Applying Project Based Learning to Middle School Science Education

An Interactive Qualifying Project submitted to the faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the Degree of Bachelor of Science

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February 27, 2018

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Abstract

Science education has traditionally been based on teaching students to observe the real world in order to make conclusions about the way things work. In an increasingly modern world dominated by technology that students cannot easily observe and understand, science education has fallen behind. In order to address this stagnation, Massachusetts has revised its teaching standards, in accordance with the newly adopted Next Generation Science Standards. However, science teachers often don't have the time or budget to create new lesson plans to include these standards. The purpose of this project was to create an inexpensive, well-structured and accessible project-based lesson which teachers could easily deploy in their classrooms. To achieve this, a game was developed to teach the topic of photosynthesis in which students simulate an ecosystem and collect and analyze data about it. A lesson plan developed around this game was then experimentally run in a classroom, and the observational data of this trial run were used to improve upon the simulation game in order to make it even more engaging and beneficial for students. The end result was a lesson plan that succeeds in transforming the complicated topics of photosynthesis and food webs into an easily understandable game.

Acknowledgements

The project team would like to thank Dr. Arne Gericke and Ms. Shari Weaver for their incredibly helpful insight and advising throughout this project. They would also like to thank Ms. Jane Goodwin for welcoming them into her classroom and working with them to implement the unit they created.

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Introduction and Background

In recent years, a major wave of educational renaissance has been sweeping the United States. The rate of progress in technology and science has surpassed the capacities of traditional education, and now the nation is rushing to catch up. Technology has a relevance in our daily lives like it never had before and our students need to be prepared to work with that technology as adults. Schools must be able to prepare students for jobs that currently do not exist. Additionally, new scientific discoveries are revealed daily, and natural issues loom over the world, increasing our need for skilled scientific researchers to help us understand and conquer these problems.

In response to this, new focus has been placed on Science, Technology, Engineering, and Mathematics (STEM) education. In particular, attention falls on elementary education to inspire young minds to think about the big picture in science and technology, as well as high school education to encourage students to pursue college education and careers in STEM fields. Unfortunately, this same level of attention is not given to middle school science, resulting in traditional and stagnating STEM classes at this intermediary level. In an effort to understand this issue and take a step towards combating it, this project team worked with a seventh-grade science teacher to develop a project based lesson plan, implement it in the classroom, and evaluate its effectiveness.

Massachusetts Science Standards

In 2016, the Massachusetts Department of Elementary and Secondary Education printed a new revision of their standards for science, technology, and engineering curriculum (Massachusetts Department of Elementary and Secondary Education, 2016). This came following a similar reform of educational standards on the federal level, in part to satisfy new federal requirements. Specifically, the cumulative work of scientists, engineers, educators, and industry professionals formed the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013), which are built around three central dimensions: crosscutting concepts, science and engineering practices, and disciplinary core ideas. In order to better reflect the NGSS, Massachusetts reevaluated its curriculum in 2016 through the development of richer performance standards that embedded these practices and core ideas.

The Primary goals of the 2016 revision are: first, the state aimed to "focus on conceptual understanding and application of concepts." This meant to teach students not only the ideas and information they need, but also how that information can be applied in scientific experiments, development of technology, research, and everyday life. Next, the standards should "integrate disciplinary core ideas and practices to reflect the discipline of science." This comes directly from the NGSS dimensions (NGSS Lead States, 2013), and emphasizes the importance of connecting the various subjects within science among each other, to real life, and to past and future grade levels. Their next goals are to "present coherent progressions of Science, Technology, and Engineering (STE) core ideas and practices from pre-K to high school," and to "include each discipline in grade-level standards pre-K to grade 8." These concern continuity between multiple grade levels, and as such were not a major factor in the development of our project. The fifth goal of the board aimed to "contribute to preparation for post-secondary success in college and careers." Finally, the standards should "Coordinate with the English Language Arts (ELA) and Mathematics standards." This final point proved relevant to our project, as we sought to ensure our lesson was fair across the diverse reading levels present in the class, and that in the sections closely tied to mathematics, our lesson was appropriate for what the students had studied previously or were currently studying.

Project Based Learning (PBL)

Project based learning is an educational approach "with the goal of increasing student engagement and helping them develop deeper understanding of important ideas" (Blumenfeld and Krajcik, 2005). As laid out by Krajcik and Blumenfeld, the most overarching concept behind PBL is to engage students, not by lecturing, but by giving them a goal and allowing them to work by applying academic work to real situations. PBL is a pedagogical method in high contrast to traditional classroom learning. In order to facilitate the creation of new PBL lesson plans, Krajcik and Blumenfeld formulated five central doctrines that together lay the foundation for any PBL lesson plan (2005):

The Driving Question

The driving question can be seen as the main motivation for students to learn. It calls attention to a genuinely interesting and engaging topic. This driving question should be selected by either the teacher or the students to be specific enough to motivate discovery about the topic. At the same time it should also be vague enough to leave the students with the freedom to not only find one of the many unique and creative solutions, but also to answer related questions in varying disciplines (Thomas, 2000).

Situated Inquiry

While the goal of science courses is to develop the knowledge of students, lectures and other standard classroom activities can and do bore students at nearly all academic levels. Thus, students must engage in activities that more closely reflect and represent their interactions with the world to truly learn and retain information (Thomas, 2000). PBL should be contextualized by its links to the natural world, reflecting the natural integration and complexity of that world (Preuss, 2002). This can differ enormously from conventional learning, which often provides short term activities for the student to complete in the classroom, often not providing enough time to allow students to make the connection between these activities and the world around them

(Blumen and Krajcik, 2005).

Collaboration

PBL should encourage discussion and group work in order to facilitate learning. By creating a "community of learners" (Blumen and Krajcik, 2005), a teacher can ensure that students will be constantly interacting with - and being forced to learn by - their peers in order to answer the driving question. Teachers, instead of guiding students, should focus on providing resources and knowledge: a coach, so to speak (Preuss, 2002).

Using technology tools to support learning

By integrating computers and other technology into the classroom, teachers can move away from what Krajcik and Blumenfeld describe as "transmission-and-acquisition". Teachers can use these technology tools to distance themselves from the normal classroom format and instead implement a project based lesson. Computers can also offer students real-time access to learning tools on the internet, which allows students to research and learn at their own pace, as well as software to "present information in dynamic and interactive formats" (Blumen and Krajcik, 2005).

Creation of Artifacts

Students learn better when they create 'artifacts', or physical representations of what they learned about the driving question (Blumen and Krajcik, 2005). Through the creation of these artifacts, students can tie together the knowledge that they have gained answering the driving question into a concrete model, game, or other physical item (Zancul et al. 2017).

Integrated STEM

An important concept on the rise in science education today is that of Integrated STEM. This is the idea that all of the areas of STEM - science, technology, engineering, and mathematics - should be integrated when presenting material because it better reflects the natural world. This moves students from learning discrete ideas to integrated learning that addresses overarching concepts. To some, this means merging science and math classes into an entirely new class that teaches practices from all four STEM fields together (Stohlmann, Moore, & Roehrig, 2012). To others, this can simply mean science teachers including more concepts directly from math and vice versa, as well as making connections to non-STEM subjects (Sanders, 2009). Many strategies for implementing integrated STEM in either of these forms, or somewhere in the middle, have been proposed by various research teams since the conception of the practice. The biggest difficulties involve adapting the traditional lesson plans of current teachers to incorporate STEM fields beyond what they are used to. This is particularly an issue for middle school science teachers, who often focus on a specific area of science in college and already must go beyond that to the other major science fields. It can also be difficult to coordinate lesson plans between science teachers and math teachers, let alone work around school scheduling to allow for combined classes as this again goes outside normal procedure. The core idea of integrated STEM is still important for us to consider as we construct a lesson plan for a modern middle school class. This includes both improving the project by incorporating mathematics concepts, as well as considering bringing in concepts and themes from other disciplines.

Goals

Many schools in the United States are underfunded and understaffed. These stresses manifest in a lack of time and money to create and implement new course material. This project was created in the hopes of aiding science teachers by creating an inexpensive, well-structured and accessible project-based learning experience. This lesson plan would be an extensive, multi-day project designed to teach the students in a hands on manner. In order to create an effective lesson plan in accordance to the NGSS, this project must directly address one or more standards. This group was tasked with creating a lesson around photosynthesis, and so this project addresses two standards: 7.MS-LS2-3 and 7.MS-LS2-4: energy cycles and population shifts (Massachusetts Department of Elementary and Secondary Education, 2016). Working with a middle school teacher, this project group implemented the lesson plan in one local school. As observers, this project group would gauge the effectiveness of the project in teaching the content material to the satisfaction of the new NGSS standards by conducting surveys and assessing the students' learning at the end of the lesson plan. Following the classroom observation of the lesson plan, this group would attempt to refine and streamline the lesson plan, so that it would be both smoother and more effective for future implementations. Finally this group would disseminate the lesson plan to other teachers where possible in order to maximize the impact of this project on improving school curricula.

This Project

Given the topic of photosynthesis and food webs, this group created a simulation game in which the students acted as individual organisms from various strata of a simulated ecosystem. In this game, the students are required to gather the resources necessary for photosynthesis and cell respiration, compete for resources, and engage in predation on other organisms in the simulation. Throughout this simulation, the students then collect data on the populations of organisms in the game. Students then use the data to draw conclusions on how an ecosystem might change over time and, based on their findings, implement their own version of the game in order to see how variations thereof might further change an ecosystem.

Central to every step of the creation process were the NGSS standards. By integrating the standards into the process of constructing the project, this group could ensure that the standards would be addressed. In order to properly teach not only the factual content of the lessons, but also the concepts of modeling, analyzing, and understanding, it was necessary to produce an integrated STE lesson. Through the course of the lesson, students would be prompted by graphing exercises, thought experiments, word problems, and group work, all of which would promote active learning and the application of cross cutting techniques.

By creating the project hand in hand with the standards, as well as with the core principles of PBL, this group created a well-designed, effective lesson plan that not only taught students, but motivated them and drove them.

Methodology

Initial Idea Creation

The first step in creating a new project based lesson for a middle school science class was to find a teacher willing to work with the team on the project. One member of the project group grew up near where the project was implemented, so the group reached out to that member's eighth grade science teacher, Ms. Goodwin, at Burncoat Middle School in Worcester, MA. Ms. Goodwin agreed to allow the project team to work with her and her students in implementing their project. The team met with Ms. Goodwin, and discussed the dynamics of her classroom and students, as well as what part of the curriculum she would be teaching in the targeted time period. For the 2017-2018 school year, Ms. Goodwin was teaching five seventh grade classes. Two of these classes are higher level "Honors" classes, while the other three are "Inclusion" classes, which include some students who are English language learners, as well as some who have learning disabilities. Ms. Goodwin informed the team she would be teaching the biology unit when the project team would be in the classroom. The standards for this unit focus on the flow of energy and matter through an ecosystem, as well as the interactions of organisms within the ecosystem and the impact of outside events on the ecosystem (Massachusetts Department of Elementary and Secondary Education, 2016). In particular, Ms. Goodwin asked that the project team to develop a lesson for photosynthesis, as this was the concept within the life science unit she had struggled with the most in the past. In addition, it was agreed upon that the unit should take five class days to teach.

Given the unit they were required to work within, the project team members began brainstorming ideas for projects with the help of their advisors. In this process, a basic idea was proposed, and then the group tried to expand upon the idea to consider it a legitimate option. The group tried to implement strategies of Project Based Learning and integrated STEM to a rough framework of a lesson plan for various ideas, while also exploring how to apply the lesson directly to the standards. Some ideas proved promising, while others did not provide enough substance to constitute a full lesson plan.

A major idea the team worked with for an extended period of time was to give the students the task of planning out how to recreate a particular biome on a spaceship or other planet due to poor conditions on Earth. This would have included discussion of what chemicals and non-living materials would be needed to sustain the ecosystem, and how to balance the populations of organisms to allow the ecosystem to be sustainable. While discussing the smaller tasks within this idea, the group came up with a short simulation the students could participate in where they would act as plants undergoing photosynthesis, gathering the necessary components (ie. water, sunlight, and carbon dioxide) and trading them in for glucose and oxygen. As this smaller idea was discussed, the team realized it could be expanded on further by adding higher organisms to "eat" the producers, and in turn convert their glucose into food for this herbivore, and then similarly a carnivore could "eat" the herbivore. This grew the small task into a full-on human simulation of an ecosystem. Upon further reflection, the group determined this game could then be modified for subsequent days of the lesson to connect to more standards. While playing out a human simulation of an ecosystem does not fall into the realm of a typical project based learning experience, it shares many aspects of it. The game provided a hands-on task for the students in which they directly interact with and model the topics at hand. In addition, while not creating a physical artifact of what they learned, the students would have the opportunity to create their own strategies on how to most effectively acquire resources and avoid predators, and also generate the final state of their simulated ecosystem. This in turn integrates themes of natural selection, which would not be covered by the project, but would be indirectly introduced in this way. The idea for this human ecosystem simulation was proposed to the team's advisors and Ms. Goodwin, and was met with enthusiastic approval.

From Idea to Lesson Plans

With an idea for the project firmly in place, the team next needed to develop that idea into fully fleshed-out lesson plans for Ms. Goodwin to teach with. The project team began by deciding which standards the concept could cover best. The primary focus of the lesson would be on photosynthesis and the flow of energy through an ecosystem, so standard 7.MS-LS2-3 (Figure 1) was chosen first. The group then considered options for what other topics the game could cover in the allotted five days. Relationships among organisms were considered, as the game provided an opportunity for students to act out these relationships themselves. Ultimately, it was decided the best route to take would be to address standards 7.MS-LS2-1 and 7.MS-LS2-4 (Figure 1) in tandem, as both require analysis of data, which would allow the project team to integrate mathematics concepts into the lesson plan. With these standards in mind, the group laid out the following plan for a five day unit built around the game they had created: (full details in Appendix B)

Day 1: Introduction

The first day of the unit begins with an introductory lecture on photosynthesis and food chains. This gives the students a general frame of reference

LS2. Ecosystems: Interactions, Energy, and Dynamics

7.MS-LS2-1. Analyze and interpret data to provide evidence for the effects of periods of abundant and scarce resources on the growth of organisms and the size of populations in an ecosystem.

7.MS-LS2-2. Describe how relationships among and between organisms in an ecosystem can be competitive, predatory, parasitic, and mutually beneficial and that these interactions are found across multiple ecosystems.

Clarification Statement:

- Emphasis is on describing consistent patterns of interactions in different ecosystems in terms of relationships among and between organisms.

7.MS-LS2-3. Develop a model to describe that matter and energy are transferred among living and nonliving parts of an ecosystem and that both matter and energy are conserved through these processes.

Clarification Statements:

- Cycling of matter should include the role of photosynthesis, cellular respiration, and decomposition, as well as transfer among producers, consumers (primary, secondary, and tertiary), and decomposers.
- Models may include food webs and food chains.

State Assessment Boundary:

- Cycling of specific atoms (such as carbon or oxygen), or the biochemical steps of photosynthesis, cellular respiration, and decomposition are not expected in state assessment.

7.MS-LS2-4. Analyze data to provide evidence that disruptions (natural or human-made) to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Clarification Statement:

- Focus should be on ecosystem characteristics varying over time, including disruptions such as hurricanes, floods, wildfires, oil spills, and construction.

7.MS-LS2-5. Evaluate competing design solutions for protecting an ecosystem. Discuss benefits and limitations of each design.*

Clarification Statements:

- Examples of design solutions could include water, land, and species protection and the prevention of soil erosion.
- Examples of design solution constraints could include scientific, economic, and social considerations.

7.MS-LS2-6(MA). Explain how changes to the biodiversity of an ecosystem—the variety of species found in the ecosystem—may limit the availability of resources humans use.

Clarification Statement:

Examples of resources can include food, energy, medicine, and clean water.

Figure 1: Massachusetts Seventh Grade Life Science Standards

to build upon as the week went on. It was discussed with Ms. Goodwin that she would also introduce the students to some of this material before the unit began in the interest of allowing more class time for the game itself. After this, students are given a packet of vocabulary activities accompanied by the definitions of all vocabulary words relevant to the unit. This worksheet is started in class with students working in groups and could be finished at home if necessary. At the end of class, a brief introduction of the game is given, along with a short reading about it so students could come into class the next day prepared to play.

Day 2: Initial Simulation

On the second day, the students are split into small groups at the start of class to address any questions they might have had about how the game is played. This gives the students a chance to clarify any small issues amongst themselves, and to identify bigger sources of confusion they should bring to the teacher. In addition to addressing any immediate questions the students have, the rules of the game as a whole can also be reviewed to ensure total understanding by all students. Once this is done, the students are assigned roles, either seaweed, crabs, or squid, each representing a different part of a simplified aquatic ecosystem. The students are given a data tracking sheet at this point, where they can record the three population sizes at the end of each round. After the game is played, the students gather into groups once again to discuss the game. For homework, they are then given a prompt to get them thinking about what changes to the ecosystem could be made to the simulation in order to lead into the next day.

A summary of the gameplay of the simulation follows, with the full rules appearing in Appendix C. Within each seventy second round of the simulation, each type of organism has a specific task they must complete as many times as they can in order to survive, or even reproduce. Distributed around the room are bins containing the various resources they need for these tasks, namely sunlight, carbon dioxide, oxygen, and water. Each resource is represented by small plastic balls of various colors. There are additional bins manned by teaching staff where students can trade in the resources they have collected for what they are trying to produce, as well as a waste chemical. Seaweed must photosynthesize by collecting water, sunlight, and carbon dioxide, and trading for a glucose (or plant) token, and an oxygen token for them to dispose of back into the atmosphere (a bin containing oxygen and carbon dioxide). Crabs eat seaweed, so they must "hunt" a student playing the role of seaweed by politely asking them for their plant token. In addition, to complete cell respiration, they will also need an oxygen token, and must gather a water token for hydration as well. These can then be traded in for an herbivore (or crab) token, and a carbon dioxide token to exhale. Similarly, the squids hunt the crabs in turn, and trade in a crab token, oxygen, and water for a predator (or squid) token and carbon dioxide. The students repeat their cycles until the round ends, at which point play stops, and the teacher checks how many of their role's tokens the students ended up with. Students below a certain threshold "die" (must sit out for one or more rounds), while those above another threshold "reproduce" (a "dead" student is added back to the game in the same role as the reproducing student). Students then record the population sizes after deaths and births occur, and the tokens are reset for the next round.

Day 3: Repeated Simulation with a Modification

Day three begins with discussion in small groups about the changes for the game they came up with in their homework. Each group is instructed to select one idea from among theirs and present it to the class, who then vote on which idea to implement in the game. These changes would be along the lines of "there's less water available" or "the seaweed have a disease and die easier." The rules include anticipated ideas and how to actually implement them in the simulation. Once the class has selected a change, students are asked to formulate a hypothesis about what will occur in the game, and then the game is played again with the selected change applied. Students again record the populations after each round. The class ends with a discussion on comparing predictions made about the change to the actual results.

Day 4: Data Analysis

Now that the students have collected data on two different conditions of the same ecosystem, they can analyze and compare this data. The day begins with a brief lecture on data analysis to refresh the class on topics from their math classes, or to introduce them on the basics if they have not encountered them before. The focus of this lecture is on how to use various types of graphs to make numerical data easier to interpret. Next, the students return to their groups and select a type of graph to use for the population data from each run of the simulation. Ideally, they should choose a line plot, but other graphs could be justified. The students draw their graphs, and then write about what these graphs reveal about the change made to the game on the third day. Afterwards, each group shares their graphs and findings about the simulated ecosystem with the rest of the class. The day is wrapped up with a discussion of data and graphs from real-world ecosystems, focusing on having the students try to explain trends in various ecosystems. This is also an opportunity to discuss general practices in data collection, for example, highlighting how only recording population changes may hide the source of the change, like a resource shortage.

Day 5: Assessment

The final day of the unit is primarily used for assessing what the students learned throughout the week. This begins with a class discussion on the major ideas of the unit. This should include helping the students make connections between the game and real-world situations, as the assessment will expect them to understand these connections without directly asking questions about the game. The students can then be given the assessment to work on individually. The assessment begins with simple vocabulary questions to check the students' understanding of photosynthesis and energy flow through an ecosystem in relation to a given food web. The next questions ask the students to explain the results of disruptions to an ecosystem based on various descriptive prompts. Finally, the students are presented with population graphs and natural resource data for a theoretical ecosystem. They are then asked to draw conclusions about changes seen in the data, like what impact a decrease in a resource had on a particular population, and why .

Evaluation Methods

This project includes three major methods of evaluating the effectiveness of the unit. First, the students' grades on the assessment are evaluated based on typical grading levels (ie. A, B, C, D, F), as well as comparison to class averages on previous tests given by Ms. Goodwin. Second, the students are given a survey both before the unit began on the first day, and after taking the assessment on the fifth day. The survey is identical both times and asks the students about their general opinions on school and science. Finally, after completion of the lesson, the project team interviews Ms. Goodwin about her opinions of how the unit went overall, including what about it was effective, what could be improved, and its effectiveness in teaching the standards. In addition to these methods, the project team would also attend the class during the implementation of the lesson and record any significant observations made in this time.

Implementation

The following section contains a summary of the unit as it was executed in a classroom, as well as the data obtained over the course of its execution.

Day 1

The first day of the lesson began with reviewing the overall plan for the week with the students and the assignment of the class's normal six Frayer Model vocabulary exercises using words from the vocabulary worksheet that we provided. The do-now encouraged the students to begin thinking about energy transfer within ecosystems in terms of food they eat. After this discussion on food chains, the lecture shifted to photosynthesis. The students were given the chemical equation for the photosynthesis reaction on the board, they copied it into their notes, and discussed what each of the reactants and products are and their role in converting energy from sunlight to chemical energy.

Following this introductory lecture, the students were given the aforementioned vocabulary worksheet (Appendix D), which listed out the definitions of words relevant to the unit and provided activities to engage the students in using these words. The students were encouraged to review their answers in groups before discussing them as a class and were assigned the parts of the worksheet not covered in class as homework due the next day. Time ran short and some of the Day 1 lesson had to be moved to Day 2.

Day 2

The second day of the in classroom test of this unit began with the work left over from the first day; the opening segment of the class began with the class being shown the video (lesson plan 1, Appendix B), which was meant to be the previous day's closer. The purpose of this video was to solidify, in a more compact form, the knowledge taught in the day 1 main lecture: food webs, chains, etc. At this point, instead of moving into the day 2 schedule, the class instead took the time to check and review the homework assigned on the previous day. This was done first by circulating around the room to check who had the problem set done, and then moving through the questions in a call and response style. These two sections combined consumed, across most classes, slightly more than half of the duration of the class period. The initial surveys were also handed out at this point.

In the remaining portion of the of the class period, the intended lesson for day 2 was performed. However, due to the unforeseen time constraints, much of the lesson plan was adjusted in favor of advancing the game section; the do now, as well as the post-game discussion and the closer were dropped, and even much of the game itself was moved to the third day. Thus, in the remaining time, the students were walked through the rules of the game (Appendix C) by one of the members of this group, and they were instructed to play one practice round. It was found in this practice round that a single round of the game took significantly more time than expected, and thus the day ended here. Once again time ran short, and some material from Day 2 had to be moved to Day 3.

Day 3

The third day, much like the second, began with a very brief review of the video shown on the second day. The class then transitioned to a second explanation of the rules of the game, in order to remind the students not only of the proper rules of the game, but also to inform those students that had been absent. The classes were then instructed to begin the game in full.

Using the first classes of the day to test the starting conditions of the game, this team made small changes to the game as the day progressed and classes cycled. These changes included changing the starting set-up from a ratio of 4 plants to 2 crabs to 1 squid to a ratio of 3 to 2 to 1, with a maximum of 2 starting squid, as well as changing the time of the runs from 120 seconds to 90-100 seconds. The students performed well on average, but even still there was significantly more time expenditure than expected. This left most classes able to complete about 5 rounds, with a few classes completing only 4. Data was collected during this time to keep track of how many players had which roles.

Day 4

On the fourth day, the first class of the day was shown a video on the impact of reintroducing wolves in Yellowstone National Park, which had a profoundly positive effect by reducing the deer population which had been straining the flora populations. After showing the class the video, they were prompted to come up with changes that could be made to the game which would impact one or more of the populations within the game. Unexpectedly, many students came up with a change that was essentially the same idea: adding a new top predator. Seeing this, we decided to delay showing the other classes the video until after this day (and ultimately after our lesson had concluded) to allow for more diversity in the students' ideas. This also allowed the other classes time to begin playing the game again on day four with the changes they proposed, which first period did not have time for.

To replace the video, a handout originally planned to be given out at the end of day two was used which encouraged students to begin thinking about changes that could be implemented in the game. After each student wrote down an idea, they met in groups and were asked to decide on one idea from each group for the class to vote on. Once a change was decided on by the class, the game was played for as many rounds as time would allow, with data saved so it could be continued the next day. Most classes, despite having more diversity than the period one class, in suggestions still settled on adding a new top predator, which was dubbed the shark.

Day 5

On day five, the class started with a do-now of writing out the food chain that was represented in the learning game (ie. seaweed is eaten by crab is eaten by squid is eaten by shark). After the students completed and reviewed the do-now, since this was the beginning of a new week, they were given the same Frayer Model assignment as day one but for the remaining six words on the worksheet. Additionally, time was spent reviewing the basics of how to play the game to make sure all students were playing correctly after being removed from it for three days. Once the class was reminded of the rules, they played a few more rounds of the game using the change they had decided on in day four.

The class played enough rounds to have sufficient data, the game objects were put away, and the students returned to their seats to discuss the impact of their change as a class. This included references to real-world ecosystems and what impact this change could have on those ecosystems. After this discussion, the students were asked to begin graphing the data from one of the two rounds, either before or after the change was added depending on which data set seemed to be more beneficial for them to practice graphing.

Day 6

The sixth day of the in class experiment was the first extension day. Because students did not have enough time to complete the work covered by this unit in five fifty minute periods, one and one half extra days were added to the unit. Day 6 started by giving extra time at the beginning of class to the students in order for them to finish the previous day's graphing exercise. After creating this graph and reviewing it via a call and response style of teaching, the teacher then guided the class in a textbook exercise covering similar material. This included discussions on drawing conclusions from graphing, impacts changes other than what the class chose could have on the game and in real life, and what information could be obtained from graphs of real-world populations.

The remainder of the class period was devoted to giving the students the assessment. The assessment was a four page standardized paper test. This assignment was not completed by the majority of students by the end of the class period, and it was decided to give the students one half day at the start of day seven in order to complete the test and post survey.

Day 7

The seventh day was the final day of the unit, and was the extra half day added as a result of slower-than-expected progress on the assessment. On this day, the class was given their test from the previous day, as well as the post-survey. They were given about half of the class time to complete these two tasks. At the conclusion of this time, this project concluded and the teacher resumed teaching her own independent unit.

Results

Surveys

Students were given two surveys during the course of this unit. The first survey was given out on day 2 of the unit in order to establish a baseline. The second survey was given out on the seventh day in order to measure the response of the students to the new unit. The surveys asked the students to respond “strongly agree”, “agree”, “I don’t care either way”, “disagree”, or “strongly disagree” with the following statements:

1. “School is generally fun and interesting.”
2. “Science class is fun and interesting.”
3. “I am normally good at school.”
4. “I am normally good at science.”
5. “I learn better when moving around.”
6. “I learned something new in science class the [sic] week.”
7. “The classes in the past week were fun and interesting.”
8. “The classes in the past week changed my opinion on science.”
9. “I would consider a career in science.”

In order to analyze the findings, each response was given a numerical value (“strongly agree” was given a 1, “agree” was given a 2, etc.). These responses were then compiled for both the pre- and post- surveys and compared against each other:

Question number (pre-survey)	Average (Truncated)	Standard Deviation	Question number (post-survey)	Average (Truncated)	Standard Deviation
1	2.98	1.29	1	2.75	1.30
2	1.99	0.90	2	2.11	1.00
3	2.05	1.07	3	2.00	1.04
4	2.25	1.10	4	2.09	1.00
5	2.26	1.17	5	2.40	1.21
6	1.74	1.00	6	1.79	0.88
7	2.28	1.07	7	1.98	0.95
8	2.63	1.22	8	2.78	1.18
9	3.54	1.32	9	3.54	1.33

Figure 2: Survey Results

Survey Question	1	2	3	4	5	6	7	8	9
Change in response	-.23	.12	-.05	-.17	-.15	.04	-.30	.15	.01
p-value	.09	.17	.37	.13	.19	.37	.018	.18	.49

Figure 3: Differences in Pre and Post Surveys

See Appendices E and F for frequency charts and the raw data. These tables show the average response and standard deviation to each survey question, as well as change between the pre and post surveys. Additionally, p-values for each of the changes in response are provided. Importantly, because a value of 1 was assigned to the "strongly agree" response, a negative value of the change in response signify a positive change. For each question, we set a null hypothesis as:

$Average(survey_{pre}) = Average(survey_{post})$

Fairly few survey questions resulted in very significant results ($Pvalue < .1$), but even still, several questions appear to have some or good correlation to our unit.

Assessment

Data regarding the in class assessment was gathered following the unit. The team collected anonymized grades, as well as 14 anonymized tests. These tests were chosen by a stratified random sample in order to eliminate sample bias, and collected in order to review specific responses to various questions. Shown below are comparisons between the honors classes and the inclusion classes, as well as between both honors and inclusion classes against their respective controls.

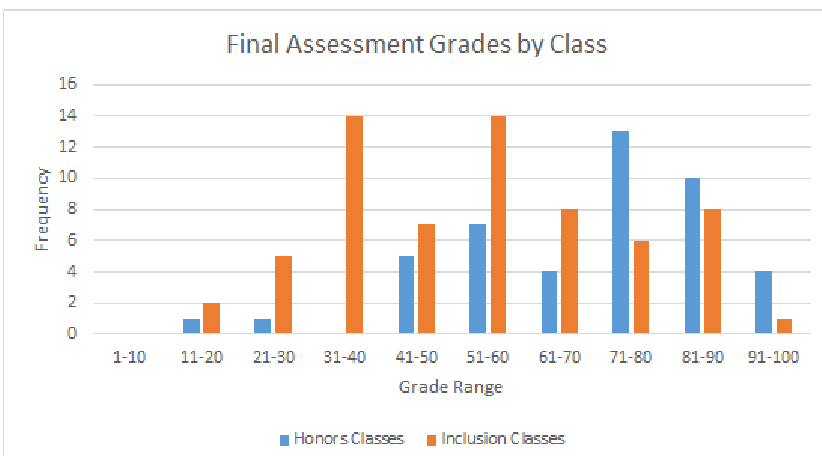

Figure 4: Final Assessment Grades by Class

The honors class is composed of better learners than the inclusion classes, and so as shown in Figure 4, it has higher scores in general than the inclusion classes. As shown in Figure 5, compared to the honors control test, the

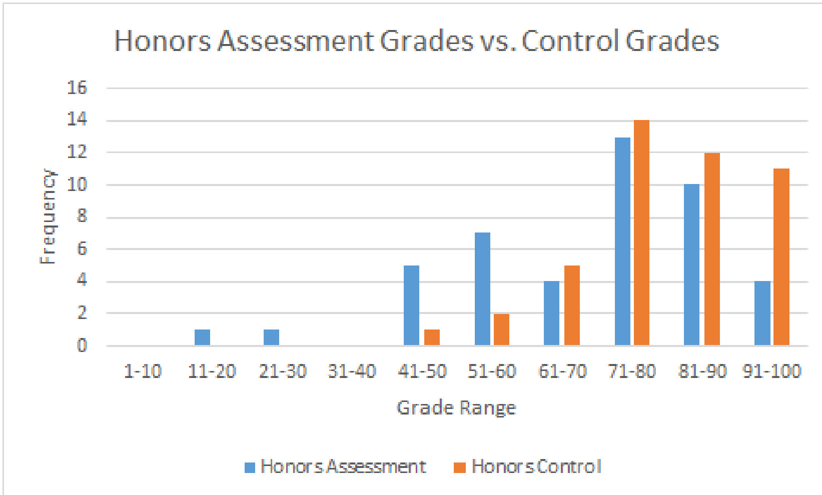

Figure 5: Honors Assessment Grades vs. Control Grades

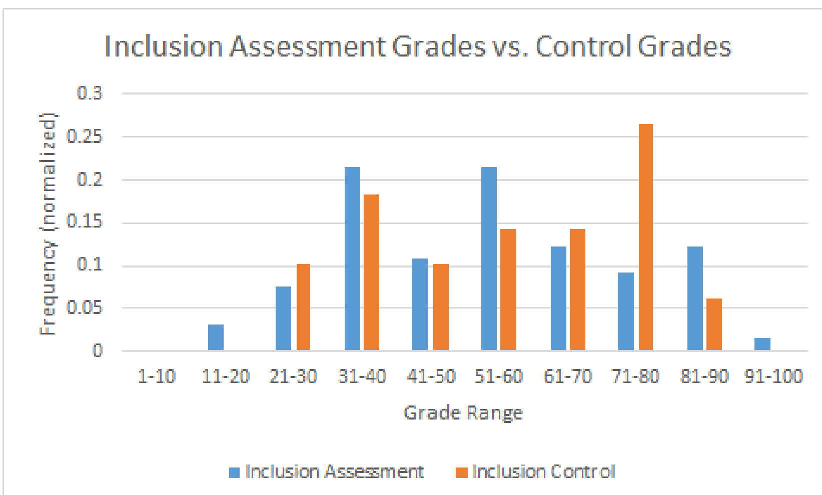

Figure 6: Inclusion Assessment Grades vs. Control Grades

honors class scored lower in general on the assessment. Figure 6 shows that the inclusion class performed approximately equivalently on the assessment as it did on its control test. The implications of these comparisons will be expanded in the discussion section.

Interview

Following the seven day unit, the project team interviewed the teacher in whose class the unit had been executed. In this interview, the team sought to find what opinions she had of the unit, including its strengths and weaknesses and whether she would implement it again in the future. We were also interested in how she though the project addressed the standards it covered and how it worked for her students' varying needs. The full interview notes can be found in Appendix G.

When asked for her feedback on the project in general, the teacher responded generally positively: "I think it had a lot more plusses than minuses. The kids loved being up and moving around," and that the students gained a sense of the components in photosynthesis. She said that the unit was successful in general, even if it had some minor drawbacks.

When asked about these drawbacks, she said, "I'd figure out a way to help the kids understand that the green balls are sugar. That was what kids had the hardest time remembering". She went on to add that "[Lower level] classes struggled with adding the adaptations… since once they learn something they have a hard time being flexible with that". She also expressed concern that the simulation game often became difficult to manage with only one adult in the classroom.

On the contrary, when asked about the strengths of the game and unit in general, the teacher responded, "I think the most effective part was them understanding the relationships between levels in a food chain, producers, consumer levels". She also stated that, in her opinion, the students really understood the concept of energy transfer through an ecosystem.

On the topic of students' reactions to our unit, the teacher had mixed, but generally positive, feelings. She said that many of her ADHD students were more engaged since they could be up and moving around. Many English-language-learners also benefited from the project because "once they understood what they needed to do they could stick with that". Her one concern with the project is that many low-motivation students remained unengaged, in spite of the higher energy activity.

The teacher was then asked how well the project covered the NGSS standards. Her one comment on how well this unit covered standard 7.MS-LS2-3 (Modelling energy and matter flows in an ecosystem) was “Excellent”. On 7.MS-LS2-4 (changing conditions in the ecosystem affect populations), she said the coverage was “Good, but I think it’s a framework that my lower level students are going to struggle with anyway, because they just don’t know enough about the world around them”. She said this unit did a very good job covering the standards overall.

Going in to this interview, this project group was mildly concerned about the difficulty of the final assessment. Retrospectively, it seemed extensive and difficult. The teacher said that the students may have been confused by the wording of the questions, since they were composed by this project team as opposed to by the teacher herself. She said that it did not accurately reflect how much the students learned from the lesson plans: “I think I knew they knew more based on what I asked them later on and referring back to the game”. We also gathered many suggestions on what could be improved on the assessment.

Finally, this team asked the teacher whether or not she would do the unit again. She said, “Absolutely. I tend to struggle with new things, so when it comes right to my classroom I have to take advantage of that”. She said that since this unit often takes more time (two-three weeks), she would like to add more information about photosynthesis to the unit and to introduce the concept more than 1 day in advance of the simulation game. She recommended that in the future, more lecture-based content should be included in this extra time. This direct instruction should focus on vocabulary and introducing the concepts of photosynthesis, food webs, and trophic levels.

Discussion

Analysis and Interpretation

Two survey questions (Figure 2) show very significant differences between the pre and post surveys. The change in response to question 1, "School is generally fun and interesting," (-.23) has a p-value of .09. This change indicates that students had more fun over the week of this unit than they had in the control week. The change in student response to question 7, "The classes in the past week were fun and interesting," (-.30) was also very significant with a p-value of .017. This strongly indicates that students view the week as more "fun and interesting" than the control week. Strangely, question 2, "Science class is fun and interesting," showed a somewhat significant ($Pvalue < .2$) change in response between the pre and post surveys of positive .12. Based on the result of this question, it is feasible to say that, in some respect, this unit was less "fun and interesting" than the unit of the week prior, but this seems to contradict survey questions 1 and 7.

This contradiction may stem from the wording of the question and the unorthodox methods of this unit; the question asks students to rank science class from 1 to 5 as "fun and interesting", with 1 being the most fun and interesting. The only difference between this question and questions 1 and 7, which ask students to do the same with school in general and the past week of classes, is mentioning "science class" in particular. It's possible, with the unit so far removed from what they are used to, that the students did not view this project as "science class". Especially by introducing the unit as an experimental project (as was done on day 1), it is possible that the students were led to misunderstand the question. This same misinterpretation is very possibly the source of the positive change in question 8, "The classes in the past week changed my opinion on science," as well. Alternatively, one or more of these three results could be random noise; a p-value of less than .2 is entirely possible to occur by chance. That said, it is less likely for both questions 1 and 7 to have been noise. In either case, misinterpretation or random outcome, it is the opinion of this project team, based on the survey questions, that this unit did actively engage the students more than the unit of the control week.

The assessment results (Figures 4, 5, 6)) show that the honors class outperformed the inclusion classes as expected. In the opinion of this project team and the opinion of the teacher, this assessment was somewhat harder than previous assessments, and it is therefore not surprising that the honors class scored approximately 11 points out of 100 less than their previous test, 70/100 compared to 81/100 ($Pvalue < .001$). What is surprising, however, is that the students in the inclusion classes scored approximately equal on this assessment as they did on their previous test: 54.5/100 compared to 57.5/100 ($Pvalue \geq .2$). The final assessment (Appendix D) did not contain many multiple choice questions, and it is nearly impossible to guess every answer and obtain a score of above 30. Because the two different levels of classes responded differently to this assessment when compared to their baselines, this group came to conclude that this unit impacts learning differently between multiple class levels.

It is likely that this unit encourages more or better learning in lower level students compared to a normal unit, but does not do so, or does so to a lesser extent in higher level classes. This would explain both how the honors class scored below their past performance, and how the inclusion classes did not. By having similar learning with a harder test, one would expect the average of the honors class to drop somewhat; honors students tend to be smarter and learn better in general than lower level students, and therefore are likely to understand the material regardless of how it is presented. Inclusion classes, on the other hand, are often composed of students that learn more slowly, have a lower reading level, don't speak English well, etc. By providing a better learning environment with hands on lessons, the students can be encouraged to learn better. They can recognize patterns that don't exist in lectures, connect reading and writing to experiential learning , and don't have to listen to someone speak the knowledge. They can learn in their own way and at their own pace which contributes to better overall learning. Therefore, even on a harder assessment, they are more likely to maintain their average, as seen in this project.

The general opinion of the teacher in the interview was positive. She indicated that she believed the unit to have "more plusses than minuses". In her opinion both major standards that this lesson was designed for were covered. Based on these responses, this team recognizes that this unit is sound. Further, these responses will inform this project team on how to refine and update the unit for better effectiveness in the future.

Validity of Interpretation

The project was, in the opinion of this project group, executed well, but there are still some possible issues relating to the proper assessment of the impact of the educational unit on student learning. The three most significant problems we have identified have to do with the surveys and assessments. The first source of error was the timing on the first survey . In the layout of the unit, the pre-survey was supposed to be handed out, filled, and collected near the beginning of the first day of the unit. Due to time constraints, the survey had to be moved to the second day of the unit, before the simulation game was introduced. The first day of the unit included large sections of lecture and traditional teaching, and it is quite possible that this impromptu change did not significantly alter the pre-surveys, but it is impossible to be certain. A possible second issue that we have identified was the nature of the questions in the pre and post survey. In retrospect, the questions on these surveys are slightly ambiguous, and could be misinterpreted by students. This could lead to inconsistent answers for the same level of agreement. This is likely to have introduced random noise in our data, but not very likely to have influenced the overall interpretation of any result. The final problem associated with obtaining data to judge the impact of our unit was in the grading of the assessments. In order to grade the assessments quickly, one of the members of this project group aided the teacher in grading. This may have introduced a small bias in the grading process which could affect the average assessment scores. Overall these assessment issues are unlikely to be so significant as to invalidate the results of the analysis, but should be considered alongside the results.

Conclusions and Recommendations

Accessibility

One of our primary goals with this project was to create a project based lesson plan that is accessible to teachers both in monetary terms and in ease of implementation. The project was able to be completed in Ms. Goodwin's classroom by spending only sixty dollars, not including costs of printing specific to the school. These sixty dollars were used to acquire 400 2.5" diameter plastic balls to use as tokens during the game. We found this to be an appropriate amount of tokens for her class size of about twenty-five students per class. While a few were damaged or lost, as a whole these balls would be reusable in future years if the project was done again. The only other material that this team foresees as a possible significant cost for implementations by other teachers is the bins used in the various resource and trade-in stations around the room. We found the game required twelve bins to operate effectively, and while we were able to gather these bins from among the belongings of the project group and Ms. Goodwin's classroom, teachers in different situations may need to purchase more bins for this project. Overall, we believe this is a reasonable cost for a multi-day unit with reusable materials, and therefore this unit can be considered monetarily accessible to most teachers.

On the topic of ease of implementation, there were ways in which this unit was successful and ways in which it was not as approachable as intended. During the dry run of the project in Ms. Goodwin's class, overall the unit was able to be implemented largely as intended. Ms. Goodwin proved able to adapt the initial plans to better fit her class dynamic without significant modification beyond allocation of time. The original plan attempted to condense too much information into too little time, which was quickly demonstrated in Ms. Goodwin's class. In the project team's interview with Ms. Goodwin, she explained that she would have spent two to three weeks on these standards normally. One area of focus in ease of implementation was how easily the rules of the game could be interpreted. In her interview, Ms. Goodwin indicated that it was very helpful to have the group in the classroom to help explain the game, and recommended creating a video tutorial for future teachers to use as reference. In addition to understanding the game, another issue was actually running the game and controlling the classroom during it. For one of Ms. Goodwin's five classes each day, the project team was not able to attend. In trying to run the simulation with this class, Ms. Goodwin had another teacher come into the room to provide additional help in managing her students and resetting the game pieces between rounds. Ms. Goodwin also said in her interview that her classes were not particularly more difficult to keep under control during this lesson and the game, but that she did need to adjust to controlling students' movement more than their focus. Based on Ms. Goodwin's feedback, this project team feels that the unit can be implemented by most middle school science teachers without much difficulty, given detailed enough instructions on the game and particularly if able to work with another teacher.

Effectiveness in Teaching

Another major goal of this project was to cover the standards chosen within the seventh grade life science unit. In the interview with Ms. Goodwin, she expressed that the coverage of standard 7.MS-LS2-3, the transfer and cycles of matter and energy in an ecosystem, was “excellent,” and that “the most effective part [of the unit] was [her students] understanding the relationships between levels in a food chain, producers, consumer levels, and that the energy was transferring through the ecosystem.” In regards to the analysis of data relating to disruptions of, or changes to resources within, an ecosystem as required in standards 7.MS-LS2-4 and -LS2-1, Ms. Goodwin indicated that the unit’s coverage of -LS2-4 was “good, but I think it’s a framework that my lower level students are going to struggle with anyway.” As discussed previously, the numerical results obtained from the written assessment of the students demonstrated grades below desirable at face value. However, given the determination between this project group and Ms. Goodwin that this assessment was more difficult than what the class is accustomed to, and the approximately maintained average score of the inclusion classes despite this, it seems the unit helped the inclusion class learn more than they would in typical lessons. In addition, in attempting to resolve the disparity between Ms. Goodwin’s positive qualitative response to the effectiveness of the unit versus the negative quantitative assessment scores, we err on the side of the opinions of someone with decades of experience in the field, rather than on the grades of an assessment created by much less experienced college students, and thus conclude that the unit created by this project team was effective in covering the Massachusetts standards it sought to teach.

An additional area of interest in assessing the effectiveness of this unit is the reaction of the students to the style of teaching. Ms. Goodwin observed that “Some ADHD students seemed more engaged because they could be moving,” which is a particularly encouraging support of this type of project, as it is very important to address all styles of learning in the classroom, and aiding students with learning disabilities is crucial to creating a fair learning environment for all. Ms. Goodwin also indicated that she noticed her English Language Learner students were better engaged by giving them a repeatable task that they could learn visually that then connects back to important concepts. However, she also pointed out that this lesson didn't particularly increase the involvement of students who typically exhibit low motivation. The results of the survey, as discussed previously, do provide additional support that this lesson engaged her students more than her typical classes. Additionally, while attending Ms. Goodwin's class as the unit was implemented, the project team collected many observations of students' responses to the activity. While some students had a negative response, these were far outweighed by the students observed to be very excited to return to the classroom after the first day of playing the simulation, and remarks that the game was "fun," or "the best," et cetera.

Future Implementation

Ultimately, this project group aims to have a finished product that can be passed along to other middle school science teachers as an engaging alternative to traditional lectures and labs. When taking the project into an actual classroom, the project team discovered many small issues with the original plans that needed to be adjusted on the fly. Based on observations made in the classroom, the adaptations Ms. Goodwin made, and her remarks in the post-project interview, the project team believes this unit can be successfully implemented by other teachers via working with the original plans, the example of the use of them by Ms. Goodwin, and the following further adjustments:

1. Expanding the total amount of time

The project team's original lesson plans did not have enough time for the amount of content to be covered. At least one more whole day should be spent at the onset of the lesson to give students more exposure to the topics before introducing them to the game. Ideally, at least one day can be spent on photosynthesis, at least one day on food chains and food webs, and then a day to introduce the game and do a practice round or two. This should be a big help in getting students to make the connections between the real-world ecosystems and the game. More time can also be spent playing the game, perhaps even having a total of three distinct iterations of the simulation, the initial base game, followed by two changes to the game proposed by the students. This would ensure better coverage of both data analysis standards (7.MS-LS2-1 and -LS2-4), as each standard's particular topics can have a dedicated run of the game. This would then require more time spent on data analysis as well, as the students would have three data sets to graph.

2. Fixing and customizing the written assessment

As has been discussed before, the written assessment created for this project and given to Ms. Goodwin's students was deemed too difficult in hindsight. While it should not test the students' knowledge of the game specifically, it would likely be easier for them to recall if they were led with some analogies back to the game. The food web and graphs given on the exam also can be simplified to something more reminiscent of those presented previously in the lesson. Another factor in the difficulty of the assessment is that it deviated from what the students are used to getting in Ms. Goodwin's class. Given an assessment covering identical material but formatted in a more familiar way, it is likely the students would have been able to perform better. Teachers using this unit in the future can use this written assessment as a guideline, but should rewrite the questions to match the other assessments they give to their students. An alternative option would be to explore performance-based assessment options in place of a written exam.

3. Reinforcing connections between game and reality

While the game engaged the students and did help them learn about the intended topics, it is a step removed from these topics. In her interview, Ms.

Goodwin remarked that the students needed more help to "understand that the green balls [plant tokens] are sugar." In discussing the game, teachers should be sure to do it in terms of photosynthesis to reinforce the chemistry of the process. Trade-in stations can be renamed "reaction stations" or chloroplasts and mitochondria, and tokens referred to as both resources and reactants and products. This will help students connect the chemistry of these reactions to the biology of the systems they occur within. More time can also be spent in connecting the changes made to the game to real-world situations. Once the students have played through two or three sets of rounds, the game can be used as a frame of reference for drawing conclusions about real ecosystems. For example, to get students to figure out what would happen to an ecosystem in a drought, teachers can prompt them with "what would happen to students acting as plants if the water bins ran out of water tokens?" By setting them up to make these connections, the strong memories they form during the game will help guide their thought process on assessing data from real ecosystems.

Final Remarks

As a whole, the results found from this particular project based lesson show promise for the idea of project based learning as a whole. While the unit did not show clear improvement of test scores, it certainly engaged the students and got them excited to return to science class the next day. The drive to explore the world around them is truly the core of science, and may be the most important thing to encourage in science classes as the progress of technology only makes the world harder to understand. This project takes a step outside of the typical hands-on science lab to further get the students directly involved in scientific topics. By having the students play a game as a method of learning, they can be more engrossed in the ideas they are being taught, while having fun and enjoying it as well. In fact, as we try to help students understand the complex technology of the modern world, it seems right to teach them by having them play a game, as they so often interact with cutting edge technology by using it to play a game.

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Appendices

A Authorship

Section	Author
Abstract	Joshua Shukan
Introduction and Background	Joshua Shukan, Gavin MacNeal
Methodology	Gavin MacNeal
Implementation	Joshua Shukan, Gavin MacNeal
Results	Joshua Shukan
Discussion	Joshua Shukan
Conclusions and Recommendations	Gavin MacNeal

B Original Lesson Plans

Lesson Plan Title: Introduction - Day 1

Teacher's Name: Ms. Goodwin **Subject/Course:** Science (Life Sciences)
Unit: From Molecules to Organisms and Ecosystem **Grade Level:** 7th

Overview of and Motivation for Lesson:
Introduction to food webs and the cycle of energy through an ecosystem. Additionally, introduction to the game that will be played on subsequent days to simulate the cycle of energy through an ecosystem.

Stage 1-Desired Results	
Standard(s): • 7.MS-LS2-3 (matter and energy is transferred through an living and nonliving parts of an ecosystem, including photosynthesis and cell respiration)	
Aim/Essential Question: • How do plants and animals get the energy they need to stay alive?	
Understanding(s): *Students will understand that . . .* • Plants use photosynthesis to store energy from the sun in glucose molecules • Animals eat the plants to gain energy through stored sugar • Animals eat animals to gain the sugars in *their* systems	
Content Objectives: *Students will be able to . . .* • Describe how plants get their food and why animals eat plants. • Identify the roles (producers, consumers, decomposers, etc.) of the members of a food web in a given ecosystem.	**Language Objectives:** ELD Level Choose an item. *Students will be able to . . . in English* Click here to enter text. ELD Level Choose an item. *Students will be able to . . . in English* • Click here to enter text.
Key Vocabulary • Producer, Consumer, Herbivore, Carnivore, Decomposer, Food Chain, Food Web, ecosystem • glucose, photosynthesis, cell respiration, carbon dioxide, oxygen, Chlorophyll	
Stage 2-Assessment Evidence	
Performance Task or Key Evidence • See Learning Activity 2	

Key Criteria to measure Performance Task or Key Evidence

- How well the teacher thinks the students did on the vocabulary application worksheet.

Stage 3- Learning Plan

Homework/Extension Activities:
We'll give them a copy of the game rules for them to read over, as well as a small bit of reading (<1 page) about ecosystems. Possibly a small activity mirroring the one done in class, about describing something in terms of vocabulary.

Learning Activities:
Do Now/Bell Ringer/Opener: What did you eat for lunch today? What did it eat before you ate it, or where did it get its energy from? Why did you eat it?

Learning Activity 1:
Lecture on photosynthesis and food webs. Make connections back to / overuse vocab to help them learn what they didn't understand yet when they were doing the vocab.
https://www.youtube.com/watch?v=ysa5OBhXz-Q

Learning Activity 2:
We hand them the vocab, and we give them a written scenario and/or a picture, and ask them to describe the scenario in terms of the vocabulary. E.x. "A cow is eating some grass and at night while the cow is sleeping, a wolf comes by and eats the cow." Students must describe that the cow is a consumer, and that the wolf, while also a consumer, is not an herbivore.
After this activity, the class should reconvene and discuss the picture or set as a whole.

Application
Describe the basics of the game, break the class into groups, and have the groups begin to discuss the game from the perspective of all the organisms - they will not yet be assigned specific roles.

Summary/Closing
Draw the food chain that includes you eating lunch today

Multiple Intelligences Addressed:

☐ **Linguistic**	☐ **Logical-Mathematical**	☐ Musical	☐Bodily-kinesthetic
☐ Spatial	☐ **Interpersonal**	☐Intrapersonal	☐Naturalistic

Student Grouping

☐ Whole Class ☐ **Small Group** ☐ Pairs ☐ Individual

Instructional Delivery Methods ☐ Teacher Modeling/Demonstration **☐ Lecture** ☐ Discussion **☐ Cooperative Learning** ☐ Centers ☐ Problem Solving ☐ Independent Projects

Accommodations	**Modifications?**
lower level classes will have a less in depth lecture, and more focus on the rules of the game. Any other accommodations are unforeseen.	

Materials and Equipment Needed:

- Vocab Worksheet
- Game Rules Reading
- Ecosystems Reading

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

Lesson Plan Title: Game - Day 2

Teacher's Name: Ms. Goodwin **Subject/Course:** Science (Life Sciences)
Unit: From Molecules to Organisms and Ecosystem **Grade Level:** 7

Overview of and Motivation for Lesson:
Simulate an ecosystem by playing a game to demonstrate the cycle and movement of energy and matter through said ecosystem. The motivation will be provided as per instructed in the rules of the game.

<table>
<tr><th colspan="2">Stage 1-Desired Results</th></tr>
<tr><td colspan="2">Standard(s):
• 7.MS-LS2-3 (matter and energy is transferred through living and nonliving parts of an ecosystem, including photosynthesis and cell respiration)</td></tr>
<tr><td colspan="2">Aim/Essential Question:
• What is the nature of the movement of energy and matter through an ecosystem?</td></tr>
<tr><td colspan="2">Understanding(s):
Students will understand that . . .
• energy moves through an ecosystem, being produced by plants and in its final stage being used by top level consumers.
• Each organism has a specific role in the ecosystem that usually does not change.</td></tr>
<tr><td>Content Objectives:
Students will be able to . . .
• Relate the ecosystem modelled by the game, to a real ecosystem
• Explain the role they played in the simulated ecosystem</td><td>Language Objectives:
ELD Level Choose an item. Students will be able to . . . in English
Click here to enter text.
ELD Level Choose an item. Students will be able to . . . in English
• Click here to enter text.</td></tr>
<tr><td colspan="2">Key Vocabulary
• Producer, Consumer, Herbivore, Carnivore, Decomposer, Food Chain, Food Web, ecosystem
• glucose, photosynthesis, cell respiration, carbon dioxide, oxygen, Chlorophyll</td></tr>
<tr><th colspan="2">Stage 2-Assessment Evidence</th></tr>
<tr><td colspan="2">Performance Task or Key Evidence
• Playing their role in the modelled ecosystem game.</td></tr>
<tr><td colspan="2">Key Criteria to measure Performance Task or Key Evidence
• Written conclusions the students come up with among their groups.</td></tr>
</table>

Stage 3- Learning Plan	
Learning Activities: Do Now/Bell Ringer/Opener: Discuss among your group anything you are unsure about concerning the game rules. Learning Activity 1: Play the game Go over the rules of the game, assign roles. This can be done either randomly if the teacher allows it, or if they are uncomfortable with random roles (for any reason, including unruly behavior of some students), by assigning them manually. Then play it. Learning Activity 2: Discuss the game Students discuss among their groups what occurred during the game, guided by questions provided in the associated handouts. Application See game. Summary/Closing List one change to our simulated ecosystem we could make that would have an impact on how the game would play out. Predict how this change would make a difference, or how it would change the behavior of each organism. "List one change you are able to make to the simulated ecosystem that could affect the game. Predict what impact this change would have on the game." **Multiple Intelligences Addressed:** ☐ Linguistic ☐ Logical-Mathematical ☐ Musical ☐Bodily-kinesthetic ☐ Spatial ☐ Interpersonal ☐Intrapersonal ☐Naturalistic **Student Grouping** ☐ Whole Class ☐ Small Group ☐ Pairs ☐ Individual **Instructional Delivery Methods** ☐ Teacher Modeling/Demonstration ☐ Lecture ☐ Discussion ☐ Cooperative Learning ☐ Centers ☐ Problem Solving ☐ Independent Projects	
Accommodations The game rules can be simplified for lower level classes if deemed necessary.	**Modifications?**

Specific students that need accommodations can be chosen for roles non-randomly.	
Homework/Extension Activities: Think of something that could change the game in such a way that each organism might have different behavior.	
Materials and Equipment Needed: • See in-depth description of game for all materials	

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

Lesson Plan Title: Changes - Day 3

Teacher's Name: Ms. Goodwin **Subject/Course:** Science (Life Sciences)
Unit: From Molecules to Organisms and Ecosystem **Grade Level:** 7

Overview of and Motivation for Lesson:
Students are to come up with changes to the game and discuss how these changes may affect the simulation game. After a suitable period of time to suggest changes, they will choose one of the ideas put forth by their classmates, and play this game. Their choice of which changes to implement will serve as motivation on top of the incentives already in place (see day 2).

<table>
<tr><th colspan="2">Stage 1-Desired Results</th></tr>
<tr><td colspan="2">Standard(s):
• 7.MS-LS2-1, 7.MS-LS2-4: Analyze and interpret data about periods of abundant or scarce resources and of disruptions to an ecosystem.</td></tr>
<tr><td colspan="2">Aim/Essential Question:
• How do changes to an ecosystem impact all the populations within it?</td></tr>
<tr><td colspan="2">Understanding(s):
Students will understand that . . .
• Changes to the abundance of resources can impact all populations, even the ones that do not directly use the resource.
• Changes to the size of a population can impact the size of other populations as well.</td></tr>
<tr><td>Content Objectives:
Students will be able to . . .
• Make predictions about the impact of changes to an ecosystem.
• Recognize the impacts of changes to an ecosystem.</td><td>Language Objectives:
ELD Level Choose an item. Students will be able to . . . in English
Click here to enter text.
ELD Level Choose an item. Students will be able to . . . in English
• Click here to enter text.</td></tr>
<tr><td colspan="2">Key Vocabulary
• Producer, Consumer, Herbivore, Carnivore, Decomposer, Food Chain, Food Web, ecosystem
• glucose, photosynthesis, cell respiration, carbon dioxide, oxygen, Chlorophyll</td></tr>
<tr><th colspan="2">Stage 2-Assessment Evidence</th></tr>
<tr><td colspan="2">Performance Task or Key Evidence
• Create changes for the simulation game, and predict the outcome of such changes.</td></tr>
<tr><td colspan="2">Key Criteria to measure Performance Task or Key Evidence
• The students' self-evaluation of their predictions.</td></tr>
</table>

Stage 3- Learning Plan
Learning Activities: Do Now/Bell Ringer/Opener: Get into your groups and discuss the changes to our ecosystem game that you came up with last night. Learning Activity 1: Class discussion about changes to the ecosystem. Break the students up into groups and brainstorm changes that could be made to the simulated ecosystem. Ask students to share the changes they came up with to the class, and what they predict would happen as a result of these changes. Then have the rest of the class make predictions as well. Ensure that enough changes are shared by asking for more until enough have been suggested. If there are some categories of changes to ecosystems that the students missed, fill these gaps with descriptions of real-world changes, and ask the class to make predictions about these too. Learning Activity 2: Put to a vote the ideas that the children suggest*. Play the simulation game again with the modifications suggested in the teacher rulebook provided. This game will last fewer rounds (teacher discretion advised) than the game on day 2, which may allow for a second vote to be held for the students to choose a second change. Run this second change if time allows. *The teacher will be provided a separate rulebook with some anticipated changes, and prepared rules modifications for said changes. This will allow some element of student initiative without overly complicating the game. It is suggested that the teacher be familiar with these extra game rules. This will allow the teacher to fit any idea to one of the suggested changes, without robbing the students of choice. Application Playing the new iterations of the game. Summary/Closing Did the outcome of our simulation match the predictions we made? If not, why do you think we were incorrect? **Multiple Intelligences Addressed:** ☐ Linguistic   ☐ Logical-Mathematical   ☐ Musical   ☐Bodily-kinesthetic ☐ Spatial   ☐ Interpersonal   ☐Intrapersonal   ☐Naturalistic **Student Grouping** ☐ Whole Class   ☐ Small Group   ☐ Pairs   ☐ Individual **Instructional Delivery Methods**

<table>
<tr><td colspan="2">☐ Teacher Modeling/Demonstration ☐ Lecture ☐ Discussion
☐ Cooperative Learning ☐ Centers ☐ Problem Solving
☐ Independent Projects</td></tr>
<tr><td>Accommodations
For lower level classes, try to keep the changes to the simulation simple. Some suggested simpler changes are included in the teacher rulebook, along with more advanced changes.</td><td>Modifications
If the teacher feels they understand the game, they can go beyond the anticipated changes and come up with more complex changes on the fly.</td></tr>
<tr><td colspan="2">Homework/Extension Activities:
None.</td></tr>
<tr><td colspan="2">Materials and Equipment Needed:
• All game materials from previous day.</td></tr>
</table>

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

Lesson Plan Title: Analysis - Day 4.

Teacher's Name: Ms. Goodwin **Subject/Course:** Science (Life Sciences)
Unit: From Molecules to Organisms and Ecosystem **Grade Level:** 7

Overview of and Motivation for Lesson:
Students will be given data from both the simulations they have run in the previous days as well as real-world ecosystems, and will be asked to analyze this data to evaluate the predictions the class made about changes to ecosystems. This will help them develop critical thinking about real problems as well as skills to analyze data that carry into all science subjects.

<table>
<tr><th colspan="2">Stage 1-Desired Results</th></tr>
<tr><td colspan="2">Standard(s):
• 7.MS-LS2-1, 7.MS-LS2-4: Analyze and interpret data about periods of abundant or scarce resources and of disruptions to an ecosystem.</td></tr>
<tr><td colspan="2">Aim/Essential Question:
• How do changes to an ecosystem impact all the populations within it?</td></tr>
<tr><td colspan="2">Understanding(s):
Students will understand that . . .
• Changes to the abundance of resources can impact all populations, even the ones that do not directly use the resource.
• Changes to the size of a population can impact the size of other populations as well.</td></tr>
<tr><td>Content Objectives:
Students will be able to . . .
• Analyze and interpret data in the context of changes to an ecosystem
• Recognize the impacts of changes to an ecosystem based on data they analyze.</td><td>Language Objectives:
ELD Level Choose an item. Students will be able to . . . in English
Click here to enter text.
ELD Level Choose an item. Students will be able to . . . in English
• Click here to enter text.</td></tr>
<tr><td colspan="2">Key Vocabulary
• Producer, Consumer, Herbivore, Carnivore, Decomposer, Food Chain, Food Web, ecosystem
• glucose, photosynthesis, cell respiration, carbon dioxide, oxygen, Chlorophyll</td></tr>
<tr><th colspan="2">Stage 2-Assessment Evidence</th></tr>
<tr><td colspan="2">Performance Task or Key Evidence
• The students' analysis of the data they are given.</td></tr>
</table>

Key Criteria to measure Performance Task or Key Evidence

- The conclusions the students draw as well as the graphs they create.

Stage 3- Learning Plan

Learning Activities:
Do Now/Bell Ringer/Opener: What have you learned in math about analyzing data?

Learning Activity 1:
Lecture on very basic data analysis and conclusion making. Ask students what they already know and build on that. Include a video to help break up the lecture.

Learning Activity 2:
The students are then put into their groups and given the data from the game from days 2 and 3, with titles describing the situation in each simulation. They are also given data from real-world ecosystems to make up for any situations that the class simulations lack. The students should analyze the data to further assess the predictions they made on day 3. The students should graph the trends in populations as a group to help them see the patterns that occurred.

Application
The work done in groups analyzing the data.

Summary/Closing
What are 3 main ideas you can take away from the simulations we ran this week and the lessons that went with them?

Multiple Intelligences Addressed:

☐ Linguistic	☐ Logical-Mathematical	☐ Musical	☐Bodily-kinesthetic
☐ Spatial	☐ Interpersonal	☐Intrapersonal	☐Naturalistic

Student Grouping

☐ Whole Class ☐ Small Group ☐ Pairs ☐ Individual

Instructional Delivery Methods

☐ Teacher Modeling/Demonstration ☐ Lecture ☐ Discussion
☐ Cooperative Learning ☐ Centers ☐ Problem Solving
☐ Independent Projects

Accommodations	**Modifications?**
Data analysis can be very simple if necessary, ie. just assessing whether populations were growing or shrinking.	

Homework/Extension Activities:

Study for tomorrow's assessment.
Materials and Equipment Needed: • Data sets • Materials for students to graph ie. paper, colored pencils

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

Lesson Plan Title: Assessment - Day 5

Teacher's Name: Ms. Goodwin **Subject/Course:** Sciences (Life Science)
Unit: From Molecules to Organisms and Ecosystem **Grade Level:** 7

Overview of and Motivation for Lesson:
Assess how much each student has learned over the course of the previous 4 days by way of the simulated ecosystem.

<table>
<tr><th colspan="2">Stage 1-Desired Results</th></tr>
<tr><td colspan="2">Standard(s):
• 7.MS-LS2-3 Matter and energy transfer
• 7.MS-LS2-4 Disruptions to components of an ecosystem impact all populations</td></tr>
<tr><td colspan="2">Aim/Essential Question:
• What did the students learn by playing the simulated ecosystem over the past several days?</td></tr>
<tr><td colspan="2">Understanding(s):
Students will understand that . . .
• Plants undergo photosynthesis to create glucose which is in turn consumed by animals.
• Shortages or disruptions to an ecosystem can cause large changes in the populations of all organisms in that ecosystem.</td></tr>
<tr><td>Content Objectives:
Students will be able to . . .
• Discuss and describe the ideas of matter and energy transfer in an ecosystem, food webs and chains, as well as the effects of disruptions on the food webs, and the interactions between organisms in the ecosystem as a whole.</td><td>Language Objectives:
ELD Level Choose an item. Students will be able to . . . in English
Click here to enter text.
ELD Level Choose an item. Students will be able to . . . in English
• Click here to enter text.</td></tr>
<tr><td colspan="2">Key Vocabulary
• Producer, Consumer, Herbivore, Carnivore, Decomposer, Food Chain, Food Web, ecosystem
• glucose, photosynthesis, cell respiration, carbon dioxide, oxygen, Chlorophyll</td></tr>
<tr><th colspan="2">Stage 2-Assessment Evidence</th></tr>
<tr><td colspan="2">Performance Task or Key Evidence
• Written Assessment</td></tr>
</table>

Key Criteria to measure Performance Task or Key Evidence • Demonstration of understanding of key concepts in their responses to the Written Assessment
Stage 3- Learning Plan
Learning Activities: Do Now/Bell Ringer/Opener: Get into your groups and discuss what you have learned by playing the game this past week. Use this time as group studying for the Assessment. Learning Activity 1: Teacher leads class in discussion on major topics they learned from playing the game and from key ideas learned from the analysis activity on day 4. Analogies from the game should not directly transfer to the assessment; instead the students should be applying the lessons of the game, via thinking critically, to real world situations that the game represented. Learning Activity 2: -N/A- Application Students will take a medium length written assignment in which they must detail what it is that they have learned, in response to several very open ended questions. Students will be expected to describe real world ecosystems, as well as discuss the effects of changes on those ecosystems and the inter-organism relationships. Summary/Closing Students submit the exam **Multiple Intelligences Addressed:** ☐ Linguistic ☐ Logical-Mathematical ☐ Musical ☐Bodily-kinesthetic ☐ Spatial ☐ Interpersonal ☐Intrapersonal ☐Naturalistic **Student Grouping** ☐ Whole Class ☐ Small Group ☐ Pairs ☐ Individual **Instructional Delivery Methods** ☐ Teacher Modeling/Demonstration ☐ Lecture ☐ Discussion ☐ Cooperative Learning ☐ Centers ☐ Problem Solving ☐ Independent Projects

Accommodations	**Modifications?**

The creators of this lesson plan believe that there is likely no possible accommodation to be made in this plan.	
Homework/Extension Activities: Survey to assess how much the students feel the project helped their learning	
Materials and Equipment Needed: ● The Assessment ● The Survey	

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

C Game Rules

Necessary Game Components:

- For the following tokens, we recommend 2.5in plastic ball-pit balls
- A large number of Sun tokens (yellow)
- A large number of Water tokens (blue)
- A large number of Carbon Dioxide tokens (orange)
- A large number of Oxygen tokens (red)
- A large number of Plant tokens (green)
- A large number of Animal tokens (pink)
- A large number of Predator tokens (purple)
- Several bins or trays (referred to herein as trays), which can be used to hold tokens

Roles:

- Producer
- Herbivore
- Carnivore

Setting Up the Room (The Basic Setup):

1. Move all the desks to the perimeter of the room, opening up a large space in the center of the room.

2. Distribute 3 trays equally spaced around the outside of the room. These will be the Sun tray, Water tray, and Atmosphere tray.

3. Place all of the Sun tokens into the Sun tray, and all of the water tokens into the Water tray. Mix the Carbon Dioxide tokens and Oxygen tokens into the Atmosphere tray.

4. Establish one to three trade-in stations, which each begin with one tray filled with Plant, Animal, and Predator tokens, a small Atmosphere tray used only for trade-ins, and another tray which is empty.

5. Assign every student a role, as defined above. Attempt to keep a ratio of 3:2:1 Producer:Herbivore:Carnivore (P:H:C). No more than 2 students should be assigned as Carnivores. One to three students should be assigned as helpers for the teacher in redistributing resources and trading in tokens for the other students.

6. Have the students begin the game, and each round, by standing in the center of the room.

Role Rules (Basic):

Producers:

The main objective for Producers is to obtain as many Plant tokens as possible. Producers will walk around the room to collect one Carbon Dioxide token, one Sun token, and one Water token.

Producers can only hold one Carbon Dioxide, Sun, and Water token at a time. Once Producers have one of each of these tokens, they must move to a trade-in station. Here they can trade these three tokens for one Plant token and one Oxygen token.

Producers must discard the Oxygen token into the atmosphere tray before they can trade in a new set of tokens.

Herbivores:

The main objective for Herbivores is to obtain as many Animal tokens as possible.

Herbivores will walk around the room, "eating" Producers. They will approach a Producer and ask them for a Plant token. If the Producer has a Plant token, the Producer must give it to the Herbivore.

Herbivores will also collect Oxygen tokens and Water tokens from the Oxygen and Water trays. Herbivores may only hold one Oxygen token, one Water token, and one Plant token at a time.

Herbivores with a Plant token, an Oxygen token, and a Water token may trade these tokens in at a trade-in station for one Animal token and one Carbon Dioxide token.

Herbivores must discard the Carbon Dioxide token into the atmosphere tray before they can trade in a new set of tokens.

Carnivores:

The main objective for Carnivores is to obtain as many Predator tokens as possible.

Carnivores will walk around the room, "eating" Herbivores. They will approach an Herbivore and ask them for an Animal token. If the Herbivore has an Animal token, the Herbivore must give it to the Carnivore.

Carnivores will also collect Oxygen tokens and Water from the Oxygen and Water trays. Carnivores may only hold one Oxygen token, one Water token, and one Animal token at a time.

Herbivores with an Animal token, an Oxygen token, and a Water token may trade these tokens in at a trade-in station for one Predator token and one Carbon Dioxide token.

Carnivores must discard the Carbon Dioxide token into the atmosphere tray before they can trade in a new set of tokens.

Gameplay:

The game is divided into rounds. Each round will consist of 3 sub-rounds, to be run consecutively within a round.

Sub-round 1: Simulation:

This is the main sub-round. In this sub-round, players will move around the room, following the rules above in order to accrue as many Plant, Animal, and Predator tokens as possible. This round will last for exactly 90 seconds from when it begins.

Sub-round 2: Life and Death:

In this sub-round, every population will undergo a check on the amount of tokens they have accrued. Play is paused, and no player is allowed to gain additional tokens of any type. Now all players are subjected to the following checks:

Producers:

Any Producer with fewer than 3 Plant tokens sits dies. Death is simulated by having the player sit down until they are "born". "Dead" players may not participate in simulation sub-rounds. Any Producer with 5 or more Plant tokens may give birth to an additional Producer. Birth is modelled by having a sitting player stand up and become the role of the player that "gives birth". Players that are added to the game by birth should also come from the helpers assigned at the beginning of the game, and dead players can become the new helpers.

Herbivores:

Any Herbivore with 0 or 1 Animal tokens dies. Any Herbivore with 4 or more Animal tokens gives Birth.

Carnivores:

Any Carnivore with 0 or 1 Predator tokens dies. Any Carnivore with more than 5 Predator tokens gives birth.

Sub-round 3: Clean up:

In this round, all players return all tokens to their respective bins. If there is a Supply Side Change (see below), apply this change now. Students should move back to the center, and all "dead" students should be sitting down or in position to help. After the Clean up sub-round, a new round can begin.

Changes:

This section is dedicated to possible changes that can be made to the game upon student suggestions. In the context of the accompanying lesson plans, this part of the rulebook will be most useful in day 3. Due to the impossible nature of predicting everything that students can suggest, this section will instead focus on specific changes that teachers can adapt to general situations. It is suggested that the scenario chosen is changed, rather than a new environment adopted.

Addition of a higher order consumer:

Examples: The students choose to add a dolphin, a different kind of squid, a human, etc.

Setup Changes: Maintain the 3:2:1 P:H:C ratio as described above. Add 1 single high level consumer. This consumer plays by the same rules as the Carnivore, except instead of consuming an herbivore, this organism consumes Carnivores. This organism survives with 1 token and reproduces with 3.

Note: This is one of the most expected changes, especially if the students are shown both videos as noted in the lesson plans.

Setup Changes:

This subsection will be about changes to the game that can be made by changing the setup somehow. These are the easiest changes to make in the game. For the following changes, any alteration to the basic setup involving tokens in abnormal trays are made with the assumption that, once depleted, these tokens can be replenished to their starting values via trade ins.

Ratio Change:

Examples: lots of Herbivores or Carnivores escaped from the local pet store, Producers had an amazing year last year, poaching season started and hunters are killing off certain Animals, etc.

Setup Changes: If Producers are in surplus, change the P:H:C ratio to 5:2:1, if Producers are in shortage, change the P:H:C ratio to 2:2:1.

If Herbivores are in surplus, change the P:H:C ratio to 3:3:1, if Herbivores are in shortage, change the P:H:C ratio to 3:1:1.

If Carnivores are in surplus, change the P:H:C ratio to 3:2:2, if Carnivores are in shortage, change the P:H:C ratio to 5:3:1.

Note: We suggest not having a surplus of Producers.

High Sun Environment:

Examples: A Sunny day, Solar flare, Desert environment, etc.

Rules Change: Place two Sun tokens into each of the Water and Carbon Dioxide trays during Setup.

High Water Environment:

Examples: Rainy days, floods, hurricanes, rainforests, etc.

Rules Change: Place 4 Water tokens into each of the Sun and Carbon Dioxide trays.

High Carbon Dioxide Environment:

Examples: Artificial environment such as a Biodome, underground environments, etc.

Rules Change: Place two Carbon Dioxide tokens into each of the Water and Sun trays during Setup.

High Oxygen Environment:

This is not a suggested change.

Supply Side Changes:

This subsection will be about changes to the game that can be made to the supply side of the game, or specifically, to the amount or position of basic resource tokens available to players throughout the game.

Low Sun Environment:

Examples: A very cloudy place, a volcano erupts and blocks out the sun, a solar eclipse, a coral reef environment with much of the sun blocked by water, etc.

Rules Change: Limit the number of Sun tokens to the number of Producers divided by 2, rounded up.

Low Water Environment:

Examples: Draught, rivers change their path, pollution makes certain watering holes undrinkable, Humans drain the nearby (lake, river, etc.) for their own drinking water, etc.

Rules Change: Limit the number of Water tokens to the number of Players divided by 1.5, rounded down.

Low Carbon Dioxide Environment:

Examples: Artificial environment such as a Biodome, etc.

Rules Change: Limit the number of Carbon Dioxide tokens to the number of Producers divided by 2, rounded up.

Low Oxygen Environment:

Examples: Plants have not been as efficient lately, Primordial Earth, etc.

Rules Change: Limit the number of Oxygen tokens to the number of Players divided by 1.5, rounded down.

Rules side changes:

This subsection will be about changes to the game that can be made to the rules of the game, or specifically, to the amount of tokens created by players or to the interactions between players.

Low Glucose Production:

Examples: Poor soil quality, Plants that produce less energy over time (red vs. green leafed Plants), etc.

Rules Change: Producers need two each of Sun, Water, and Carbon Dioxide tokens to trade in for a Plant token.

Note: This change can be difficult for the Producers simply because this is a lot of tokens to carry.

High Glucose Production:

Examples: Good soil quality, Plants that produce more energy over time (red vs. green leafed Plants), etc.

Rules Change: Producers trade in their tokens for 2 Plant tokens instead of 1.

Disease, Pestilence:

Examples: A virulent disease infects many Animals or Plants.

Rules Changes: Whichever population is affected requires more tokens during the death/birth phases of the game. Producers and Herbivores will require one extra Plant tokens in order to stay alive between rounds, Carnivores will require two extra tokens to stay alive. These organisms will also require this many more tokens to procreate during this phase.

Note: Do not use this change over every population unless mass chaos is desired. Target only one population or role to introduce strain into the simulation.

Hungrier Animals:

Examples: Mass changes in Animal behavior, unforeseen suggestions.

Rules Changes: Herbivores now require an extra Plant token to obtain an Animal token. Or Carnivores now require an extra Animal token to obtain a Predator token. Players may only take one token from another player at one time.

Note: This change introduces strain on at least two populations at one time. For this reason, it is not suggested that this change is used in low level classes. For example, Herbivores will eat more Plant tokens per unit time, causing a decrease in Producer populations over time. Since the Herbivores will also produce less over time, they are under pressure, and since there are less Animal tokens, the Carnivores will be under pressure.

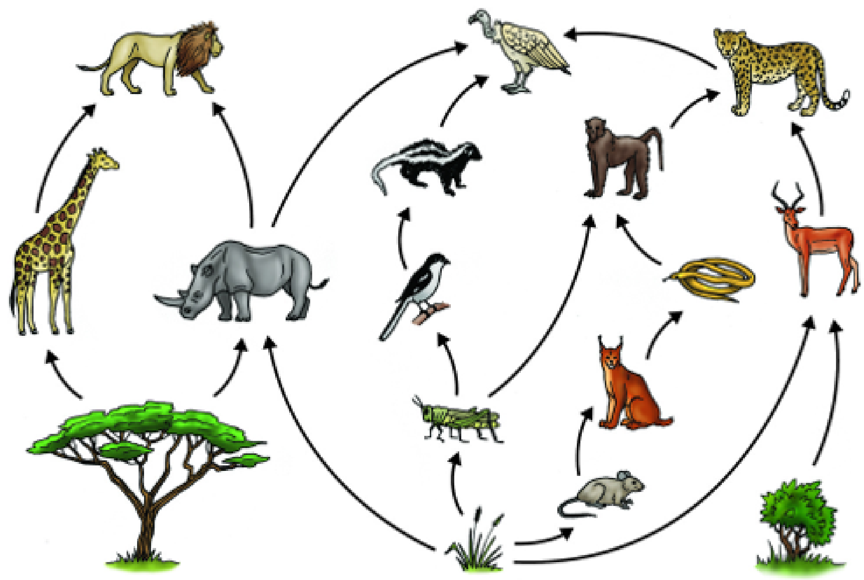
D Student Handouts

Name: ______________________ **Date:** ____________ **Period:** _____

ECOSYSTEM VOCABULARY

Words to Know:
Producer: an organism that uses an outside energy source, such as the Sun, and produces its own food
Consumer: an organism that cannot make its own food and gets energy by eating other organisms
Decomposer: a consumer that eats deceased organisms and returns excess chemicals and nutrients from the deceased organisms to the environment
Herbivore: a consumer that eats only producers
Carnivore: a consumer that eats only other consumers
Omnivore: a consumer that eats both producers and consumers
Food Chain: a series of organisms where each depends on the next one as a source of food
Food Web: a model of energy transfer that can show how the food chains in a community are interconnected
Ecosystem: a community of interacting organisms and the physical environment around them
Photosynthesis: a series of chemical reactions that convert light energy, water, and carbon dioxide into the food-energy molecule glucose and give off oxygen
Chlorophyll: a molecule found in green plants that facilitates photosynthesis
Cell Respiration: a series of chemical reactions that convert the energy in food molecules into a usable form of energy called ATP

1. Answer the questions below based on this picture:



a. What does this picture show?

____

b. What role in the ecosystem does the tree fill?

____

c. What two vocabulary words could describe the giraffe?

____

d. What two vocabulary words could describe the cheetah?

____

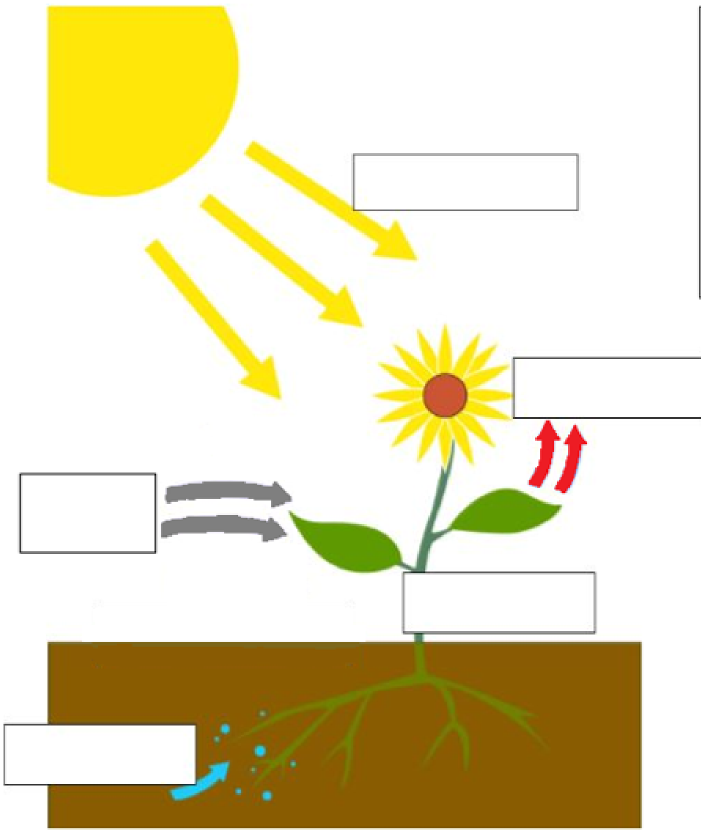
2. Describe how energy is transferred among organisms in the following situations. Be sure to explain where the energy came from initially, and use vocabulary words to describe the roles of the organisms.

a. A cow eats grass during the day. At night, a wolf comes by and eats the cow.

b. A hawk catches and eats a squirrel. The squirrel had been eating the acorns from an oak tree. Later, the hawk dies, and worms feed on its body and return nutrients from it to the soil.

3. Place the words from the box on the right into the empty boxes on the picture below. What is the process shown in the picture?

____



Water
Oxygen
Sunlight
Carbon Dioxide
Glucose

4. Circle the correct answers to each of the following questions. There may be more than one correct answer for some questions, so you can circle more than one.

a. What form is energy in when it enters an ecosystem?

Chemical Light Electrical Kinetic

b. What is needed for a producer to convert this energy into a form it can store?

Water Soil Carbon Dioxide Chlorophyll

c. What form do producers store energy in?

Chemical Light Electrical Kinetic

d. What molecule do producers store energy in?

Chlorophyll Carbon Dioxide Glucose Oxygen

e. What process do consumers use to convert energy stored in what they eat into a form of energy they can use?

Cell Respiration Photosynthesis Transcription Reduction

Name: ______________________ **Date:** ____________ **Period:** _____

Day 2 Worksheet

1. What role were you in the ecosystem game? What actions did you take, and what tasks from a normal ecosystem did these actions represent? Talk to your groupmates and ask them what their roles were, and what they did. How do their actions represent different tasks in the same ecosystem?

____

____

____

____

____

____

2. Occasionally, in real ecosystems, one or more plant or animal gets eaten too quickly and dies off. Imagine what would happen in the game if the consumers ate too many producers, and there were only two producers left. What would happen to the rest of the players? Was there ever a time when one role had too few players for them to perform their role well? What happened then? See if your group can come up with an idea of what could happen if any role had too few players.

____

____

____

3. If you were the same role for at least two rounds, did you feel that your behavior changed over the course of the game? How, and why, did you change behaviors? Did the change help you or hurt you when trying to get food? For example: if you were an herbivore in the first round and stood in one place, but in the second round you moved around to try and get more plants. Talk amongst your group to see what they changed over the course of the game.

Day 2 Closer

List one change you are able to make to an ecosystem that could be portrayed by the game. Predict what impact this change would have on the game.

Population \ Round	0	1	2	3	4	5	6
Seaweed							
Crabs							
Squid							

Day 3 Handout - Data Tracking Sheet

Day 3 Closer

What change did the class make to the simulated environment?

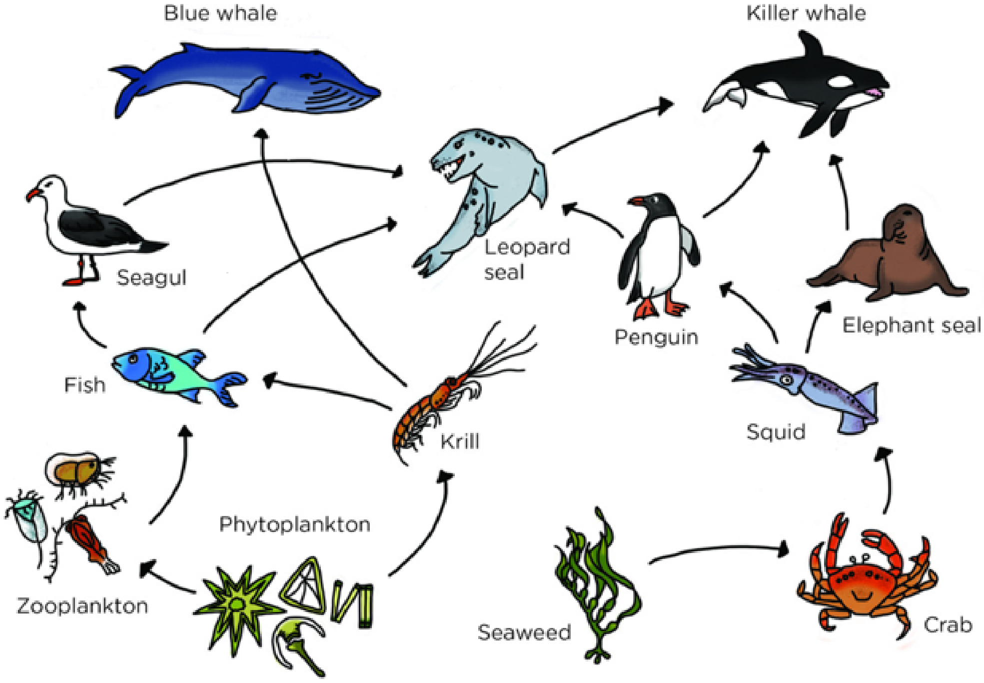
How was it represented in the game?

What did the class predict would happen compared to the first game yesterday, and, how did the predictions compare to what actually happened?

Name: ______________________ Date: ____________ Period: _____

ECOSYSTEM ASSESSMENT (ANSWERS)

Answer the following questions based on the food web below.



1. a. What organisms in this ecosystem are producers?

Phytoplankton and Seaweed

b. What process do the producers use to create food?

Photosynthesis

c. What chemicals and/or energy sources are needed for this food creation process?

Water, Carbon Dioxide, and Sunlight

d. What chemicals are produced as a result of this food creation process?

Glucose and Oxygen

2. Describe what you think would happen to some of the populations within the ecosystem in each of the following situations, and why.

a. A ship carrying penguins to a zoo is damaged, and the penguins escape into the ecosystem, drastically increasing their population.

First Level:
- Squid population goes down because more penguins eat them
- Leopard seal and/or Killer whale populations go up because they have more food available to them

Second Level:
- Elephant seal population goes down because it has to compete with more penguins for squid
- Crab population goes up because there are fewer squid eating them

As time goes on:
- The increase in predators and decrease in prey for the Penguins causes the Penguin population to normalize, as well as the others over time

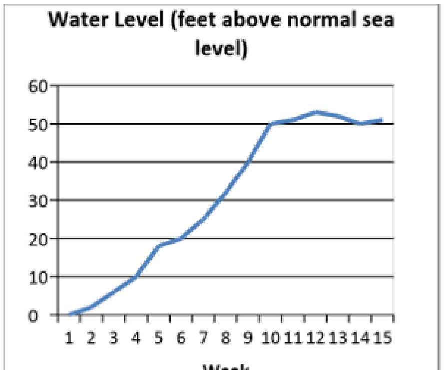
b. Chemicals released into the ecosystem by humans react with carbon dioxide, reducing the amount of carbon dioxide available to the organisms.

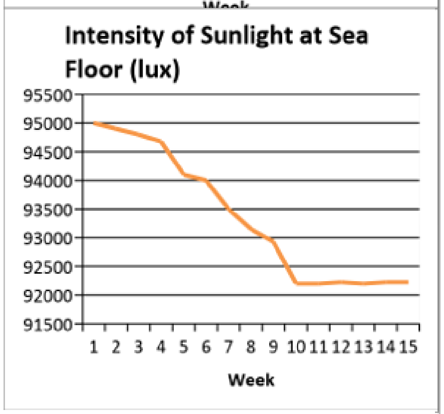
First Level:
- Phytoplankton and Seaweed populations go down because they cannot photosynthesize without carbon dioxide

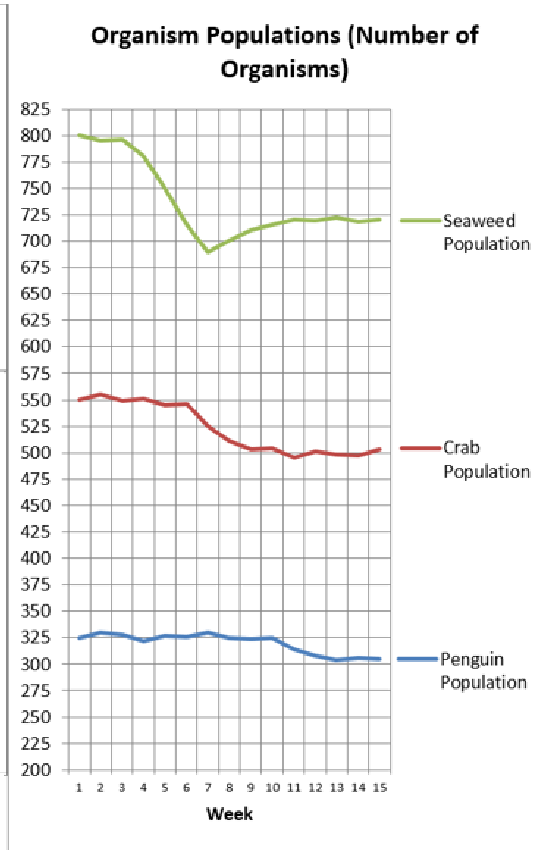
Higher Levels:
- Consumers gradually decline after their food sources do. For example, the reduction in Seaweed then gives Crabs less food, so their population goes down, then Squid, and so on

As time goes on:
- When the primary consumers decline, this reduces pressure on producers, so they rise again. This carries up the food chains until the populations stabilize again.

The graphs below show changes in some populations from the ecosystem above, as well as changes in some non-living parts of the ecosystem, over the course of 15 weeks. Answer the questions on the next page based on these graphs.







3. a. Describe the pattern in the water level and sunlight intensity from week 1 to week 10.

The water level is rising over these weeks, and the sunlight intensity is dropping

b. Describe the pattern in the Seaweed population from week 3 to week 7.

The Seaweed population is going down over these weeks

c. Describe the pattern in the Seaweed population from week 7 to week 15.

The Seaweed population rises again, and then levels off

d. Describe the pattern in the crab population from week 6 to week 11.

The Crab population is going down over these weeks

e. Describe the pattern in the Crab population from week 11 to week 15.

The Crab population stays fairly steady over these weeks

f. Describe the pattern in the Penguin population from week 10 to week 15.

The Penguin population drops slightly, then levels off

4. Use the graphs and your answers to all the parts of question 3 to help you answer these questions.

a. Based on the two graphs showing water level and sunlight intensity, describe what happened to resources available to the ecosystem, and why this change could cause a change to the populations.

- The water level rose
- This caused sunlight to be less intense at the sea floor
- Sunlight is needed for photosynthesis, so the Seaweed cannot produce food as effectively, and begins to drop

b. Based on your knowledge of energy in ecosystems, and the graph of organism populations, which species was directly impacted by this change?

Seaweed

c. While one population was affected the most, there were changes in all three populations shown on the graph. Based on your knowledge of energy in ecosystems, why were the other two populations affected as well?

- The Crabs eat the seaweed, so shortly after the Seaweed population dropped, the Crabs had less food, so they dropped too.
- The Penguins eat Squid, which eat the Crabs. The Squid would have had less food when the Crabs declined, so then they would have dropped, and the Penguins would have less food. Since this is a few levels away, there is less of a change and it is delayed.

d. In the last five weeks, while the water level and sunlight levelled out, the seaweed population began to rise again before levelling out. Why do you think this occurred?

- The Crab population declined, so there were fewer Crabs to eat Seaweed. Having fewer predators allows a population to grow.

e. How do you think the crab and penguin populations will change in the weeks that come after week 15 in the graph? Why?

- Since the Seaweed population rose a bit again, the Crabs will have more food and will rise as well.
- This will travel up the food chain and the Penguins will eventually go back up a bit too.
- Since the water level and sunlight are staying the same, when the populations eventually settle back in and stay steady, they still will be lower than where they started, since there is less energy available to the ecosystem as a whole.

Survey

Please do <u>not</u> write your name.

Please read and think about the following statements. As you read the statements, think about if you agree or disagree and check the box that matches your opinion. There are no right or wrong answers, and you will not be graded, so please answer honestly. Please answer exactly once for each statement.

For Example:

	Strongly Agree	Agree	I don't care either way	Disagree	Strongly Disagree
I enjoy petting cats and dogs.		X			

In this example the statement is "I enjoy petting cats and dogs". The "X" indicates that student in this example agrees with the statement.

Please turn to the next page for the statements.

	Strongly Agree	Agree	I don't care either way	Disagree	Strongly Disagree
School is generally fun and interesting.					
Science class is fun and interesting.					
I am normally good at school.					
I am normally good at science.					
I learn better when I'm moving around.					
I learned something new in science class the past week.					
The classes in the past week were fun and interesting.					
The classes in the past week changed my opinion on science in general.					
I would consider a career in science.					

E Pre Survey Data

Every column represents one survey. The top row is question one, the second row is question two, etc. Every yellow row separates multiple surveys.

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F Post Survey Data

Every column represents one survey. The top row is question one, the second row is question two, etc. Every yellow row separates multiple surveys.

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G Interview notes

Italicized text are interview responses. Text preceded by “J:” or ”G:” are interviewer responses. Struck-through questions are ones the interviewers did not feel the need to answer based on other responses.

How do you feel the project went overall?

I think it had a lot more plusses than minuses. The kids loved being up and moving around,, and did get a sense of the components in photosynthesis and cell resp. I'd figure out a way to help the kids understand that the green balls are sugar. That was what kids had the hardest time remembering within the equation.

What particular parts of it do you think were done well?

Learning the basic game went very well. Inclusion classes struggled with adding the adaptations. That's not to say we shouldn't have done them, but they did struggle more, since once they learn something they have a hard time being flexible with that. Pre- and post- survey was good, some questions may have needed better wording. Good amount of space for the game.

What parts do you think were not successful?

Struggled with the assessment, so I would modify it somehow. I haven't thought a lot about the specifics of how to modify it. I think part of the problem was that they're used to how I write questions, and so having questions written by you guys threw them off. Manning the three stations alone is the part I would worry about, so I had another adult come into the room when I was running the game alone. Both management and controlling all three stations. I would've done more preteaching ahead of the lesson. One thing the kids continuously didn't do correctly in the game was not taking the waste gas token. This took more reminding to get them to do correctly.

J: What would you have done in terms of preteaching?

I would've spent more time on photosynthesis so they would be able to better connect the game to the photosynthesis and cell respiration processes. Maybe with reading the text and/or a video. Some students had absolutely *no background in chemistry, so that changed how I needed to approach the chemical equation of photosynthesis.*

What would you consider the most effective part of the lesson plan?

I think the most effective part was them understanding the relationships between levels in a food chain, producers, consumer levels, and that the energy was transferring through the ecosystem.

~~Is there some improvement that could be made to this part of the lesson plan?~~

How effective do you feel the lesson plan was in covering the Massachusetts education standards that it sought to cover (7.MS-LS2-3, 7.MS-LS2-4)?

2-3: excellent

2-4: good, but I think it's a framework that my lower level students are going to struggle with anyway, because they just don't know enough about the world around them.

How long would you normally take to teach these standards (or this content) to the students?

At least two weeks, 2-3. I went and added more after you left

~~If she says it takes less time than our lesson: Do you feel that the students were engaged enough to justify spending the additional time on this lesson?~~

If she says it takes more time than our lesson: Do you feel that our lesson plan could take advantage of the full amount of time a standard lesson plan would normally take?

Yes.

J: We'd add more lecture-style, background info content

Would you do the project again? Why, or why not?

Absolutely. I tend to struggle with new things, so when it comes right to my classroom I have to take advantage of that

If you were to do the project again, what would you change about it or add to it?

More information ahead of time about photosynthesis and food chains.

Give them more time with the vocabulary. More on-task time, especially with shorter classes.

~~If not, are there any parts of the project you would use in creating a new project to cover the same or similar standards?~~

In your last class of the day, Gavin and I were not there to help with the game. To what extent were you able to conduct the lesson plan when you were on your own for your 10th period class?

I did only two days of playing the game. I taught them the game and ran the game with them, and we did one change, but I didn't go beyond that point, so they didn't get as much practice with them. At that point I needed to move on in terms of my curriculum.

Did you feel the lesson or some parts of it needed additional help to be executed properly?

It works well when there's 2 or more adults in the room. 2 you can manage, especially if you know the kids. It helps things move much smoother, especially with resetting the game between rounds.

Do you think you could have interpreted the lesson, and particularly the game, without us being there to help explain it to you and the students?

I did struggle with that, and it was really good to have you guys there to dry run it with the kids and with me. You may want to create a video tutorial, because when you just read it in print, it doesn't translate very well to what needs to physically occur.

J: I could patch those rules up a bit to make them simpler.

I really think if you can get the chance to run it with another classroom and take a video it would be very helpful.

Compared to traditional lessons, did you notice a difference in which students were engaged, or which students learned more, from this lesson?

Yes and no. Some ADHD students seemed more engaged because they could be moving. I have a fair number of low motivation kids that I hoped to see more involved but that didn't necessarily happen for most of them. It *seems like nothing engages them. I don't have a lot of really low level ELL students, but this helped them because once they understood what they needed to do they could stick with that.*

Was it any easier or harder to enforce discipline in your students when using this lesson plan, and specifically during the game?

I don't know if there was a significant difference. It was more movement oriented than focus. I had to make sure they weren't moving in ways they weren't supposed to be.

How, if at all, did you adjust your approach to controlling your classroom during this lesson?

Had to control movement rather than engagement, make sure they were playing correctly, not touching each other, rather than take your notes, eyes up here, etc.

What did you think about the paper-and-pencil quiz at the end of the lesson plan?

See above in "What parts do you think were not successful"

Do you think the students' grades on the paper-and-pencil quiz accurately reflected how much they learned from the lesson?

Not completely. I think they were somewhat thrown by some of the wording of the questions, and I think I knew they knew more based on what I asked them later on and referring back to the game.

If she says no: What could be done to scale the paper-and-pencil quiz to lower level classes, in order to make it fair for all students?

Simplify the food web to remove the second producer so it reflected more what we had in the game. A lot of the kids struggled with number 2. Maybe keep the scenario but ask for one or two populations that would change, or one that might increase and one that might decrease. I loved the graphs but kids struggled with them. The lux one in particular threw them off with the big numbers. The multiple choice section seemed to go over well. Ask for sun intensity and water level separately.

G: Having water increase and sunlight decrease may have confused them

**agreement*

A lot struggled with 4d. Adding verbal explanation to what they were reading helped them think about it more.

J: May have been wording difficulties as well

G: They hadn't seen much effect of populations on other populations

**agreement*

~~If she says yes: We got the feeling that it was at least somewhat unfair to the students, or more difficult than we intended it to be.~~

What other forms of assessment could be used to test student learning?

Other science teacher created a packet with a variety of food webs. It may be better to see if they can transfer their knowledge to other food webs. I also do a photosynthesis and cell respiration puzzle with color coded index cards that can be used to test if they understand the chemistry of it.