollution.
Summary:	In this activity, students will be presented with a giant pile of waste (garbage). Facing an immediate issue, students will be asked to form a think tank to begin to solve the problem of waste management, without creating more pollution in an effort to reduce human impact. Upon arriving to the classroom, students will see full garbage bags taking up most of the classroom space. Somehow, all of the schools garbage from the day before has been dumped into your classroom! The students, facing an immediate problem, will be asked to participate in a think tank to find a solution. On the board, the class will start a list of problems and solutions. The class will start by discussing where the garbage came from (the problem) and they will begin to discuss where it should go (solutions). For each solution presented, the teacher should prompt the students to consider problems with that solution. E.g. If the students suggest we take it out to a dumpster, the problem would be, what happens when the dumpster gets full. One by one, students should naturally be guided through a discussion of the different forms of pollution that occur from trying to solve problems of waste management. At the end of the activity there should be a collective list of ways in which human activities create pollution. Students should be able to visibly see the need for sustainable solutions in which pollutants and waste are not created or are recycled into something constructive. Students will further discuss some of the sustainable practices that are currently being used and the repercussions of environmental pollution from human waste.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • All of the schools garbage bags from the day before placed on the desks or chair of each student • White board/chalk board/ poster board 2) Upon arrival students should begin to ask questions about what to do with the garbage at their desk.

	3) Once all students are in, the teacher should inform the students that she/he does not know what to do with the garbage and that students will have to figure out what to do with all of it in a think tank. The only rule is that the final solution must have done more than just move the waste and the solution can not create more problems than when it started. 4) Guiding a class discussion, the teacher will prompt students to discuss possible solutions to waste management while also discussing the harmful repercussions associated with each. Below is a guiding list. o Solutions → Problems o Buried in Land fill→ decomposition causes chemical leaching, not everything will degrade, and what does degrade will produce carbon emissions (CH4) o Burn it → creates carbon emissions and acid rain o Send into space → Rockets produce carbon emissions by burning fuel and clutters the sky/ atmosphere, trapping greenhouse gases o Recycle → must be sorted from non recyclables (still waste), requires energy (usually melting) to transform materials which produces carbon and chemical waste o Consume waste free goods!!!!! (Only possible solution right now) 5) Students should all carry garbage out side. Then they will finish the discussion from before. PART 2: DISCUSSION QUESTIONS 1) What are some of the ways humans create waste? 2) How do our waste products pollute the environment? 3) What are some of the repercussions of environmental pollution? 4) Do we have any sustainable solutions right now? 5) What is the best thing we can do in our everyday lives to help reduce pollution and waste?
Rationale: (Connection between SSI and standard)	Carbon is critical to all organic living forms of life. It is the most basic component of life. Carbon is a single molecule that flows through the planetary ecosystem, including the biosphere, atmosphere, hydrosphere, and geosphere. All four of Earths spheres have components, which utilize the carbon to maintain homeostasis, transform it, and pass it on to be used by other life. Each time the carbon molecules change shape they have the potential to be re-used. Photosynthesis, the process in which plants produce energy by absorbing carbon dioxide, and cellular respiration, in which carbon based glucose is used to make energy and produce carbon dioxide are both essential to the carbon cycle. Human activities have effects on the carbon cycle. Human waste is actually an important part of the carbon cycle. We excrete carbon

	based matter as well as CO2. This carbon can be reabsorbed by the planetary life at different points in the carbon cycle. However, as the population has increased rapidly, we are producing more waste than can be reabsorbed. Physical waste matter is pilling up in land fills, whose contents leach pollutants into the surrounding soil and run off into water, often depleting sources of nutrients and killing populations near by. Physical waste is also being dumped into the bodies of water that make up the hydrosphere, directly polluting the water and the species that live with in it. When life dies, the carbon cycle cannot flow for there is no life to process the carbon. Since 1960 our waste has tripled from 100 million tons of waste to a year to almost 300 million tons of waste per year. Some solutions have been able to reduce some of the strain of the increased waste. For example, we recycle 1/6 of our waste, we compost another 1/6, we burn off another 1/6, and we place the other ½ of our waste into the landfills. The combustion of garbage creates its own pollution, carbon emissions into the air. Burning of anything produces carbon emissions. After the industrial revolution of the1700's carbon emissions from burning fossil fuels has increased by 35 million tons annually. Electricity, heat, cars, and industrial processes all rely on burning fossil fuels. As population increases every year, pollution, waste, and carbon emissions rapidly increase as well. Today, there is more carbon in the atmosphere than ever before. Further, other human activities are causing a decrease in plant and animal life that would otherwise help to recycle the carbon through our Earths system. While carbon is a building block of life, too much carbon acts as a pollutant. The carbon dense atmosphere is trapping heat around the earth causing global warming. Global warming is a phenomenon in which the temperatures of the atmosphere of Earth rise causing major shifts in the ecosystems. These shifts in the ecosystem are responsible for habitat loss and the endangerment of many plant and animal species. This is a deadly cycle we as humans are engaging in. The more land we take up, the more carbon we emit, the more plant and animal life we lose, the more the planet becomes uninhabitable for us. This is an issue for all members of society. We all create waste. Most of us are not even conscious of the waste we create. Students should be aware of the choices they make and the impact they have on the surrounding environment. We need scientifically literal citizens who will make informed decisions about recycling, composting, what kind of car they drive, how much electricity they use, etc. Further, we need students who are scientifically inspired to drive innovation and technology that will help us to combat or even end pollution to our climate.

Relevance to Leading Education Research:	In this activity, students are presented with an issue they face everyday, they are just unaware of…. Where will all your trash go? Here students are forced to face this real world, socio-scientific issue head on. This activity ensured that the problem they are facing is not theoretical, it is literally right in front of them. Faced directly with an issue students are presented with an understanding of the phenomenon that is coherent with their real life understanding and deepens their interest. In a study by Jack, Lee, Yang, and Lin (2017), the idea that connecting science phenomenon directly to the students life through teaching benefits and risks increases student interest and therefore motivation to learn, is supported. Increased engagement in activities surrounding real world phenomenon and societal issues creates the potential for citizens who are highly informed and self-motivated to participate in the decisions that effect and advance society.
Possible Misconceptions:	• Human waste includes, but is not limited to, poop. Human waste also includes carbon emissions from burning fossil fuels and garbage, non-biodegradable plastics, trash, toxic chemical emissions, nuclear waste.
Recommendations:	• Images can be used to show students landfills and masses of waste. • Data on human waste production and carbon emissions should be shared in this lesson. • A visual graphic is helpful to demonstrate the cycles of human waste into pollution (like the carbon cycle and nitrogen cycle) in the subsequent lessons.
Adaptation for remote learning:	Students may be asked to consider where their garbage goes? How do we actually get rid of our trash and not just move it around? They may also be asked to imagine the most sustainable solution to trash they can. Students can share their thoughts through a virtual format before discussing as a class.

#13	
Topic:	Ecosystems: Interactions, Energy, and Dynamics
Course:	High School Life Science
NYS Standard:	HS-LS2-6 Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
Disciplinary Core Idea:	A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status, as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
Socio-scientific issue:	Climate change/global warming.
Activity:	"Climate change… again!?"--Create a time line of extinction.
Summary:	In this activity, students will explore the Earth's long history of climate change and how fluctuations in environmental factors (natural or induced) can challenge both ecosystems and their inhabitants. Students will be asked to work in groups to create a historical time line of Earth that answers the question, "how many mass extinctions have there been?" This time line should include all of the mass extinctions that have occurred, how much habitat and life was lost at each, and what was the cause of each. The class will then work together, using the information collected from their own timelines, to create a single collective timeline at the front of the room. This timeline should include all five of the mass extinctions through out history as well as the 6th potential mass extinction we are facing right now. After creating a collective timeline, students will participate in a class discussion. Students will analyze the causes of the extinctions from the past, comparing natural and unnatural causes. Ultimately students will evaluate how critical the current 6th possible mass extinction is, its connection to climate change and global warming, and what we can do to stop another extinction from happening.
Steps: (example, can be modified)	STEP 1: ACTIVITY 1) Materials/prep: • Computers and internet access • Poster paper/white board/chalk board 2) To begin, students will be divided into small groups. 3) Groups will be asked to make a time line of Earth that answers the question, "How many mass extinctions have their been?" Students will use their computers for research.

	4) For each mass extinction, students will include how many species went extinct and what caused the extinction. 5) When students have finished their timeline, they will use their collected information to create one cohesive timeline (guided by the teacher). 6) After creating a timeline, students will participate in a class discussion about the cycle of climate change, the effects of global warming, and the possibility of extinction. STEP 2: DISCUSSION QUESTIONS 1) How many mass extinctions have happened in the past? 2) How many species have to die for an event to be considered a mass extinction? 3) What were the main causes of the past extinctions? 4) Based on our history of extinction, can you determine if climate change is a natural phenomenon? If so, what is the cause? 5) Based on the timeline, should we be having another mass extinction right now? (Hint: focus on time between extinctions) 6) What could have brought on an increased rate of climate change that could cause another mass extinction so soon? 7) From this information, can you determine the difference between climate change and global warming? 8) How might humans take action to reduce global warming and slow down climate change in order to prevent another mass extinction? 9) Based on data from past extinctions, is it possible for the human race to survive a mass extinction?
Rationale: (Connection between SSI and standard)	We are not the first population of animals to inhabit this Earth. With an age of 4.6 billion years old, this Earth has seen much life flourish, but it has also seen many mass extinctions. When the ecosystem of Earth is in complete balance, life flourishes. When the temperature is just right and food and water is abundant life will grow. This life takes the form of plants, animals, and other living organisms. We know complex life has been on this planet for at least the last 500 million years. In that time frame, there have been five mass extinctions, in which 80% of life or more died and all the ecosystems that existed collapsed. It appears that when minor changes occur in an ecosystem, living organisms can adapt. However, when major changes occur drastically, rapidly, or over an exhaustive period of time, ecosystems are vulnerable to collapsing and species are susceptible to extinction. About 440 million years ago, the 1st mass extinction occurred. This first extinction occurred when plant life population grew to be too large, taking so much carbon out of the air during photosynthesis that the Earth's temperatures began to drop. As the Earth cooled, life declined to a small population adapted for colder weather. Once the majority of the plant life was gone, carbon collected in the atmosphere

	and the Earth began to heat again, killing the remaining life adapted for the cooler temperatures. 365 million years ago, the 2nd mass extinction occurred. As plant life flourished again, deep routed plants grew, expelling an abundance of nutrients into the oceans, feeding the algae and creating algae blooms. These algae blooms released oxygen suffocate much marine life. Simultaneously the Earth was cooling and heating again from the over abundance of plant life. 252 million years ago, volcanic activity produced so much extra carbon into the atmosphere that carbon-eating bacteria became over populated, producing access amounts of methane into the air as well. These green house gases polluted the atmosphere, warming temperatures of the Earth as well as producing acid rain, polluting the marine habitats as well. 201.3 million years ago the 4th mass extinction occurred, again due to volcanic activity, global warming, and acid rain. Lastly, the 5th mass extinction occurred about 66 million years ago. Some scientists believe an asteroid crashed into earth, pushing debris into the atmosphere and causing global cooling again. Others believe global cooling occurred naturally at this time. These mass extinctions show how one catastrophic event or one population causes a serious of events that could lead to complete ecosystem collapse. Today, we as a society contemplate whether we are on the verge of the 6th extinction. Some people believe that global warming and cooling are apparent natural cycles of the Earth and that we are approaching a naturally induced era of global warming. Others believe that the rapid increase in human population and human waste caused or at least sped up the global warming process that is occurring right now. Either way, scientific evidence shows that global warming is real. Ice caps are melting, water levels are rising, carbon in the atmosphere increasing, human waste increasing, plant populations are decreasing, and pollution and acid rain are increasing. Whether it is a human induced phenomenon does not matter when considering how we will combat the global warming taking place. Evidence and history have shown us that drastic changes in the ecosystem can cause a strain on life and sometimes-even extinction. We are experiencing drastic changed to our ecosystem right now. It is imperative that students understand how their environment is changing around them and what this could mean for life for them for the future. As a society, we need members who can make informed decisions about choices that could either increase or decrease the rate of global warming. Some of these choices are person, such as electricity use, gas usage, recycling. Other choices are democratic, such as policies for clean energy use. Further, we need innovative scientists who will find creative solutions to the problems that we face as a global community on the brink of another extinction.

Relevance to Leading Education Research:	In research by Forsythe, Jackson and Conteras (2018), it is suggested that reading can play an integral role in engagement when it is paired with the right activity. This activity is another example in which this theory is utilized. By pairing autonomous research, inquiry learning, and hands on creating with historical reading, students are able to encounter multimodal functions of engagement. Here students are able to build on prior knowledge through their own inquiry, become self motivated through autonomous research, utilize the conceptual power of kinesthetic learning, and gain scientific literacy skills built through reading.
Possible Misconceptions:	• The entire planet is not wiped out during an extinction event; some species survive which eventually replenishes the planet. • Climate change is a natural cycle that occurs because as life increases, energy increases, which causes inevitably increased temperatures through various activity. • The difference between global warming and climate change should be clarified
Recommendations:	• When creating the final class time line, the teacher should review how they know scientifically about each extinction event. • The combination of natural events and man made events to create a possible 6th extinction should be explored thoroughly. • The difference between global warming and climate change should be discussed in reference to each extinction event.
Adaptation for remote learning:	Students should be able to do independent research to make their own time lines. Students can use their on information to edit one large time line in a shared document. The teacher can review the time line, the connections to climate change, and the possible extinction we are facing in a virtual classroom format.

#14 **Topic:**	Ecosystems: Interactions, Energy, and Dynamics
Course:	High School Life Science
NYS Standard:	HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
Disciplinary Core Idea:	Anthropogenic changes in the environment-including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change – can disrupt an ecosystem and threaten the survival of some species.
Socio-scientific issue:	Human impact: habitat destruction via monocrop farming.
Activity:	"Farm for your life!" - - Evaluating the pros and cons of monocrop farming.
Summary:	In this activity, students will act as farmers, who are responsible for producing enough food for all 8 billion people on the planet. Students will separate into groups; each group will plant seeds in their own small box garden. Each group will be given a variety of seeds. Half of the groups will be given data on the most used crops. The other half of the groups will not be given data. Students will work together to decide on a design for their garden and which crops to plant. Students will have to explain their thinking. Following this activity, students will discuss the design of their gardens. Students will learn about poly-crop farming and mono-crop farming. They will make educated guesses based on their own experience planting gardens as to why farmers might use poly-crop vs. mono-crop methods and the pros and cons to both.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Garden boxes • Gardening tools • Seeds • Data on current world crop usage 2) Students should be split into groups and given garden tools. Half of the groups should be given data on crop usage to help their garden planning. 3) Students will act as "farmers", who need to plant a garden that can sustainably feed the world. Students will work in groups to design and plant these gardens. 4) Students will place completed gardens in the window to be cared for through out the year. 5) Students will participate in a class discussion to share their designs and logic. They will explore the difference between monocrop farming and polycrop farming, the reason for the rise of monocrop farming, its downfalls, and how we can farm

	better in the future. PART 2: DISCUSSION QUESTIONS 1) How did you design your garden and why? 2) Based on the activity you just performed, would your farming method be considered mono-crop farming or poly-crop farming? Why? 3) Why might mono-crop farming have first been invented? 4) Which method of farming seems more natural? 5) Where in nature can you find only one type of species to exist alone? 6) Can you determine which method of farming has more biodiversity? 7) What would happen if a disease came and whipped out all of the corn crops on a mono-crop farm? What about a poly crop farm? 8) Where do you think they might build mono-crop farms? 9) Which crops are the highest yielded in mono-crop farms? Can you explain why? 10) What is a more sustainable solution to mono-crop farming and why?
Rationale: (Connection between SSI and standard)	Humans are intellectual beings, using our minds to dominate in the game of survival of the fittest. However, in our conquest to grow as a species, we have over extended the natural order of life. Many human activities have caused anthropogenic changes in the environment, putting other species at risk. Unfortunately, nature thrives on the principle of biodiversity. Biodiversity, or the principle of the diversity of life, accounts for the adaptability of each ecosystem. Without biodiversity, ecosystems are less stable and easily collapse. Anthropogenic changes such as habitat destruction, pollution introduction of invasive species, overexploitation, and climate change are reducing biodiversity on Earth, as the human population continues to clime. In some instances, human activity is directly reducing biodiversity. One example of this is monocrop farming. Monocrop farming is the agricultural practice of growing a single crop, on the same land, year after year in large yields. Corn, soybeans, and wheat are three of the larges crops on monocrop farms. These three ingredients make up the majority of all processed foods that feed the 7.5 billion people that exists today. While monocrops refer to crops that are grown in singular species, cattle ranches house only one species of animal for human consumption also pose problems, producing large pockets of bacterial disease and methane gas emission. Monocrop farming came into existence out of the belief that it would be easier to produce large quantities of a product this way. This was necessary as the human population increased and the demand for foods and goods increased. However, with soy, corn, and wheat as the

	top crops, humans are not consuming enough of the healthy natural foods we need. Processed foods have become that majority of consumption, triggering a cycle in which more monocrops for such materials are then needed. In order to make way for monocrop farms, other habitats are destroyed. Forests are cut down, grasslands are run over, and aquatic centers are over fished. As habitats are destroyed, plant, bacterial, and animal life are lost. Not only does that area completely lose biodiversity but the over all biodiversity of Earths ecosystem decreases. When an area loses its biodiversity, the monocrop farms in its place become far more susceptible to death through drought, pests, and disease. Because of this, many farmers actually struggle today. Today, most species on this planet are endangered because of human activity. We struggle to provide healthy foods to a large portion of humans even though we are destroying other life in order to maintain ours. People have suggested returning to the origins of farming which is polycrop farming, also considered sustainable farming. Polycrop farming grows a variety of vegetables and houses a variety of wild life that works in symbiosis with each other to create a flourishing well balances habitat. The issue with this type of farming is that its yields are too low to produce the same amount of a single crop as monocrop farming. However, a simple solution would be to implement more polycrop farms to local communities. Right now, consumer choices drive the necessity for certain crops. If we all stopped eating processed foods and began demanding fresh vegetables, the need for so much corn and soy would decrease. However, if we really want to impact supply and demand, consumers have the option of shopping at local farms or even better, growing their own food. Students of science should understand where their food comes from and how it impacts the world around them. Even better, students should understand how to grow their own food sustainably. If we don't start making different choices about how we feed ourselves, our feeding practices will destroy our ecosystem. It is important that students become informed citizens able to make decision on the sustainable practices that feed our future.
Relevance to Leading Education Research:	In a study by Cross and Kahn (2018), the use of gardening in science lessons was proven to be a highly engaging activity for students. The use of gardening taps into the greater learning theory of place-based learning. In placed based learning and in this activity, students are immersed in the content activity. Here students are not just asked to discuss farming, they are actively experiencing farming. Not only does it provide engagement through full immersion in real world phenomenon and kinesthetic learning, it also provides knowledge of skills that can allow for autonomous and sustainable living in the future.

Possible Misconceptions:	• The teacher should discuss how and why we moved from natural polycrop farming to monocrop farming. • It should be discussed that mono-crop farm soil can lack nutrients because of the diversity of plant life, which inevitably makes the soil less viable in years to come. This is part of the reason poly-crop farming is sustainable.
Recommendations:	• Students who are given data on crop usage should be encouraged to use that data in their design, the goal is for them to have less diversity in crops planted • The teacher should highlight the amount of habitat destruction that occurs for monocrop farming to exist. • There should be some basic guidelines about how much space each seed needs. • Although the act of planting the garden is the entirety of this engagement piece, students should be guided to continuously care for the garden through out the year to see the fruition of their hard work and their ability to create food and a sustainable life style! • Further, self-farming or self-gardening should be highlighted as a practice that ensures self sustainability (non-reliance on the system)!
Adaptation for remote learning:	The teacher can send the students garden boxes if this is practical and they can do this activity independently. Half of the students can still be given the data on crop usage. If this is not an option, the teacher may opt to have students watch a variety of the videos that exist on YouTube for and against mono crop farming. They may be assigned the task of uncovering what monocrop farming is, its pros and cons, why we use it, and sustainable solutions. Answers can be discussed via virtual format.

#15	
Topic:	Ecosystems: Interactions, Energy, and Dynamics
Course:	High School Life Science
NYS Standard:	HS-LS2-8 Evaluate evidence for the role of group behavior on individual and species chances to survive and reproduce.
Disciplinary Core Idea:	Group behavior has evolved because membership can increase the chances for survival for individuals and their genetic relatives.
Socio-scientific issue:	Endangered Species
Activity:	"Tag you're endangered"- - Explore the role of group behavior on species survival, in the wild savanna.
Summary:	In this activity, students will play the classic game of tag, but with a twist! In the beginning of class, students will be divided into groups and given a species type (lions, hyenas, wildebeests, and humans). Each species will have different rules for play, but the basic rule is if you tag someone, they are out. When your species gets down to one player left, it is considered an ENDANGERED species. When everyone from your species is out, you are considered extinct. The game ends when there is only one species, which is neither endangered nor extinct. After the game, students will participate in a class discussion to evaluate which behaviors were advantageous for survival in the game and how humans have managed to master survival and reproduction better than any other species, causing many other species to become endangered.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Field or gymnasium • Cones or tape for making boundaries (game space should be as large as a court or field, with clear line boundaries around the field and the field broken up into 4 quarter sections) • T-shirts for different species (different color per species) • Whistle 2) Students will be divided up into four even groups. The groups represent different species in the savanna ecosystem: humans (poachers), lions, hyenas, and wildebeests. Each group will wear a different color shirt (or jersey). 3) Students will be given game instructions: o The field is the wild savanna. Students are playing as their assigned animal. The object of the game is to get the other species out, by tagging them. o WILDEBEESTS – are at the bottom of the food chain, each wildebeest will be assigned one of the four

	sections of the field to occupy. They cannot leave that section, they cannot be near any other wildebeests and they cannot talk to any other wildebeests. They cannot tag anyone out, they can only run. o HYENNAS – are one trophic level above wildebeests, they can run anywhere within the boarders of the Savanna. They cannot communicate with one another but they can help each other out. They can only tag out wildebeests. o LIONS—Lions are tertiary consumers, they can run anywhere within the boarders of the Savanna. Lions can communicate verbally with each other and can help each other out. They can tag anyone in the game out. o HUMANS—humans consume everything. They can run in and out of the boarders of the Savanna. When they are outside of the Savanna, no other species can tag them. Humans can communicate across the board as well as meet outside of the boarder of the Savanna to plan and work together. Humans can tag anyone in the game out. 4) Students will play out the game. The teacher will use the whistle to communicate players who are tagged out and players who are acting inappropriately. When there is only one person in a species left in play, that species is considered endangered. When there is no player's left of a species, that species is extinct. 5) The game ends when only one species is neither endangered nor extinct. 6) After the activity, students will participate in a class discussion. Students will analyze the role that group behavior, communication, and other characteristics had on species survival. Students will consider the various ways in which the human species has capitalized on the advantages of group behavior, and the effects it's had on other species populations. PART 2: DISCUSSION QUESTIONS 1) Which order did species become endangered or extinct in? 2) Which characteristics were advantageous for species? 3) What are some real life ways in which group behavior aids in survival and reproduction? 4) How has group behavior helped the human race survive? 5) What are some of the ways the survival of the human race has negatively impacted the survival of other species? 6) What are some solutions to the negative impacts that human domination has on other species? 7) How can humans survive efficiently with out destroying other

	species populations and habitats?
Rationale: (Connection between SSI and standard)	Members of a species living in an ecosystem tend to work together. Large mammals tend to move in packs, birds fly in flocks, and fish swim in schools. These are examples of group behavior and they protect species from death. Not only do species have power in numbers when it comes to surviving an attack, but they also have power in numbers when it comes to recovering from an attack. For example, when a school of 100 fish is attacked by a shark, it is much more likely that a few will survive to reproduce and replenish the population. As opposed to, just a couple of fish swimming alone. Group behavior is a mechanism adapted to help species survive and reproduce over time. While most species have adopted this practice to protect themselves, some species do it much better than others. Ants, for example, have a population of 10 trillion or more (some have estimated 10 quadrillion). Ants have a unique ability to work in large colonies, sometimes comprised of over a million ants in a single colony. We have all stepped on ants before but destroying a whole colony is nearly impossible and because of this the ant population has become masters at survival and reproduction. Next to ants, human beings are the second most populous species, with a population of 7.8 billion people. Unlike ants, other species have difficulty moving in such large populations. Most ecosystems limit the population of species in that ecosystem and for all animals except humans; communication between populations of different ecosystems is limited and hinders their ability for populations of species in different areas to work together. However, like ants, humans are able to function in large communities of millions of people. Due to advances in technology like transportation, radio, telephones, and internet humans have been able to connect and function on larger scales as giant communities. Today, we are a global community. Our species has worked together to overcome all issues we have faced in nature to ensure our survival and reproduction. We have medicine to cure the ill, we have specialized care for individuals with disabilities, we provide food and shelter for those without, and we work endlessly to extend the lives of our elderly. No other species has these abilities. Some argue that our need to survive has become unnatural. There is evidence that humans have gotten so good at group behavior and survival that we have overpopulated the Earth. As the human population rises it dominates all corners of the Earth and its ecosystems. As humans take over land for housing, hunt and fish for food, destroy ecosystems for crops and cattle, pollute the environment through increasing waste, and disrupt ecosystems by introducing invasive species into new ecosystems as we transverse the globe we are taking away homes and resources for all of the wild species, putting their species populations at risk for

	extinction. These at risk populations are called endangered species and there are more now than ever before. Since 2007, the number of endangered species has doubled, totaling upwards of 14,000 endangered species currently. There are roughly 8 million wild species that exist today. However, the most populated species besides humans are cows, pigs, sheep, and dogs because humans have ensured their survival and reproduction for their own benefit. While it is true that species extinction is a natural part of survival of the fittest. There is concern that humans have over exploited their power and are upsetting the natural order of the Earth's ecosystem. It is scientifically proven that ecosystems rely on biodiversity for survival. Some believe that the Earth will find ways to adapt to support the rising human population and the extinction of other species. Others fear that as we lose respect for the beauty and importance of biodiversity, and focus only on our selves, we are threatening our own ecosystem and therefor our own survival. As humans we are often removed from the battle that's happening out in the wild. Students should understand what is happening in the wild parts of the world around them as it provides so much of the abundance that we rely on. Citizens should be able to make informed decision about land usage, hunting, and fishing for their own action, when deciding on laws, and when purchasing consumer goods. Consumer choices drive many of the operations that inevitably endanger species and therefore threaten our ecosystem. It is important students to have the knowledge of biology to understand how important all species are.
Relevance to Leading Education Research:	This activity utilizes role-playing games as a highly activity form of kinesthetic learning. According to Guha (2013), role-playing games have the opportunity to be fully immersive and fully engaging. It is suggested by Richards (2012), the use of novel games that utilize the whole body aids in creating novel memories and increases conceptual understanding.
Possible Misconceptions:	• In a real food chain, the population of herbivores (wildebeests) is always larger than its consumers (hyenas), which is always larger than its consumer's population (lions). So in the real world, the wildebeest population would be much larger than the lion population. This allows wildebeests and other predators to survive as a species. This is a part of the balance of an ecosystem and its carrying capacity. However, for the sake of time of game play, we start this game with equal number populations. This allows the characteristic of group behavior to have a more visible role in species survival.
Recommendations:	• Try to make the groups as fair as possible, so that the group behavior of higher up consumers has a larger impact. • It should be made clear that humans are the cause for many

	species endangerment and how group behavior has helped us to have an advantage over other species.
Adaptation for remote learning:	If a game of tag cannot be played in person, students may be directed to review the endangered species list online, found at https://www.worldwildlife.org. Here, students can choose one species of interest and do independent research into the cause of their endangerment. Students can post their research to a blog for the class to review. The whole class can discuss their findings in a virtual meeting.

#16	
Topic:	Heredity: Inheritance and Variance of Traits
Course:	Middle School Life Science
NYS Standard:	HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
Disciplinary Core Idea:	Each chromosome consists of a single very long DNA molecule and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.
Socio-scientific issue:	Genetic cloning
Activity:	"To Clone or Not to Clone?" - - Evaluating the ethics of genetic cloning.
Summary:	In this activity, students will be given role playing cards. Each person will have a short story, including a reason they might benefit from genetic cloning. Each student will take turns at the front of the classroom, reading his or her story. Students will vote as a group, to whether the students at the front will have access to cloning technology or not, evaluating the ethics of genetic cloning on a case-to-case basis. After all students have shared their story, everyone will participate in a class discussion. Students will compare the cases in which genetic cloning appeared ethical, and the cases in which genetic cloning appeared unethical. Students will explain both sides and explore the limitations of genetic cloning right now. Students will explore the process of natural genetic replication versus genetic cloning, and consider the potential dangers of genetic cloning.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Whiteboard or chalk board • Create enough character cards for each student in your class (character cards should include a reason for cloning) Here are a list of controversial examples: o My pet dog is old and I'd like the same exact dog o My liver is failing because I am an alcoholic and I need a transplant o I am 92 and my heart is failing, I need a heart transplant or I will die of old age o My husband died at war and I want to see him again, even If he is 30 years younger than me

	○ My boyfriend dumped me and if I don't make a clone I will never find another person like him ○ Mahatma Gandhi was the greatest man who ever lived, we should clone him to use his wisdom ○ Our country is always at war, we can use cloning to make more soldiers to win ○ There is a food shortage, if we use genetic cloning we can make an endless amount of crops and no one will starve ○ Killing animals for food is cruel, but if we start cloning cattle we can kill only the clones for meat, and let real animals live ○ Killing animals for food is cruel; we can clone certain sections of an animal and use that for food. All meat will be made in a lab, that way we never have to kill a real animal again ○ Thousands of species are on the verge of extinction, we can use cloning to repopulate these species ○ My son is a perfect human specimen, we should clone more of him so that his genes are dispersed around the world ○ My child was a still born, I'd like to make a clone so I can have a chance to raise my baby ○ I miss my grandfather, I'd like to clone him and raise him as my son ○ We can use clones in zoo's to avoid animal cruelty ○ I was treated for cancer and I'd like to use genetic cloning to regenerate the tissue I lost 2) Teachers should start class by prompting students to recall their knowledge of genetic replication as well as genetic cloning. 3) Students will be given instructions: each student will be handed a character card. They are to read their character card to them selves. One by one, students will read the script from their character card, asking the class to approve their request for genetic cloning. The class will act as an ethics committee; they will either approve or deny the use of genetic cloning for each character. 4) Characters whose request gets deny will be listed on one side of the board, characters whose request gets approved will go to the other. 5) When all character have been approved or denied, students will participate in a group discussion about their decisions on the use of genetic cloning. Students will evaluate which circumstances seemed ethical and which did not. Students will also explore the current limitations of genetic cloning as well

	as the potential dangers. PART 2: DISCUSSION QUESTIONS 1) Looking at the list of approved and denied uses of genetic cloning, what are some common reasons to use genetic cloning? 2) What are some of the reasons you decided genetic cloning was unethical? 3) Who should get to make these decisions in the real world? 4) Should there be a set of laws or should it be determined on a case-to-case basis? 5) How is genetic cloning different than normal reproduction? 6) What would you guess are some of the real world ways we use genetic cloning now? 7) What are some potential hazards of genetic cloning (biological and sociological)?
Rationale: (Connection between SSI and standard)	During reproduction, DNA is passed from parent to offspring in the form of chromosomes. While DNA is the actually genetic code that determines your characteristics and traits, it comes tightly wound in the form of chromosomes. During reproduction, the genetic material is copied, proteins read and carry out the instructions of the DNA to form the offspring. In asexual reproduction there is one parent whose DNA is copied completely, creating an identical offspring. In sexual reproduction, 2 parents mate, each giving half of their chromosomes to the offspring, whose DNA is a combination of both parents and there for looks similar to both parents but never identical. All animals, including humans reproduce sexually, which is why we never look the same as our parents or our siblings. In the late 1900's scientist began openly studying cloning. Cloning is a scientific intervention of sexual reproduction in which the sexually produced embryo is stripped of its DNA, which is then replaced with the DNA extracted from the mature cell of the ideal parent. The first animal was successfully cloned in the 1990's and it was a sheep. Since then many animals, including cows and pigs, have been successfully cloned. Although the reproduction of clones has been successful there are many questions as to the health of cloned animals. Some of the noted problems with cloned offspring are defects in vital organs and decreased immune system. In theory, a duplicate of a healthy animal should create another healthy animal but when life moves out of its natural order there tend to be unintended consequences. Today, there is still conflict over policies concerning cloning. Some countries have banned it all together while others have put various limitations on it. An optimistic use of cloning could be used to repopulate endangered species. Cloning could also be used to create

	more livestock for human consumption. While this could solve some famine issues, it also comes with more issues. First, more livestock would produce more greenhouse gases increasing global warming. Second, if cloned animals are known to have damaged organs and decreased immune systems there's a good chance that eating cloned animals would be less healthy and more risky. It is not just animals that researchers aim to clone. There are debates over the ethics of cloning humans. While human clones could provide offspring to infertile couples, provide organ donors for the sick, or provide living humans as tools scientific research. However, the ethics of duplicating human life in an unnatural process are very unclear. Many believe that there would be problems with laws concerning rights for human clones, people would lose their right to individuality, and life would no longer be finite. Could you clone an ex-boyfriend with out his permission? Could you clone yourself before you die so you can live again? Cloning puts a lot of power in the hands of humans. As it stands, in the United States, human cloning is illegal, however animal cloning is not. The FDA has approved cloned animals as "safe to eat" and there are currently no laws that require packaged meat to be labeled if it is from a cloned offspring. As we move away from the natural cycles of life, we are unsure of the effects of consuming unnatural products. There are many people today who fight against genetically modified foods because of the unknown affects in the human body, and cloned meats are just that. Students should understand the role of genetics in the cycle of life. Scientific literacy is required for individuals to understand new technology as it developed and how its potential uses could affect their lives. Students, as citizens need to be able to make informed decisions on laws and funding that govern the use of genetic cloning.
Relevance to Leading Education Research:	In this activity, students role-play and vote on the socio-scientific issue of genetic cloning. This issue has both historical and current controversial context. The controversial nature and real world relation of socio-scientific issues make them emotionally invoking, motivational, and curiosity driving. In an article by Biddy (2015), he suggests that these controversies can be used in the 5E model to increase motivation to learn and interest in scientific concepts.
Possible Misconceptions:	• That clones make exact duplicates in the moment. Clones duplicate exact DNA but that DNA still needs to replicate and divide to create a functioning organ or being. Any cloned animal or human would start as a baby.
Recommendations:	• Some of the issues around cloning are very sensitive. Students should be warned that this could be hard material to consider. This should definitely be altered for children below 9th or 10th grade.
Adaptation for remote learning:	This activity can take place virtually. The roles can be given out, students can share and vote in an online format.

#17	
Topic:	Heredity: Inheritance and Variance of Traits
Course:	High School Life Sciences
NYS Standard:	HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
Disciplinary Core Idea:	In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis, thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutation in genes, and viable mutations are inherited.
Socio-scientific issue:	Genetic testing & gene editing.
Activity:	"Engineer your own debate"-- Construct an argument for or against the use of gene testing and editing.
Summary:	In this activity, students will be given character cards with narratives to follow. Students will utilize both their character narrative and their own understanding of ethics to pick a side to debate one. Students will either choose to be for genetic testing and gene editing or students will choose to be against genetic testing and genet editing. Students will participate in a classic debate. Each side will have an opportunity to make points, as they argue back and forth to determine whether it is safe and ethical to use genetic testing and gene editing as a medical practice. While the students debate, either the teacher or an assigned student should act as the debate reporter, recording key points of each side of the debate on the board. Once the debate has ended, students will reintegrate to discuss and evaluate the conclusions on the ethics of genetic testing and gene editing. In a class discussion, students will explore the implications of genetic testing and the method of gene editing. Students will examine the limitations of genetic testing and gene editing right now as well as the possibilities for the future.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Character cards with narrative Examples: o My first born son was born with a genetic disorder, I'd like to test my unborn son and use gene editing to prevent him from having the same genetic disorder o Everyone in my family has blonde hair but my

	wife has black hair, I'd really like to use gene editing to change the color of my sons hair o I'm a doctor, I'd like to see genetic testing and gene therapy used to prevent disease and disorder o I'm a doctor, I'd like to make a lot of money offering people gene editing to create the offspring of their choice • Chalk board or white board 2) Students begin with a prompt to recall genetic replication and the expression of traits. 3) Students are then introduced to the concepts of genetic testing and gene editing, as means to control genetic replication and alter the expression of traits. 4) Character cards are passed out to students. 5) Students have a minute to read the narrative and to decide which side of the debate they will be on (for or against genetic testing and gene editing) 6) Students will split into two sides of the room, facing each other to participate in a classic debate to answer the question; is the use of genetic testing and gene editing as a medical practice safe and ethical? 7) Students will go back and forth, all students will be prompted to at least share why they chose that side of the debate. 8) When the debate naturally subsides or a certain amount of time has passed, the class will regroup as a whole to discuss and evaluate the outcome of the debate. 9) Students will consider how genetic testing and gene editing are done, how they can be used to help people, how they can be used improperly, and where the ethical boundaries are. PART 2: DISCUSSION QUESTIONS 1) How is genetic testing done? 2) What are some of the commonly applied uses of genetic testing in use right now? 3) How would you think gene editing is done? 4) What are some positive applications of gene editing? 5) What are some of the ways gene editing should not be allowed to be used? 6) What are some of the issues with allowing the use of gene editing? Why is gene editing a controversial issue? 7) What are some solutions to the controversial problem of gene editing?
Rationale: (Connection between SSI and standard)	During reproduction, the genetic material is copied from the parents to the offspring. However, genetic material of the offspring is not identical to the parents and new genes may present themselves. Genetic variation occurs during reproduction due to a few different factors.

	First, during sexual reproduction, when cells are combining DNA from two parents, these combinations can produce new genetic expressions. Second, during the replication process random mutations are known to occur. Third, environmental factors like chemicals or radiation can causes changes or mutations in an individuals DNA. Some mutations to DNA are advantageous, they look appealing, they improve survival skills, or they increase immunity and health. Other mutations are less advantageous. Genetic disorders are genetic diseases caused by mutations that are inhibiting or debilitating to some degree. For example, down syndrome is caused by a mutation to the 21st chromosome, Crone's disease is a genetic disorder that effects digestion and Huntington's disease is a genetic disorder that causes nervous system damage. Genetic testing is used by scientists to read the DNA of an individual and uncover any harmful mutations that might exist. After the success of cloning in the 1900's, scientists began looking further into the possible work they could do with genetics. In the 2000's gene engineering became an area of study in which they insert new genetic material into the hosts' genome. Today, genetic engineering has evolved to gene editing, a practice in which they can precisely replace a genetic sequence to obtain a desired outcome or expressed trait. A machine called the CRISPR makes editing genes in this way easy and accessible. Gene editing is currently only practiced on animal, as society continues to determine the ethical impacts of gene editing. There are strong pros and cons to the use of genetics testing and gene editing. Genetic testing is used in the medical field to confirm genetic disorders and offer proper treatment. Right now, parents can opt for early genetic testing to predetermine if their child might have any array of genetic disorder. The upside to this early testing is that it allows parents time to prepare for their child's future needs. The downside to this testing is that parents often wish there was something they could do to change circumstances. Gene editing would allow experts to remove genes causing any genetic disorder and replace them with a healthy gene sequence. While this would be a noble use of gene editing, once allowed on humans, many instances of unclear use could arise. Parents might ask to edit the appearance of their offspring. Maybe they want to make them faster or stronger. Maybe we use gene editing to remove all vulnerability to disease. Maybe we edit genes so that DNA can be copied indefinitely and we never age. The possibility for the impact of the use of gene editing is far and wide. It could change life, as we know it. While optimistically we'd like to believe it would provide opportunity to enhance all life, there is a strong possibility that only the wealthy would be able to afford gene editing. Enhancing the appearance, health, and longevity of the wealthy, creating a larger gap between the rich and the poor. Students should understand the importance genetics plays in our

	humanly function. Scientific literacy should allow students to understand the current research and laws on gene testing and editing. While there is a lot of good that can come from the medical use of gene editing, it could have disastrous societal impacts if used with greed. Students and citizens need to be able to make informed decisions about the use of human gene editing.
Relevance to Leading Education Research:	Science itself is about formulating ideas (hypothesis) and finding evidence to support that claim. This is the same structure as a good argument. On this basis, good argumentative skills are good scientific reasoning skills. This activity uses role-play and active debate to tackle the controversial use of genetic testing and gene editing. A study by Ozturk and Doganay (2019) correlates a very strong relationship between socio-scientific issues based instruction and the development of complete argumentative skills by students. Further, the controversial nature of the issue is a strong motivating factor for students.
Possible Misconceptions:	• Students should be informed of the difference between genetic engineering and gene editing. • Students should understand the concept of genetic mutation. It should be distinguished that although some random genetic mutation leads to disability, other random genetic mutation leads to new advantageous characteristics that lead to adaptation and evolution. Genetic control might eliminate unwanted genetic mutation but it might also limit evolutionary mutations that could occur.
Recommendations:	• To ensure all students participate, each student should be required to at least share the narrative of their character card and explain why they chose the side they were on. • The debate should have a time limit so it doesn't go on forever.
Adaptation for remote learning:	This debate can also be done virtually. The following website can be used in preparation for the debate to understand the role of gene therapy. https://www.exploregenetherapy.com/how-gene-replacement-therapy-works?gclid=CjwKCAiA5IL-BRAzEiwA0lcWYstiBluxgOkl9sGrhk5IgrEZ7RZwSW9W7NAv8ANtlXzJkQuRpnRR6xoCaagQAvD_BwE

#18	
Topic:	Heredity: Inheritance and Variance of Traits
Course:	High School Life Science
NYS Standard:	HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
Disciplinary Core Idea:	Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.
Socio-scientific issue:	Epigenetics.
Activity:	"Epigenetic Lock" - - Exploring the keys to changing your genetic code.
Summary:	In this activity, students will explore the ways in which your environment can alter the expression of your genetic traits. In the beginning of class, students will be given half of the letters to a 30 digit DNA strand. This will represent their own genetic code or DNA. Students will begin a hunt for the rest of the code, but not all will be able to get the code. Students will interact with their environment, looking for "factors" (stations around the room with questions about the environment) that will either turn on more of their genetic code (add letters) or turn off more of their genetic code (erase letter), based on how they interact at that station. Once the students have made it to every station, at end there will be 3 "locked" doors, their code will allow them to open one of these doors. This is the "expression" of their genes. Inside each door will be a piece of paper students will take back to their desk and complete independently, it will include a short note about the environmental factors that affected their genetic code along the way and a small space for students to reflect on their own interactions with the environment. After students have had time for personal reflection about their own environment and behaviors, they will participate in a class discussion. Students will be asked not to share anything personal about what their genetic code unlocked. Instead students will be asked to share their observation and analysis of how the environment can effect ones genetic expression.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Make up a random 15-letter DNA strand. This will be given to students in the beginning of class. • Paper and pencil. • 15 Stations around the room. Each station should include; an object representing some environmental factor, a question about that factor, a yes or no option, and a consequence for each. o Station 1 (Car, do you live near a lot of traffic/car

	pollution? yes- erase a letter, no- add a T) o Station 2 (Tree, do you live near a lot of trees? yes- add an A, no- erase a letter) o Station 3 (Shoe, do you spend a lot of time outside? yes- add a C, no- erase a letter) o Station 4- (Water bottle, do you drink filtered or spring water? yes- add a G, no- erase a letter) o Station 5- (Boxing gloves, do you get mad often? yes- erase a letter, no- add a T) o Station 6 (Pillow, do you get 7 hours of sleep at night? yes- add an A, no- erase a letter) o Station 7 (Empty cigarette carton- do you smoke tobacco or live with anyone who smokes tobacco? yes- erase a letter, no- add a G) o Station 8 (Soccer ball, do you play sports or stay active? yes- add a C, no- erase a letter) o Station 9 (Paintbrush, do you find ways to creatively express yourself? Yes- add an A, no- erase a letter) ETC. • Code instructions: After you have been to all 15 stations, count the number of nucleotide bases (letters) that make up your genetic code. If you have 0-9 letters, the expression of your genetic code is 0, use this number to unlock the first box. If you have 10-20 letters, the expression of your genetic code is 1, use this number to unlock the second box. If you have 21-30 letters, the expression of your genetic code is 2, use this code to unlock the third box. • Reflection papers for each box. o Box 1: The expression of your genetic code was 0. This means there are multiple environmental factors in your daily life that are limiting the expression of your genetic code. With simple, positive changes to your environment or your behaviors, you can unlock DNA and increase the productive function of your body. Some aspects of life are hard to change, but the first step is becoming conscious. Below, reflect on environmental factors that might impact your genetic expression? How can you use what you've learned here to increase your health? o Box 2: The expression of your genetic code was 1. This means you have a balance of environmental factors limit your genetic expression and enable your genetic expression. This is like staying neutral. By becoming conscious of little interactions with your environment, you can make small changes that will result in enhanced genetic expression and increased productive

	function of your body. Below, reflect on environmental factors that might impact your genetic expression? How can you use what you've learned here to increase your health? o Box 3: The expression of your genetic code was 2. This means you have an abundance of positive behaviors and environmental factors that enhance the expression of your genetic code. Stay conscious and keep making good choices. Below, reflect on environmental factors that might impact your genetic expression? How can you use what you've learned here to increase your health? 2) Students will begin this activity by copying the first 15 letter of the code from the teacher, onto a piece of paper using pencil. This will represent their genetic code. 3) Students will then interact with the 15 stations around the room, answering the questions and following the consequent instructions. Positive interactions will unlock genetic code and negative interactions with shut down genetic code. 4) After students have been to all 15 stations they will follow the "code instructions" to obtain the secret paper form the lock box. 5) Students will read the paper from the lock box and answer the reflection questions. 6) After personal reflection, students will participate in a class discussion. Students will not be asked to share their code numbers or the answers to their personally questions. Students will evaluate connections between environmental factors and over all genetic expression. PART 2: DISCUSSION QUESTIONS 1) How did the environmental factors and behaviors effect your genetic expression? 2) What are some positive factors that might enhance genetic expression? 3) What are some negative factors that might limit genetic expression? 4) Based on this activity, how would you define epigenetics? 5) What are some real life examples of epigenetics at work?
Rationale: (Connection between SSI and standard)	DNA is recombined during reproduction to produce a novel looking offspring. Even when offspring are not related, they may bear similar characteristics when raised in the same environment. Research suggests that an organism's observed traits are a combination of genetic and environmental factors. While genetics may provide the base code for the function of an organism, environmental factors may lead to chemical and physical changes inside the cells of the body that alter how the genetic code is read. Epigenetics is the term for any

	factor that alters genetic expression without altering the DNA sequence. For many years scientist debated the reality of epigenetics, under the impression that changes in DNA were necessary to facilitate changes in expression. Now, enough research has been done to prove that environmental factors can alter genetic expression. One example of epigenetics is methylation, during methylation a methyl group attached to one of the nucleic acids that make up DNA and alters its function. Methylation of DNA is found in many types of cancer and a few other illnesses. Besides methylation, other chemical processes like acetylation, phosphorylation, and sumolytation are known to impact genetic expression. These chemical processes are a result of environmental factors such as pesticides, heavy metals, diesel exhaust, tobacco smoke, radioactivity, viruses and bacteria. Epigenetics affect us all, even with a perfect set of genetics, their expression can be altered by harmful factors in the environment. It's important for us all to determine which factors cause damage to our genetic expression and eliminate them from our society. Pesticides are on the majority of our foods. Certain pesticides have been banned after having direct links to causing cancer. Heavy metals, like lead, have been used through out time for the production of various objects and even paint. Old houses in impoverished locations often still contain lead paint and the potential for lead poisoning. A large percent of Americans smoke tobacco and others are at risk from second hand smoke. Further, there is a present debate over the epigenetic effects of vaccinations, as viruses are known epigenetic factors and vaccinations function by injected viruses into the body. If anything, epigenetics show us how important our environment and what we absorb into our body truly is. While all of the materials mentioned above cause epigenetic damage to the body, proper nutrients can effect positive, healthy epigenetic change! Students should understand the environmental impact on gene expression. It is crucial to have informed individuals who can consciously understand how the world around them impacts their body so they can make healthy decisions. As a society, we decide whether things like vaccines or nuclear energy are safe by understanding the leading research and making informed decisions on laws and regulations. As a society, our health depends on our understanding o science.
Relevance to Leading Education Research:	This activity asks students to make real world connection to their life, exploring the effects of their everyday behaviors and choices. This activity asks students to be active learners as well as active and conscious advocate for their own health. In a study by Karahan and Roerhig (2016), it is suggested that socio-scientific issues based activities have the ability to promote student agency and the individual power of the student in their decision-making. Here students are able

	to increase autonomous decision-making skills relevant to their real life choices.
Possible Misconceptions:	• That every action you take causes an immediate change in your genetic expression. This is not true, however, we are still learning about how intricate the facets of epigenetics are.
Recommendations:	• This activity may cause students to have to face hard realizations about their own environment and behaviors through real reflection. Be observant of student attitudes and behavior and be prepared to have conversations with students if necessary. This activity is intended to demonstrate how important your environmental factors can be on your overall health. • Students should be asked to be honest but should be made to feel like the classroom is a safe space to do so.
Adaptation for remote learning:	Students can explore this PhET simulation on gene expression. https://phet.colorado.edu/en/simulation/gene-expression-essentials

#19 **Topic:**	Biological Evolution: Unity and Diversity
Course:	High School Life Science
NYS Standard:	HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
Disciplinary Core Idea:	Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.
Socio-scientific issue:	Racism vs. one human race.
Activity:	"Who are you?" - - Analyzing data to prove a common ancestry between all humans.
Summary:	In this activity, students will look at headlines from articles through out history highlighting the controversy of the long-standing race war that had plagued our nation. Students will then analyze and compare multiple lines of empirical evidence between ape and human species over time. Students will be able to compare human genomic records from multiple races as well as multiple species. Students will then use this data to determine whether various human races are more different or more alike and how we could use this information to bring people together. Students will analyze fossil records, DNA sequences, anatomical structure, and embryological structure from multiple different species over time, as well as 2 human species of different races. The students will be given a list of possible species, but they will not know what any of the identities belonging to the evidence, including the humans. Students will analyze and compare evidence to determine which species is which, based on proof of evolution and evidentiary lines of decent. After students draw conclusions about the species and relationships of the samples, they will participate in a group discussion. Students will discuss the line of descent, from one sample species to the next, explaining how they drew conclusion about common ancestry from the empirical evidence. Further, students will explore the relationship of common ancestry between the two human samples, discussing the social implications of knowing that we come from the same ancestor.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Shocking headlines from articles about the race war in our nation spanning American history. • Evidence from at least five sample species; ideally, two

	humans of different races, a chimpanzee, a gorilla, and an orangutan. Evidence must include; fossil records, DNA sequences, anatomical structure, and embryological structure. • Computer and internet 2) Headlines should be placed on student's desks. They should be given a few minutes to read the headlines. 3) Students should be asked to infer what these headlines are referring to. 4) Students will then examine and compare evidence from the sample species to determine which sample belongs to which species. 5) Students will then use the evidence to draw conclusion about common ancestry between all species in the creation of an evolutionary tree. 6) Students will participate in a class discussion about the classification and common ancestry discovered between humans and apes. Students will also explore the social implications of understanding that all humans descend from the same ancestor. PART 2: DISCUSSION QUESTIONS 1) Of the species examined, which two had the least in common? 2) Use your computers; how long ago did they share a common ancestor? 3) What were some similarities and differences found in the evidence? 4) Of the species examined, which two had the most in common? 5) Use your computers; how long ago did they share a common ancestor? 6) Were there any differences between these two species samples? 7) What kind of social implications can be made about the various human races when considering what we call descendants from one common ancestor? 8) How does drawing these conclusions help bring us together and end division? 9) If we are all one human species with no evolutionary splits since the humans came into existence, how can we define race? 10) How can we use scientific evidence, to bring us together as a global community, and end division and racism?
Rationale: (Connection between SSI and standard)	There are nearly 8 billion humans living on the planet right now. Every single human that lives or ever lived has a completely unique genetic identity. That is, the DNA sequence that makes up their genome has never and will never be seen again. While it is true that we are all unique individuals, we also share similarities. Members of the same family share a genetic lineage. Their genes are closely related and you can find evidence of their common ancestry through their genetic

	information. DNA sequences can be compared to find identical sequences amongst their long unique DNA strand. Through the process of comparative DNA individuals can trace their ancestry back generations. Companies like Ancestory.com will do this for you. Scientist use fossil records from species as old as we can find to uncover connections between species. Through this research we have uncovered that humans share a common ancestry with apes that lived over 6 or 7 million years ago. Around this time, the human species evolved, branching off into its own classification, but the common genes that link us to our common ancestor can still be found. It's a misconception that people from different regions or races do not have anything in common. In fact, all humans that exist today share ancestral DNA, which means we all come from the same origins. Unfortunately, today, humans start wars over race, religion, and national pride. The notion that we all come from the same origin is lost. Countries and borders divide people. Race creates division among members of the same community. Millions of humans have died because a group of humans believes they are better than another group of humans. Racism and war plague humanity. When countries fight they fight for the people to which they feel connected. When racism ensues its because one group of people believes they are superior to another. These patterns of thought lead to social inequalities, economic disparities, and death that plague communities. These patterns of thought stem from the misunderstanding that there are different types of humans. This year in the U.S. 14 people died in the black lives matter movement, in which people fight for the equanimity and equality of black Americans. During the civil rights movement, in which African Americans fought for equal rights, at least 41 people died. In the early 1860's more than 620,000 Americans died fighting in the Civil War, half fighting to keep African Americans enslaved and the other half fighting for their freedom. Conflict among humans happens everywhere and it is always caused by differences among them. If humans worked together with an understanding that we are all brothers and sisters of the human race perhaps societies could be relieved of the strain that comes from war and conflict. Growing up in such a polarized world, students should understand that all humans come from the same origin. Students should be able to use empirical evidence from genetic information and fossil records to conclude that humans are all related through our ancestral DNA. Society needs scientifically literate citizens who can use critical discoveries and data to resolve social issues.
Relevance to Leading Education Research:	This activity utilizes shocking, controversial, and emotion evoking headlines to grab student's attention and drive engagement. Headlines are short and have the ability to drive student inquiry to learn more,

	especially when concerning relevant socio-scientific issues. An article by Harris, Stevenson and Joyner (2015) supports the theory that controversial headlines evoke an emotional response to create engagement and heightened interest. These headlines concerning socio-scientific issues therefore make a great attention-grabbing introduction into the issues and relevant content.
Possible Misconceptions:	• The term "common ancestor" refers to a species that directly evolved into two new species. • It should be clarified that humans (of all races) are included in the same species, Homo sapiens, which should be supported by empirical evidence.
Recommendations:	• If you can get real fossils and bones, that makes this activity far more engaging.
Adaptation for remote learning:	Pictures of fossils can be used as evidence for students to analyze at home. Virtual meeting space can be used to share findings and for class discussion.

#20	
Topic:	Biological Evolution: Unity and Diversity
Course:	High School Life Science
NYS Standard:	HS-LS4-2 Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for species to increase in number, (2) the heritable genetic variation of individuals in species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
Disciplinary Core Idea:	Natural selection occurs only if there is both (1) variation in genetic information between organisms in a population and (2) variation in the expression of that genetic information-that is, trait variation- that leads to differences in performance among individuals
Socio-scientific issue:	Novel Coronavirus (2019) –(biological disease & warfare)
Activity:	"Super spreaders" - - Examining how genetic variation can work against us and for us.
Summary:	In this activity, students will explore how quickly viruses, like novel coronavirus can spread. Students will also be able to compare how genetic variation of the coronavirus enabled it to spread so quickly and how genetic variation in humans saved us from extinction. Upon entering class, students will be exposed to glow in the dark paint. Students who unknowingly touch the clear paint will continue to spread it around the classroom and other students as they interact normally. Student socialization will be encouraged for a few minutes longer than usual, until suddenly there is an emergency news flash; "CORONAVIRUS IS IN THIS CLASSROOM, scientists say this is not the first coronavirus, this one moves fast and quiet and it glows in the dark!!!" Students will be directed to turn off the lights and we will examine who has the virus (the glow in the dark paint) on them. Another news flash; "this corona virus kills all students with black hair or brown eyes instantly". If you have either of these traits you must drop to the floor immediately. Students will observe how much of the population survives the classroom coronavirus. Students will then participate in a class discussion. Students will work to uncover the original source of the virus in the classroom. Students will evaluate how genetic variation saved the population of humans. Further, students will explore how genetic variation in the virus caused increased effectiveness of it's own population.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Glow in the dark paint or UV light paint • A fake "news flash" video about a virus in the classroom • A second "news flash" video calling out the students

	who will be affected 2) Strategically place the paint (the virus) on the door and door handle, so that students touch it upon entering the room. 3) Allow the students to socialize for the first 5-10 minutes of class. Allowing the virus (the paint) to spread around the classroom via interaction. 4) Pop on the first news flash video (volume up to grab students attention); informing students that there is a virus in the classroom and that it is visible in the dark (or under UV light). 5) Turn off the lights and allow students to observe where the virus has spread. 6) Pop on the second news flash video; informing students that it will affect all students with black hair or brown eyes. (They must immediately drop to the floor.) 7) Students observe how much of the population is remaining. 8) Class discussion PART 2: DISCUSSION QUESTIONS 1) What part of this activity represented a virus? 2) How did the virus spread around the classroom? 3) Why didn't everyone die from the virus? (In the simulation and in real life) 4) How many people in the class would have "died" if you all had identical genes? 5) How is genetic variation important for human survival? 6) Genetic variation doesn't just help humans; it helps all species with survival. How did genetic variation help the coronavirus?
Rationale: (Connection between SSI and standard)	In 2020, the world faced its first global pandemic. The first issue that has plagued all populations on the planet since the last global extinction some millions of years ago. The pandemic, caused by a viral population known as Coronavirus or COVID-19, has killed 1.23 million people worldwide. The coronavirus is a strain of virus that comes from a family of similar viruses. An older version of this virus has existed for some time. Not infectious or deadly enough to successfully grow, which is the goal of all living things, to a significant population size the virus evolved. After a series of mutations led to 4 variations still with no advantageous characteristics finally a mutation occurred that caused the SARS-covid virus. In 2002, the outbreak of SARS affected 26 countries, killing 8,000 people. Eventually, humans found a way to minimize the impact of SARS. 18 years later, the virus evolved again to become COVID-19. COVID-19 is the evolved version of the coronavirus. It's genetic evolution allowed for greater population growth, great ability to compete for limited resources, and enhanced survivability and reproduction. Coronavirus is not the only organism evolving to survive. Humans have been evolving to better compete for limited resources, survive and

	reproduce since they emerged. In our evolution, we have managed to outcompete, out survive, and out reproduce most other species. Even in the wake of coronavirus, the humans who are able combat the coronavirus are those with predisposed genetic advantage. Through the variation of human genetics and its expression, natural selection will allow the most fit of the species to survive an attack, like coronavirus, and evolve into the next level of human being. Today, humans evolve at a faster rate than most species. However, this does not mean we will always be superior to other species. Something as small as a virus can intelligently evolve to challenge us. Students should understand that through genetic mutation and competitive survivalism, all species have the opportunity and the likelihood to evolve. Citizens need be able to conceptualize the roll of evolution in our own lives as well as the lives of other organisms, which challenge us. Further, the world needs scientist who will study the evolution of small organisms like bacteria and viruses in order to protect us from another pandemic.
Relevance to Leading Education Research:	Education literature suggests that introducing socio-scientific issues into the secondary science classroom not only directly develops critical thinking skills, it prepares students for the real world and increases motivation to learn through real life relevancy. In an article by Smith, Ji and Shiyan (2019) it is suggested that using fictional narratives is a good way to introduce socio-scientific issues. Activities such as this one provide students the opportunity to explore real world important issues while also using their imaginations to create solutions that feel relatable to their lives as they are now. Through this activity in which students play out a fictional disease spreading narrative in the classroom, students are able to understand the real world phenomenon of disease spread such as COVID-19 which is a current socio-scientific issue. Through this activity, students are able to develop in-depth understandings of pressing socio-scientific issues but were offered the opportunity to connect to their real lives through the narrative of fictional creativity.
Possible Misconceptions:	• COVID-19 is not the first corona-virus. Genetic variation is how Covid-19 became a successful spreader. Genetic variation is also how humans became successful survivors of the virus. Genetic variation is a consistent driving factor in evolution.
Recommendations:	• To increase spreading, the teacher can place paint in more commonly touched areas. The teacher can use paint on his or her own hand and high five all students on their way in to ensure spread.
Alternative SSI's for this standard:	Students can use their own first hand accounts of living through coronavirus. Teachers may opt to have students write an "emergency diary" in which students recall how the Corona-virus spread across the world.

#21 **Topic:**	Biological Evolution: Unity and Diversity
Course:	High School Life Science
NYS Standard:	HS-LS4-3 Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait to increase in proportion to organisms lacking this trait.
Disciplinary Core Idea:	The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. Adaptation also means that the distribution of traits in a population can change when conditions change.
Socio-scientific issue:	Resistance adaptation.
Activity:	"How fast can you adapt?"- - Create resistance and analyze how we adapt.
Summary:	In this activity, students will demonstrate how competing species will adapt for survival. Student's role-play as "farmers" and "pests", working against each other. Farmers work to protect their crops. While pests work to obtain their crops. This a slow strategy game. Farmers take their time using tools to protect their crops. Pests use tools to obtain them. Farmers and pests take turns going back and forth. Each round only one team can be successful, either the crops are protected or they are not. The unsuccessful team must adapt by adjusting their strategy for the next round. When the game play is over, students will participate in a class discussion. Students will analyze how adaptation helped each team survive and draw comparisons to real life examples of adaptation.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Balls to represent crops • Tools for game play: sticks, string, boards, books, pillows, etc. (anything students can find to build with is okay to use as long as it is not dangerous) 2) Students split into two groups or multiple groups. Groups pair up to face off. One team is the "farmers" and one team is the "pests". 3) Farmers go first. Using the assortment of random tools, farmers have one minute to create a barrier so that the pests cannot steal the balls (the crops) from them. 4) Pests go second. Using the assortment of random tools, pests have one minute to attempt to break the farmers barrier and obtain the balls (the crops). 5) Steps 3 and 4 are repeated back and forth for the duration of the game. Game ends on a time limit. The team with the most

	successful rounds wins. 6) Class discussion. PART 2: DISCUSSION QUESTIONS 1) How many times did your team have to change your strategy? 2) Why did you need to change your strategy? 3) How would you define adaptation? 4) Was the adaptation seen in this activity behavioral or genetic? 5) What are some ways you adapt in your life? 6) Every time you adapt (in the game and in real life) did you have to face a new challenge? 7) Long-term adaptation is genetic in nature. What is the term for this? 8) When two species are in a competitive relationship and one species evolves, what happens to the other species? 9) In agriculture, farmers use pesticides to protect crops against pests. Sometimes pests develop resistance adaptations. What does this mean? 10) What are some other areas of modern life in which a population might develop resistance adaptations? 11) Why are resistance adaptations an issue for the human species? 12) What are alternative solutions to pesticides, antibacterial medicines, and vaccines? OR How can humans adapt to compete against resistance-adapted species?
Rationale: (Connection between SSI and standard)	Viruses, bacteria, and insects are the smallest living organisms known today. Though tiny, all of these forms of life are naturally intelligent, constantly developing ways to evolve. Like all other forms of life, their root purpose is to survive and reproduce and evolution is the best way to ensure that continues to happen as changes in environment are bound to occur and new challenges are met. Viruses and bacteria discovered long ago that they could obtain the necessary resources and increase reproducibility by entering a host organism. When a virus or bacteria enter a human (or an animal) it is called an infection. Viruses and bacteria are responsible for human diseases such as the flu, chickenpox, shingles, HIV, polio, step throat, chlamydia, and pneumonia. Humans, who have evolved to be strategic thinkers and problem solvers, have found ways to combat these viruses and bacteria. We created vaccines to combat viruses and antibiotics to combat bacteria. The issue is that both viruses and bacteria are programed to evolve as well. While at first vaccines and antibiotics are always effective at reducing unwanted populations, eventually the virus or the bacteria evolves. For the virus or bacteria to evolve a mutation in its DNA must occur that allows it to survive, even against vaccines or antibiotics. When this occurs, the new strain of the virus or the bacteria will reproduce, replenishing the once diminished population. This phenomenon is called resistance and it occurs when a virus or bacteria becomes resistant to death by

	treatment through vaccines or antibiotics. There is growing concern that vaccines and antibiotics are in effective long term solutions and that they are not healthy for the human body. Today, there is a collective of people who fight for the ideology that vaccines are dangerous for human use. Insects have the ability to become resistant as well. As the human population has increased, the dependence on large-scale food production has also increased. Crop farmers, who produce large quantities of food, rely on healthy viable crops each year. When a large population of insects eats through a large crop farm it destroys the crop, these insects are called pests. This is a common problem among farmers. To combat this problem, pesticides were invented. Pesticides are chemicals sprayed on crops to prevent pests from eating them. The issue here is also that pests can become resistant to pesticides. It takes constant rejuvenation of pesticide formulas to keeps pests out of crops, and the deeper issue is that humans ingest those pesticides so they need to be safe for human consumption (many of which have been proven not to be). Similarly, there is growing conflict over the effectiveness and health of the use of pesticides. In 2019, a pesticide company called Round Up lost a court case in which it was proven that their pesticides caused human cancer and disease. Students should understand how the patterns of evolution directly impact their lives, allowing the most favorable characteristics to be reproduced. Further, students should understand how vaccines, antibiotics, and pesticides work as well as how they can fail us. We rely on scientist to use their understanding of the biological and evolutionary processes to solve problems concerning the degradation of our food source by pests and the degradation of our bodies by other viruses' and bacteria. Informed citizens can decide whether the benefits of the use of vaccines, antibiotics, or pesticides outweigh the risks. Future scientist may create a new way to combat these problems.
Relevance to Leading Education Research:	This activity utilizes role-playing games combined with tinkering or design based learning to allow students to explore the real world phenomenon of pest resistance. Bevan, Gutwill, Petrich, and Wilkinson (2015) suggest that hands on exploration found in tinkering and design based activities is engaging for learners, and the ability to make choice during learning drives initiative and intentionality. As students are able to autonomously problem solve, these activities demonstrate students growth in conceptual understanding. Jones, Chittum, Akalin, et. al. (2015) prove that design based activities increase engagement through hands on exploration and increase student empowerment through the ability to make their own choices.
Possible	• Behavioral adaptations happen all the time throughout life.

Misconceptions:	Genetic adaptations occur slower, and happen over generations. Genetic adaptations lead to long-term evolution. Although behavioral adaptations can lead to genetic change through epigenetics, also leading to evolution! • Resistance to a harmful variable is an advantageous heritable trait. Inevitably, resistance is a genetic variation that leads to evolution of a species. This can be related to the previous lesson.
Recommendations:	• There should be a time limit for each section of this activity Ex. 5 minutes for each team to either build or penetrate. If there is too much time for each, the point will get lost.
Adaptation for remote learning:	This activity cannot be completed remotely. An alternative might be to have students do independent research on an example of resistance adaptation. The discussion covers the same points, in a virtual format.

#22 **Topic:**	Biological Evolution: Unity and Diversity
Course:	High School Life Science
NYS Standard:	HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
Disciplinary Core Idea:	Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment.
Socio-scientific issue:	Invasive species.
Activity:	"Invasive musical chairs"- - Explore how invasive species disrupt natural selection.
Summary:	In this activity, students will play musical chairs to demonstrate the natural selection process that allows species to find their niche in an ecosystem. When students from another class unexpectedly stop by, students will explore how an invasive species can disrupt the balance of the ecosystem by stealing a species niche! In some ecosystems, species will adapt to the invader, with native species winning through natural selection. Other ecosystems will collapse, being over run by the invasive species. Students will analyze how the ecosystem first formed through natural selection and how the ecosystem was disrupted by the invasive species. Further, students will compare the ways in which ecosystems might adapt to invasive species and the ways in which invasive species might destroy an ecosystem.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Chairs set for musical chairs. Instead of one big circle, chairs should be in four small groups, representing different habitats (tundra, grasslands, desert, rainforest, etc.) For the first round there should be enough chairs for everyone in the class. • Music • Students in class each represent a whole species • Four volunteer students or teachers from another class represent invasive species 2) Students will play musical chairs. Chairs will be set in fout small circles, labeled as various ecosystems. For the first round, students will walk around all four small circles until the music stops. When the music stops they will find a chair in their new habitat. Every student should have a chair. Through natural selection, they have found their niche. 3) Students will play a second round, this time around the smaller circles, staying in their habitats. No chairs were removed. When the music stops the students find a chair. With every chair in each habitat filled, the ecosystem is in balance.

	4) Students will play a third round. This time 4 students from another classroom have snuck in. When the music stops, each of these four new students will steal a chair at each of the habitats. 5) One student at each habitat will be without a chair, that student is out and has been removed from its niche by the new student (the invasive species). 6) Students will play subsequent rounds, each time removing a chair, until there is only one species left in each habitat. 7) Class discussion PART 2: DISCUSSION 1) What part of this game represented natural selection? 2) At what point in the game was your ecosystem in balance? 3) Who in this game represented an invasive species? 4) What makes a species invasive? 5) What are some real life examples of invasive species? 6) What are some ways invasive species get to new, foreign places? 7) How do we resolve the issue of invasive species? 8) Would you consider humans invasive species? 9) Can the Earth and the other species on it still adapt to survive or have we destroyed the ecosystem?
Rationale: (Connection between SSI and standard)	With in an ecosystem, many different species co-exists. Through a well-balanced food web, energy is transferred around the ecosystem. This energy determines a balance which keeps the ecosystem and equilibrium and species populations relatively stable. Through natural selection, each species takes its role (also called niche) in the ecosystem. When there is a change in the ecosystem, species either evolve or die; this is the essence of natural selection. Today, many ecosystems face threats from human activity that are well beyond the natural order. When a change in the ecosystem is too drastic, the organisms don't have enough time to evolve. Some human disturbances are so drastic that whole species population and even some ecosystems collapse. One of the most underrated ways that humans can destroy ecosystems is through the introduction of invasive species. Invasive species are species that were unnaturally moved from their native habitat to another. Due to increased distance and frequency of human migration and travel, we have accidentally, and sometimes purposefully brought invasive species to unwanting ecosystems causing irreparable damage. When an invasive species finds itself in a new ecosystem it will need food and shelter, displacing native species and leaving others to starve. Some invasive species simply take the place of another species, dominating its niche and essentially kicking it out of its spot. In other instances, the invasive species eats the food

	belonging to multiple other species in the food chain and there is no species above them in the food chain to keep them in check, so their population is able to run rampant, sometimes taking over whole ecosystems. An example of an invasive species is the stinkbug! Stinkbugs are actually native to Asia; however, they are now populating the United Stated. Unchecked by any predators here, their population soars as they can be found in almost any home across North America. Any invasive species threatens the biodiversity that arises from natural selection and therefore threatens the stability of the ecosystem. However, there are some invasive species that do more damage to the environment than stink bugs. Some invasive species destroy land, rot out trees, or carry disease. Students should understand the importance of natural selection for the continued survival of each ecosystem. Further, they should understand the impact of complex human action, like traveling and importing goods, could have on your immediate environment. Once settled, invasive species are nearly impossible to get rid of and sometimes just as hard to keep in check. Scientifically informed citizens can make effective decision about their own actions as well as policies and solutions for the invasive species problem.
Relevance to Leading Education Research:	One of the basic principles of the Nature of Science states, that scientific models, mechanisms, and theories explain natural phenomena. This activity uses role-play to model the natural phenomena of invasive species. In a study by Herman (2018), it is indicated that the use of activities that highlight principles of the Nature of Science help students conceptual understanding of real world phenomenon, socio-scientific issues and scientific concepts.
Possible Misconceptions:	• Students should understand that staying in the game of musical chairs is akin to surviving in the wild. • Natural selection is the process by which the naturally more adapt students will take a chair, akin to finding their niche and surviving in the wild.
Recommendations:	• Costume or colored t-shirts for the "invasive species" will help students to more clearly see what is happening during the game.
Alternative SSI's for this standard:	Students can explore natural selection through the virtual PhET simulation on natural selection in the wild. https://phet.colorado.edu/en/simulation/natural-selection Class discussion can still take place in a virtual meeting space.

#23	
Topic:	Biological Evolution: Unity and Diversity
Course:	High School Life Science
NYS Standard:	HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
Disciplinary Core Idea:	Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic the opportunity for the species evolution is lost.
Socio-scientific issue:	Forest fires.
Activity:	"Engulfed in flames"—Analyze the impacts of forest fires.
Summary:	In this activity, students will observe the shocking impact of fire first hand as we set multiple objects on fire (safely, with guidance of a teacher). The students will analyze the remains of the burnt objects to answer the question; is it salvageable? As a class students will vote, if the object is salvageable or not. The last object that will be burnt is a small tree. Students will work together to put the "forest" fire out. Using only scalable amounts of water, comparable to real forest fire fighting equipment. After the fire has been put out, students will evaluate the damage to determine whether the tree is salvageable or not. What about the whole forest and all of its in habitants. Can that recover from a wildfire? As a class they will make a final decision. Upon returning to the classroom. Students will search for evidence to support their claim. Using online resources, students will examine recovery time and species loss from wild fires. Students will then participate in a class discussion about their findings.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Materials/prep: • Volunteer fire fighter • Water supply • Fire extinguisher • Lighter • Small filled water balloons (at least 10) • Filled water guns (as many as possible for students to use on fire • Small tree or plant • Other junk objects to burn (ask students to bring in objects) • Designated safe space to start fires • Computer and internet 2) Class will gather with a fire fighter with a designated safe space 3) The class will safely light objects on fire one at a time

	4) Students will work together to put out fires, observing how long it takes to put out the fires and whether the remains are salvageable 5) The last object students will set on fire is the small tree or plant. They will work together using overhead balloon drops and water streams from squirt guns to put out the fire. 6) Students will analyze the burnt tree remains and decide if the tree can regrow or if it is unsalvageable. 7) Upon returning to the classroom, students will use their computers to research the average recovery rate from a forest fire and the average species loss. 8) Class discussion PART 1: DISCUSSION QUESTIONS 1) Were any of the objects salvageable? 2) How long did it take put out the fires? 3) How long did it take to put out the tree fire? 4) Do you think it could regrow after the fire? 5) There are a lot of forest fires annually, what is the average recovery rate of the habitat? 6) How many species are lost on average during that time? 7) What are the greatest issues we face as a society regarding forest fires? 8) We are lucky our Earth is so resilient that it is constantly able to recover from forest fires. What are some of the circumstances in which forest fires might cause irreversible damage to the ecosystem? 9) How can we protect our forests and residences from forest fires in the future? 10) How can we better fight forest fires in the future?
Rationale: (Connection between SSI and standard)	About 30% of the worlds land is covered in forests. 80% of the worlds known terrestrial animals call the forest their home. Almost 50% of the organic carbon material on the planet exists in the forest. Not only do forests hold the key to biodiversity and sustainability. They also provide and protect the most precious material for life, carbon. In 1910, approximately 3 million acres of U.S. forest burned across 1,500 forest fires. Today, in 2020, there have been 48,000 forest fires, with about 8.6 million acres of forest being burned. The increase in damage from forest fires is an extreme fluctuation in the environment and poses a threat to the ability of the land to recover. Forest generally have the ability to recover from wild fires but the increase in damage causes added stress to the ecosystem making it harder to recover. During the fires, habitats are lost, diversity of plant life decreases, and species of animals become endangered. Some of these changes to the ecosystem are irreversible even if the organic plant material is able to grow back. The damage from forest fires destroys human habitats as well. In 2019, 4.6 million homes have been burned from wild fires. The

	smoke and soot that lingers in the air for weeks and sometimes months after theses large scale fires is a damaging carcinogen for humans to inhale. Displaced humans due to habitat loss require societal interference. Forest fires do occur naturally, with increased temperatures due to climate change and increased dryness, a small spark or the hot sun can ignite a fire. However, statistics show that most forest fires are caused by human action; smoldering fires, cigarettes, arson, fireworks, damaged power lines, etc. Once the ground is smoldering, it can remain smoldering for months, where it can easily be brought back to life again by strong winds or intense heat. Currently, we are struggling to find effective ways to combat forest fires, further; we have no way of preventing them. Students should understand how human activity and global warming have caused a rapid increase in the amount and intensity of wild forest fires. Students should also understand the importance and necessity for forest wild life to maintain human life, and the indirect and direct imminence of forest fires on human health. As students become active citizens they should be conscious of the ways in which they can protect wild life and prevent forest fires. Further, we need future scientists to help create solutions to extreme emergencies such as forest fires, as well as inventive preventative measures. Developing citizens who are knowledgeable enough to know the value of our forest will care to take action to protect it, maybe even becoming fire fighters themselves.
Relevance to Leading Education Research:	Socio-scientific issues are real world issues we experience in the modern world that are both social and scientific in nature. The issue of forest fires is both a current and historical controversy. Research by Biddy (2015), suggests these controversies provide engagement in content by evoking emotional responses. Further, controversies allow students to problem solve for a solution for the future. The visual nature of this activity adds a shock value that also increases emotional connectivity to content, much like shocking headlines do, as suggested by Harris, Stevenson, and Joyner (2015).
Possible Misconceptions:	• Students should understand why forest fires are different from the small fires they are watching. The embers that remain on the ground can keep the fire burning for long periods of time. • Often it is difficult to put forest fires out at the source on the ground because there is so much tree burning high up.
Recommendations:	• Ask your local fire station to send a fire fighter down to monitor! • Have safety precautions in place
Adaptation for remote learning:	It is not recommended that students participate in fires independently! Students may explore a wide range of data on forest fire destruction. The website below shows active forest fires around the globe. https://livingatlas.arcgis.com/wildfire/#@=-139.595,50.519,2 Discussions can take place in a virtual meeting space.

#24 **Topic:**	Biological Evolution: Unity and Diversity
Course:	High School Life Science
NYS Standard:	HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
Disciplinary Core Idea:	Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspiring value.
Socio-scientific issue:	Preserving the wild: Animal preservation, national parks, and wild life refugees.
Activity:	"VISIT A NATIONAL PARK!" - - Explore the beauty of national parks.
Summary:	For this lesson, students will experience first hand, the beauty of the wild land we have preserved. This will require a student field trip! Students will take a trip to a national park, a wild life preserve, an animal preservation, or a zoo. After the visit, students will participate in a class discussion. Students should consider why wild land is preserved and its importance.
Steps: (example, can be modified)	PART 1: ACTIVITY 1) Students will explore a park or wild life preserve, taking a tour of our beautiful wild nature. 2) Students will list at least five things they find beautiful about the park. 3) Students reflect on what makes these parks so special and why it is important that we preserve this land. 4) Class discussion. PART 2: DISCUSSION QUESTIONS 1) What were your favorite aspects of the park and why? 2) Why is it important that we preserve this land? 3) How do national parks help mitigate adverse affects of human activity on biodiversity? 4) What are some of the controversies that national parks face? 5) What are some other ways we can help mitigate adverse affects of human activity on biodiversity?
Rationale: (Connection between SSI and standard)	At the culmination of the high school life sciences content, it becomes visible that life is everywhere, completely connected to each other. All living organisms, including humans rely on the world around them for resources. Greater biodiversity means more resources for a greater variety of species. Biodiversity also creates more stability

	within the ecosystem. It is a form of protection and innovation for life. As life interacts with its ecosystem, evolution occurs. The interconnected continuously evolving nature of life is both beautiful and inspiring. To understand its true beauty is to fall in love with life. Those who love life want to protect it, and if you understand biology you know that protecting life requires caring for the life around us. Unfortunately, the modern citizen is not concerned with the complex science that governs the world around us and much from their educational practices has been forgotten. In the wake of everyday life, we leave waste uncared for, spout carbon pollution thoughtlessly as we move about, consume goods with adverse affects, and add to the collective loss of animal and plant life without even a conscious thought about it. Around 10,000 BC it is estimated that the human population was just 1 million. In the 12,000 years since, that population has climbed to almost 8 billion. We take up more land and resources than any other species. In the process of natural selection and evolution we have more than achieved our goals of survival and reproduction. Due to our rapid intellectual and technological evolution we have been able to escape most natural causes of death and in this achievement have overpopulated the Earth. Wrapped up in our own success, we have only, in recent years, begun to consider the ways in which our actions have negatively impacted our habitat. Mainly we have become conscious of our human impact because we have uncovered how much we truly need the world around us. In the early 1900's the first conservation efforts were made, as the first land was preserved by law through the formation of national parks. Today, there are more than 4,000 national parks that exist around the world and over 500 national wild life preserves. The International Union for the Conservation of Nature (IUNC) and the National Parks Services work to protect this land. While protecting some of our land is a step in the right direction, we still face many obstacles. Rogue hunters kill endangered species for sale on the black market. Worldwide pollution contributes to the declining health of the over-all wild. Policies get shifted in the interest of the wealthy to gain access to preserved land. Services that protect our land are well underfunded and as humans venture into these protected lands for inspiration and adventure, they often leave behind a footprint that can be damaging to the natural order; this could be trash that accumulates over time, smoldering fires that turn into wild fires, or unintended introduction of invasive species. Students should understand the importance of the natural and wild life around us, both plant and animal. The interconnectedness of the survival of all life to the survival of our own should become apparent. Environmentally responsible and conscious citizens can draw inspiration from the use of the wild land while still protecting it

	through careful action. Further, scientifically literate citizens will be able to participate in making informed decisions on policies that govern the funding, protection, upkeep and expansion of national parks, wild life refugees, and wild animals.
Relevance to Leading Education Research:	This activity takes students out of the traditional classroom and into the real world for a first hand immersive experience. As such, students are able to create relatable ties to the real world phenomenon and emotional connectivity to the content. Research by Martin, Durksen and Williamson, et al. (2016) provides evidence that place based learning and real world emersion aid in students content comprehension through experiencing learning in the most authentic and immersive way. The results showed increased content knowledge as well as increased self-efficacy, values, motivation, and aspiration. Students want to move, think, problem solve, interact with the real world, and have first hand experiences. Place based learning of socio-scientific issues provides the opportunity for enhanced engagement, motivation, and learning.
Possible Misconceptions:	• Students should understand the difference between national parks, animal preservations, zoos and wild life refugees • Students should also understand the pros and cons of each attempt at preservation
Recommendations:	• Teachers should pick the most awe-inspiring park near by (Ex. Rochester- Letchworth state park) • The beauty of the wild as an inspiration for protecting natural land should be clear • If a field trip cannot be taken, the adapted lesson for remote learning can still be used in class.
Adaptation for remote learning:	Students can explore all of the national parks in the United States using the link below. Students can be asked to explore the variety of national parks and pick the one they'd like to visit most. They can follow the same guiding questions to consider why preserving land is so important for our future. https://upgradedpoints.com/virtual-tours-of-national-parks-in-us

Final Reflections

Education reform is in the making. The traditional form of schooling is being challenged. As such, it our duty as educators and members of a community to participate in the collective reform. Ideas should be communicated so that we can continue to provide quality education to each generation of students. As we advance intellectually, scientifically, spiritually, technologically, socially, economically and globally, it is our job as a humanity to reform our policies and systems. This thesis proposes a theory as well as usable material that merge old themes with new in order to keep classroom learning progressive, engaging, and successful.

Students, teachers, parents, and citizens have become critically aware that many traditional classroom formats are not able to maintain student attention and interest anymore. This is why it is time for reform. Leading educational, psychological, and scientific research suggests many ways we can improve the education system. Some of these theories include the use of multimodal learning, kinesthetic movement, place based learning, socio-scientific uses, real world relevancy, and the 5E cycle.

Multimodal learning means that students are being presented with an array of learning experiences. They are not just reading or listening. Instead they are playing, listening, reading, writing, calculating, moving, viewing, creating and integrating technology. Life is dynamic and learning should be dynamic as well. Kinesthetic movement is full body movement. In the classroom this means students are moving around, they are not just sitting in one spot the whole time. Not only does movement improve engagement but it also has a high correlation with increased memory and conceptual understanding. Again, life is dynamic and learning should be too. Place based learning suggests that students are actually learning from first hand experience. This is akin to taking field trips. If students are learning about biodiversity, they should be outside in nature. While this is

difficult to manage given the time constraints of the current school day this is a major learning theory! It is proven that students learn better when they are fully immersed in the content. Not only does place based learning give you full immersion but it also incorporates multimodal learning and kinesthetic learning. As a young student, there seem to be many more opportunities for field trips and that is an injustice to older learners. School day reform and an effort to get students out of the classroom would do wonders for our learners.

All of the above theories are important and are incorporated into the activities produced in this body of work. This book can simply serve as a reference for how to incorporate these modes of learning into the classroom. However, the main focus of this activity book is to provide insight and examples of how to use socio-scientific issues to create emotional connection to content, real world relevancy, and engagement. Socio-scientific issues are issues that we currently face as a society that are both social and scientific in nature. These issues are pressing and require collective problem solving to create a solution. When presented in the classroom, they provide a real world connection and indicate to students why the learning content is relevant to their lives. Further, their pressing nature provides emotional connection for students and their unsolved nature provides an opportunity to engage students in complex problem solving and creative thinking. Not only does the use of socio-scientific issues offer engagement for increased student learning, they also offer the opportunity to create prepared and conscious citizens who are ready to participate in creating the real world solutions to these issues, which is indeed necessary.

While socio-scientific issues can be presented to the classroom in a myriad of ways, this thesis supports the notion that they work best when they are presented first to the class as an engaging introduction into a new topic. The 5E model for science learning, proposed by Roger Bybee is relatively new and promotes an active cycle of learning that works well with modern intellect. The 5E

model, which can be adapted to other subjects, suggests learning should flow in five steps. These five steps are; engage, explore, explain, elaborate, evaluate. The book of activities proposed here are intended to fit into the 5E model at the beginning phase of engagement. They prove to capture student interest, draw out prior knowledge, drive student inquiry, and create emotional connections to the content. After an engagement activity is presented, it is the teachers' duty to then explore, explain, elaborate and evaluate the scientific content of each standard in detail.

This project outlines 24 activities for teachers to reference. Each of the Next Generation Science Standards is paired with an engagement activity, a socio-scientific issue, alternatives for remote learning, and rationale. This activity handbook directly correlates with High School Life Science content. However, the content can easily be adapted for other levels of Life Science learning. This book can also be used as a reference for relevant socio-scientific issues. Further, teachers of any subject can use this book at any age as an example of how to engage students through kinesthetic movement, emotional connection, and real world phenomenon. As teachers look to reform their classrooms, there is a plethora of research that is within this thesis that can be used for exploration of modern theories on student learning and engagement. Lastly, each activity comes with an adaptation for remote learning. As this thesis was written during a global pandemic, remote learning is a reality and a possible continuous future for education. This thesis offers ideas on how to adapt lessons to remote learning.

It is my most sincere hope that active teachers find this content useful and that it makes a difference in student learning. As we move forward, education should progress with us; I hope this thesis makes a small contribution.

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