SCAFFOLDING FOR BIOLOGY

An Interactive Qualifying Project Report

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Abstract

In this project, a microworld was created in a Science ASSISTment, a computer based learning environment that assists students with inquiry as it collects data to assess their performance. The microworld assessed middle school students' knowledge of ecology and inquiry skills while addressing common misconceptions in food webs. The students' prior knowledge of ecology was assessed through pretest items. Through two problem scenarios in the microworld, the students were assessed on their inquiry skills and content knowledge. Their gains in knowledge were then assessed through the same pretest items given in a posttest. The project did successfully assess the students' inquiry skills and knowledge, although there is room for improvements in the microworld and scaffolding that should be made before further implementation in a larger setting.

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Introduction

Inquiry skills are a big focus in the National frameworks for science (National Science Education Standards, NRC, 1996), however they are often not put to use in the classroom. Classroom biology and field biology had developed a disconnect, with the former focused on memorization of facts and popular theories, and the latter based around experimentation and hands-on learning. Using experimentation to teach students proves to be effective and gives them a more established idea of real life biology (Wilensky & Reisman, 1998).

Typical classrooms lack problem solving based learning and assessment. Instead they focus on rote knowledge and fact based tests and assessments. However this does not address the National Frameworks focus on inquiry skills and hands on learning. Instead classrooms should be focusing on using problem-solving and reasoning strategies in both their learning and assessment tools, such as using performance assessments (Fadel, Honey, & Pasnik, 2007). Performance assessments allow the students to use the knowledge and skills they have learned to perform tasks that involved real world problems, allowing them to use problem solving skills. Due to their high cost and the difficulty of training of teachers to use the tools, performance assessments are not often used (Ruiz-Primo & Shavelson, 1996).

The ASSISTments program described below is helping to bring performance assessments into classrooms by developing a platform that can be used by teachers as both a learning and an assessing tool that has the students engage in scientific inquiry skills in order to help work towards incorporating the Nation frameworks reform in classrooms (NSES, 1996).

ASSISTments

The ASSISTments platform, located at www.assistments.org, provides a computer-based learning environment for assisting students with inquiry tasks while collecting assessment data on their performance. Dr. Janice Gobert and her team are utilizing this platform by developing a science ASSISTments program at Worcester Polytechnic Institute (www.scienceassistments.org). The program consists of virtual microworlds that provide engaging activities for students to solve inquiry tasks. This program allows data on both student inquiry skills and scientific knowledge to be collected and analyzed. The Science ASSISTments problems that use these microworlds are designed in accordance with the Massachusetts Science and Technology/Engineering Curriculum Framework and the NSES for scientific inquiry (NSES, 1996). The tasks use a microworld to provide an avenue for students to develop a hypothesis and experiment, analyze their data, and communicate their findings, thus honing inquiry skills while simultaneously deepening scientific content knowledge.

Background

Massachusetts Education and Learning Strands

The Massachusetts Department of Education has established a curriculum standard that specifies what students of each learning level are expected to learn. With regard to middle-school level life science, topics should cover the connectedness of biological systems, from the different features of individual cells to the dynamics of whole ecosystems. The primary focus for this study is strand 13 for grades 6-8, which is about the interactions of organisms within an ecosystem and the functions they perform. The lesser, secondary focus is strand 14, which is about the roles that producers, consumers, and decomposers have in an ecosystem, as well as the transfer of energy (Massachusetts Department of Education, 2006). Therefore the intended subjects of this Science ASSISTments project are middle-school level students, who are expected to have learned these topics in science class.

System Dynamics

For some science topics, such as ecology and other complex systems, system dynamics is a good way for students to be able to learn the underlying causal system. In ecology a change in one organism affects the whole ecosystem over time. For that reason, system dynamics is a good underlying system in order to model the workings of food webs and see the changes brought about over time.

A study by Alessi compared different system dynamics modeling systems in several schools to look at their ease of use and effectiveness to see whether or not it would be good to implement in the education system (Alessi, 2000). The study found that all three systems provided students with improved learning, however one of them was easier to use and could only be applied to science. They concluded that implementing system dynamics models, like the ones they explored, would help to enhance the students' learning but are often time consuming and challenging to integrate into the curriculum (Alessi, 2000).

Another study was done by Quellmalz on the use of games and simulations to help teach students science in the classroom. It looked at two-dimensional simulations of science topics, virtual laboratories, and various games and how successful they were in helping the students to learn concepts, as well as how successful they were in assessing what the students had learned. The simulations were found to be useful for measuring learning by students, but the depth of the understanding of the students could not be concluded as more research was needed. The games were found to be a fun way for the students to learn science; however, more work needed to be done in developing the assessment of the learning acquired (Quellmalz, 2009).

A study was also done by The BioKIDS research group on another assessment system, called PADI (Principled Assessment Designs for Inquiry), to see if it was effective for measuring students' inquiry skills and cognition. The PADI system was hypothesized to provide an accurate assessment by combining aspects of knowledge and learning rather than treating them as individual parts. A random sampling of 100 from a group of 2000 sixth graders from high poverty urban schools was tested. Students took a pretest before attending an eight week course to learn cognition and inquiry in areas of science, and then a posttest was used to assess the results. The conclusions were that by focusing on and better understanding a curriculum, assessment can be done more accurately to create all around more beneficial learning environments. Though some estimated difficulties of questions seemed to be inaccurate, the PADI system provided a more comprehensive form of assessment than comparative systems, which could be further tweaked for more accurate use (Gotwals & Songer, 2006).

Wilensky and Reisman conducted yet another study, theirs focusing on the effectiveness of using dynamic models to teach children ecology, and how much students were able to infer without outside help. Middle school students were given StarLogoT language dynamic models of various environments to use and a specific scenario to try to achieve, such as a stable sheep-wolf population. The students created their own rules and ran simulations, then revised them without outside help. Students were able to make inferences about the rules needed for the goal environments, and through experimentation, were able to achieve accurate models (Wilensky & Reisman, 1998).

Studies on Misconceptions in Ecology

In a study done by Gallegos it was found that students had preconceptions as to what a carnivore and an herbivore were and this influenced their creation of food webs. They believed the carnivores were big and ferocious and therefore picked them to be the top predator, while the herbivores were passive and smaller than carnivores and were placed lower on the food web. The students believed that larger animals ate smaller animals, and even though this is sometimes true, it is not always. This misconception led them to incorrectly indentifying the order of a food chain given to them (Gallegos, Jerezano, & Flores. 1994).

Gotwals and Songer conducted a study in which over a course of a year they taught a curriculum to a group of 318 sixth grade students in the Detroit Public Schools. They then tested the students with 20 items in which the students had to make a claim, support the claim, and explain reasons why the evidence supports the claim. They discovered several misconceptions amongst the students with regard to food chains and food webs as well as ecology. One of the misconceptions was the way the students interpreted the arrows in the food chains. They did not draw the arrows going the correct direction even though in the interviews they would explain the food web correctly (Gotwals & Songer, 2009).

Another concept that Gotwals found students showed trouble with was the effects of one organism in a food web on another. The students did give a correct claim when asked what would happen to the large fish if the small fish died out, however they could not explain their reasoning well. Also in another item the students had difficulty reasoning how changes in one level on the food web would affect another one that was not directly connected. When the organisms were directly connected in a predator prey relationship they were able to understand how they would be affected, however when they were not directly connected then students showed difficulty in reasoning the effects it would have. They also found that students had trouble reasoning about the effects a change in predator would have on its prey, although the authors of the study were not sure if this was due to the organism used being unfamiliar to the students or actual difficulty in reasoning with the food web (Gotwals & Songer, 2009).

In addition, AAAS Project 2061 researched middle-school students' gaps in understanding about interdependence in living systems by issuing distracter-driven test questions. Test questions were each accompanied with meta-questions, asking the students to explain their understanding of the test questions, so that any aspect of uncertainty could be picked up on even if the test question was answered correctly. The two factors indicating misconceptions that were tested showed extremely significant impact. The use of symbols instead of animal names when introducing a food web, as well as the focus on indirect rather than direct food web effects, resulted in many fewer correct answers (Lennon &. DeBoer, 2008).

Goals

The goals of this Interactive Qualifying Project were to create a Science ASSISTment microworld and activity that would assess middle school students on their knowledge of concepts in ecology while engaging in inquiry in an interactive microworld. Using the background information above, a microworld was created to address the concept of interconnectedness in food webs and the misconceptions the students may have surrounding that concept. This microworld was then integrated into the Science ASSISTments system and tested on the middle school students in order to achieve the goals of this project.

Method

Participants

The participants in this study were eleven middle school students aged 13 to 15 from an after school program in Central Massachusetts.

Procedure

In a computer lab at Worcester Polytechnic Institute, the participants were individually tested on computers. To begin, they did a content knowledge pretest to assess their prior knowledge of the subject of ecology and food webs. The questions targeted the interrelationships of the food web and asked how the organisms affect one another.

Once the pretest was completed, the students then proceeded to the first problem scenario in the microworld. There they were asked to explore the ecosystem and follow the directions in order to stabilize the ecosystem. They made a hypothesis, experimentally tested it by manipulating the number of organisms and recording their data, and then were asked to analyze their data. The microworld was followed by some embedded assessment questions, in which the students were assessed on how much they could apply their prior knowledge to this ecosystem, and on being able to communicate their findings. The students then completed the second problem scenario on shrimp farms in which they did the same things as described above, followed once again by questions that assessed their ability to communicate their findings.

Lastly, the students completed a content knowledge posttest. This was the same test given to them in the pretest. This was used to see how much knowledge was gained through completing the microworlds.

Materials

The following sections describe the pre test, post test, and microworld that can be seen in the Appendices.

Pre- and Post-test

The pretest was comprised of one open response question about relationships in an ecosystem and ten multiple-choice questions. Six of the multiple choice questions were also concerned with relationships in an ecosystem, three had to do with classifying roles in an ecosystem, and finally one was about energy within an ecosystem. The main focus for our ASSISTment exercise was relationships within an ecosystem, with a minor focus on roles with an ecosystem, and so the question topics reflected this.

Pretest 1 (Appendix 1a)

Question one dealt with relationships in an ecosystem and introduced and explained the standard food web diagram, then asked about how a decrease in prey population affects a predator.

Pretest 2 (Appendix 1b)

Question two was about the transfer of energy in a food web and asked how energy initially enters the ecosystem.

Pretest 3 (Appendix 1c)

Question three was concerned with classification and asked the student to identify one of the consumers in the ecosystem.

Pretest 4 (Appendix 1d)

Question four was concerned with classification and asked the student to discern the list of producers out of the four lists given.

Pretest 5 (Appendix 1e)

Question five was concerned with classification and asked the student to identify one of the secondary consumers in the ecosystem.

Pretest 6 (Appendix 1f)

Question six was an open response question that dealt with relationships in an ecosystem and asked how an increase in a specific population would affect the populations of some of the other species.

Pretest 7 (Appendix 1g)

Question seven dealt with relationships in an ecosystem and reiterated the proper way to read food web diagrams, then asked which organisms could be affected if a specific population changed.

Pretest 8 (Appendix 1h)

Question eight dealt with relationships in an ecosystem and again reiterated the proper way to read food web diagrams, then asked how a specific organism's population would be affected if another specific organism's population decreased. This was phrased as an overfishing scenario, and it should be noted that the two organisms in question were not in proximity to each other within the food web.

Pretest 9 (Appendix 1i)

Question nine dealt with relationships in an ecosystem and again reiterated the proper way to read food web diagrams, then asked how a specific organism's population would be affected if another specific organism's population decreased. This was phrased as an overfishing scenario, and it should be noted that the two organisms in question were again not in proximity to each other within the food web.

Pretest 10 (Appendix 1j)

Question ten dealt with relationships in an ecosystem and again reiterated the proper way to read food web diagrams, then asked how a specific organism's population would be affected if another specific organism's population decreased, given that an intermediate organism's population remained the same.

Pretest 11 (Appendix 1k)

Question eleven dealt with relationships in an ecosystem and again reiterated the proper way to read food web diagrams, then asked how a specific organism's population would be affected if another specific organism's population decreased. It should be noted that the two organisms were not in proximity to each other within the food web.

Microworld Design (Appendix 3b)

The ecosystem microworld was designed to align with the knowledge presented in middle-school level textbooks, and revolves around a simplified, linear food web that moves from seaweed to shrimp to small fish to big fish (Appendix 2b). It consists of an ecosystem area in which organisms of each of the species can be placed with varying numbers. These numbers correspond to simulated populations, and when the microworld is scanned, a custom algorithm determines the progression of those populations over a span of 80 virtual days. The algorithm requires a sufficient prey population for a species not to starve, and not so many predators that the species would get wiped out. The algorithm's purpose is to be educational more than to be completely realistic. To the right of the ecosystem area is the section that contains each of the four organisms that can be added or removed using a drag and drop interface. The progression of populations from the most recent scan is shown in four graphs to the far right. A "toggle charts" button merges these graphs into one, allowing students to observe the correlation between dips and rises in the population of each species (Appendices 7a & 7b).

For each of the problem sets, the microworld begins in an unstable state, meaning that when scanned, and the simulation runs for 80 days, some of the populations would drop to zero (i.e. some species would be wiped out). It is the task of the students to hypothesize what change in the initial populations would cause the ecosystem to become stable, and then collect data through sequential scans to either support or refute this hypothesis. Though this setup is meant to assess knowledge and understanding of ecosystems, it also expects comprehension of the scientific method. Students who are unfamiliar with the process of hypothesizing, gathering data with controls, and then connecting the data back to the hypothesis may not gain in their content knowledge as would others who have a deeper understanding of scientific inquiry.

Microworld Problem Scenarios

Problem Scenario 1: Lack of Seaweed (Appendices 3a-3c)

The student is shown a microworld setup with a popup message stating that they are in the Hypothesis phase. The popup provides instructions for how to state a hypothesis, which is by clicking on the organisms and choosing whether more or fewer of them are needed to stabilize the ecosystem. After clicking "OK" to make the popup disappear, the student is able to make a hypothesis. The microworld presented to them consists of an area representing the ecosystem with one big fish, three small fish, two shrimp, and one seaweed, none of which can be manipulated. Right above this area the problem with the ecosystem is stated to be that "The ecosystem collapses because it lacks seaweed." Below the ecosystem area are three buttons. "What am I supposed to be doing?" appears in every phase, and causes the instructional popup to reappear. "I have completed my hypothesis" moves the student on to the Experiment phase, while "I need to explore more" transfers the student to the Explore phase. Once the student has formulated a hypothesis, which is displayed below the organisms to select and to the right of the ecosystem area, the student can then click "I have completed my hypothesis" to move on to the Experiment phase.

The Explore phase (Appendices 3c & 4) provides a similar popup explaining that the Explore phase is for the student to become familiarized with the microworld and the scanning procedure. When done exploring, the student may move back to the Hypothesis phase by clicking "I'm ready to make a hypothesis."

The Experiment phase (Appendices 6a & 6b) functions nearly identical to the Explore phase, however each scan stores data for later analysis. Since it is noted above the ecosystem area that the problem with the ecosystem is a lack of seaweed, and even explicitly stated that the student should select “more seaweed” within the popup instructions for the Hypothesis phase, it is expected that the hypothesis the students formulate for Problem Scenario 1 is “If the ecosystem has more seaweed then it will be stable.”

Again a popup is shown, this time explaining that the student should add or remove organisms from the ecosystem area, scan it to accumulate data, and that “It is OK if your hypothesis turns out to be incorrect!” The hypothesis is displayed above the ecosystem area, where the problem with the ecosystem was displayed during the Hypothesis phase, and below the ecosystem area is a table that contains each scan made by the student. On the right side of the microworld are four graphs to represent simulated populations of each of the four organisms for each scan result. A scanned configuration that results in every population remaining above zero is considered to be a stabilized ecosystem. At any point the student may click “I’m done experimenting. I’m ready to analyze.” to move on to the Analyze Data phase. It is not required that they actually have any data to do so.

At the start of the Analyze Data phase (Appendices 8a-8d), a popup instructs the student to decide if their data supports or refutes the hypothesis, and that “It is OK if your data refute your hypothesis.” Just as in any other phase, they have the option to return to the previous phase as well. Once the student makes a decision, more instructions appear, indicating that the trials which support the student’s claim should be dragged into the Evidence Folder, an image in the middle of the setup. Clicking “Submit Analysis” allows the student to finish the microworld portion of the problem scenario. Again, it is not required that any data be submitted as evidence to do so.

Problem Scenario 1: Embedded Assessment Questions (Appendices 9a & 9b)

Once the microworld portion is complete, the student is presented with an embedded open response question stating: “Pretend you have a friend who did not explore the ecosystem. Describe to him or her anything you noticed in regard to how different organisms in the ecosystem you explored affect one another.” This is to help measure the student’s comprehension of the exercise and observation skills, as well as to see if they are able to communicate their findings coherently. The student is then given four multiple choice questions in which they were asked to select as many as apply. For each question, the options are each of the four organisms involved in the microworld. They ask, respectively, “Which of the organsims [sic] is/are the producer(s)?”, “…primary consumer(s)?”, “… secondary consumer(s)?”, and “… tertiary consumer(s)?” This information is not obtained from the microworld. It is for measuring the student’s prior vocabulary knowledge, and whether they can apply it to the microworld food web.

Problem Scenario 2: Shrimp Farming (Appendices 10 & 11a-11e)

Before doing the activity in the microworld, the student is presented with the following open response question, “Before we move on to the microworld what are your thoughts on the relationships between [sic] predator and prey? How do predators affect their prey populations? (Appendix 10) Once they have answered this question, they then move into the microworld. The activity follows the same progression as described in Problem Scenario 1. The goal of this activity, however, is to be able to stabilize the ecosystem so that the population of the shrimp is at its highest. The ecosystem starts with no big fish, one small fish, three shrimp and four seaweeds. In order to maximize shrimp, the students must add both small fish and big fish to the ecosystem. Adding just small fish will stabilize the ecosystem with a reasonable amount of shrimp, however for the shrimp population to be maximized both big and small fish must be added.

Just as in Problem Scenario 1, the student must make a hypothesis, experiment to collect data, and then analyze the data in the same way using the same widgets.

Problem Scenario 2: Embedded Assessment Questions (Appendices 12a & 12b)

Once the student finishes the activity, they were then presented with embedded assessment questions, as in Problem Scenario 1. There were two open response questions that assessed their skills at communicating their findings.

The first question asked “One of your friends is going to start an eco friendly shrimp farming business and wants to know the details of the experiment you just performed. Unfortunately he doesn't know anything about ecology or shrimp. What can you tell him about the role of predators in the shrimp farm ecosystem you experimented with? Was this an expected result?” This question assesses whether or not the student is able to communicate the findings from the results of the activity. By being able to answer this, it shows that they have an understanding of what was happening in the ecosystem of the microworld, and are able to portray this knowledge to others.

The second question asks, “Now that you told him the details of the shrimp farm ecosystem your friend is curious to know your thoughts about the predator and prey relationships in general? [sic] Do you think natural ecosystems need predators? How are all the organisms in an ecosystem related?” This question assesses the student’s skill at taking their findings and knowledge and expands it to larger implications and other applications. Being able to expand on one's findings into a larger implication is very important in science so that one can apply concepts to different scenarios in science rather than just the one specific experiment that was conducted.

Coding of Data

As the students worked through the pre and posttest and problem scenarios, their actions were logged. This log included answers to pre and posttest questions, their hypotheses, moving, adding or subtracting of organisms from the microworld, the analysis of their data and the answers to embedded questions. These data collected from the students' log files were scored in order to assess their prior knowledge of the content, skills at performing inquiry tasks, and knowledge gains through completing the inquiry task. All of the multiple choice questions, including the pretest, posttest and embedded questions, were auto-scored by the ASSISTment program, as either correct (1 point) or incorrect (0 points).

The open response questions in the pre and posttests and the embedded questions were graded by hand on a 0-2 scale. A score of 0 corresponded to no response or the answer provided did not answer the questions asked, 1 corresponded to a partial answer that attempted to answer the question but did not fully, and 2 corresponded to a complete answer that answered the question well.

The students' hypotheses were also scored based on the following point system: maximized the solution (3 points), was a good solution (2 points), stabilized the ecosystem and showed some effort (1 point), or none of these (0 points).

Results

Tables 1 through 4 below show the students' scores for the Pretest (Table 1), Problem Scenario 1(Table 2), Problem Scenario 2(Table 3) and the Posttest (Table 4). Due to a low sample size of eleven students, quantitative analysis of the data was not possible and instead qualitative analysis was performed. Case studies of six of the students are presented explaining their pre test scores, logged actions in the microworlds, embedded question scores, and post test scores.

Table 1: Student Pretest scores

	Pretest												
Student ID	MC 1	MC 2	MC 3	MC 4	MC 5	MC 6	MC 7	MC 8	MC 9	MC 10	MC pretest total	Pretest OR	Pretest total
110967	0	0	0	0	1	0	0	0	0	0	1	1	2
110963	0	0	0	1	0	0	0	0	0	1	2	2	4
110972	0	0	0	0	0	1	1	0	1	0	3	1	4
110966	0	1	1	0	0	1	0	1	1	0	5	1	6
110969	0	1	0	0	1	1	1	0	1	0	5	1	6
110970	0	1	0	0	0	0	1	1	0	1	4	0	4
110959	0	1	0	0	0	1	0	1	1	1	5	0	5
110965	1	1	1	0	1	0	0	1	1	1	7	2	9
110962	1	1	0	0	1	1	1	0	1	0	6	2	8
110961	0	1	1	0	1	1	0	1	0	1	6	1	7
110968	1	1	1	0	1	0	1	1	1	0	7	2	9

Table 2: Student Activity Scores for Problem Scenario 1

Problem Scenario 1													
Hypo-thesis	Design and Conduct					Interpret Data			Communicate Findings	Embedded Multiple Choice			
Hypo-thesis Score	Scan baseline	# scans	# distinct scans	test hypo-thesis	stabilize ecosystem	# trials submitted as evidence	reject or support hypothesis	trials support claim	Open Response	1	2	3	4
0	No	2	0	No	Yes	0	Support	No	1	0	0	1	0
0	No	12	4	No	Yes	1	Support	No	1	0	0	1	0
3	Yes	21	6	No	No	1	Support	No	1	0	0	1	0
0	Yes	14	6	Yes	Yes	0	Reject	no	0	1	1	1	1
0	No	8	1	No	Yes	5	Support	No	1	0	0	1	0
3	no	3	1	no	yes	3	support	no	0	0	0	0	0
3	no	3	0	no	no	2	reject	yes	1	0	0	0	0
3	no	1	1	yes	yes	0	support	no trials	0	0	0	0	0
3	no	10	5	yes	yes	3	support	no	2	1	0	1	0
1	yes	3	1	no	yes	0	support	no trials	0	0	0	0	0
0	no	7	5	no	yes	0	support	no	1	1	1	1	1

Table 3: Student Activity Scores for Problem Scenario 2

Shrimp Farm Problem												
	Observe	Hypo - thesis	Design and Conduct					Interpret Data			Communicate Findings	
OR 1	went back to Explore phase	Hypo-thesis score	Scanned baseline	# scans	# distinct scans	test hypo-thesis	stabilize ecosystem	# trials submitted as evidence	reject or support hypothesis	trials support claim	OR 2	OR 3
2	No	0	No	1	0	No	Yes	0	Reject	Yes	1	1
2	Yes	2	No	50	39	Yes	Yes	1	Support	Yes	0	0
1	No	0	No	1	1	Yes	No	1	Support	No	1	0
2	No	0	No	10	4	Yes	Yes	0	Reject	No	2	2
1	Yes	1	No	5	0	Yes	Yes	4 (all same)	Support	No	1	1
0	no	1	no	1	0	no	yes	1	support	no	0	0
1	no	1	no	1	0	no	yes	1	reject	no	no log	no log
2	yes	0	no	1	0	yes	yes	0	support	no trials	0	1
0	yes	2	no	10	4	yes	yes	3	reject	no	no log	2
1	no	0	yes	2	0	yes	yes	0	support	no trials	1	no log
2	yes	0	in explore	3	1	yes	yes	0	reject	no trials	0	no log

Table 4: Student Posttest Scores

Posttest												
MC 1	MC 2	MC 3	MC 4	MC 5	MC 6	MC 7	MC 8	MC 9	MC 10	MC Total	Posttest OR	Posttest Total
0	0	1	1	0	0	1	0	0	0	3	1	4
0	0	0	1	0	0	0	0	1	1	3	0	3
1	1	0	0	0	1	0	0	0	0	3	1	4
0	1	1	0	0	0	0	1	0	0	3	2	5
0	1	0	0	0	0	0	1	0	0	2	1	3
0	1	0	0	0	0	1	1	0	1	4	0	4
0	1	0	0	0	1	0	0	1	1	4	0	4
1	1	1	0	1	0	0	1	1	1	7	1	8
1	1	1	0	0	0	1	0	1	0	5	2	7
0	1	1	0	0	1	0	0	0	0	3	2	5
1	1	1	0	0	0	1	1	1	0	6	2	8

Student Analysis

Student 110968

Pretest

Student 110968 scored a total score of 9 out of 12 on the pretest. He received 7 out of 10 points for the multiple choice and the full 2 points on the open response. This high score suggests the student may have some prior knowledge of the subject he could use to help him in the problem sets.

Problem Scenario 1

Microworld

The student went back and explored the ecosystem in the Explore phase of the microworld rather than making a hypothesis and going to the Experiment phase. In this he did not scan the baseline. The student started by adding in all of the different organisms, therefore showing no control for variables. The next five scans were distinct, as the student only changed one variable in each of them. These trials did show him controlling for variables. He was able to stabilize the ecosystem during this Explore phase.

The student then moved on to the hypothesis widget and hypothesized that “If the ecosystem has more seaweed, shrimp, big fish, and small fish then it will be stable.” This was scored 0 points as it showed little effort and understanding because he just said to add more of everything. The directions told him to hypothesize that more seaweed was needed so this shows he either did not read the directions or chose to disregard them.

The student did not perform any trials in the Experiment phase of the microworld. Because of this he did not test his hypothesis and did not collect any data to be used in the Analysis phase. He thus submitted no trials as evidence of his claim that his data supports his hypothesis. Based on this the student did not show understanding of the scientific method of observing, hypothesizing, testing, and then interpreting the data. He did all his testing before making the hypothesis and then did not do any experimenting in which he could gather data to interpret and also did not scan the baseline. Even though he has prior knowledge of the subject, as seen through his pretest score, he did not show understanding of the scientific method while doing this problem scenario.

Embedded Post-questions

The student got a score of 1 on the embedded open response question. His answer did not fully answer the questions and showed little understanding gained from the problem scenario that had just been completed. He did however score the full 4 points on the embedded multiple choice questions. This shows the he used some prior vocabulary knowledge and applied it to the food web shown in the microworld.

Problem Scenario 2

Embedded Pre-question

For the open response pre-question the student received a full 2 points. His answer as to what his thoughts were on predator/prey relationships was complete. Although he was only partially correct in his answer, it was a complete answer on an opinion based question and therefore he received full credit.

Microworld

In the Explore phase of the microworld, the student did scan the baseline. He then added shrimp to the ecosystem and scanned it, giving him one distinct scan. His next scan however was not distinct as he added seaweed, small fish, and big fish to the ecosystem. Because only one of his scans was distinct, he did not show control of variables.

The student hypothesized that "if the ecosystem has more big fish, more small fish, more seaweed and more shrimp, then it will be stable." Although this will stabilize the ecosystem, this is not the correct hypothesis and was scored 0 once again because it did not show any effort since he just said to add more of everything.

The student did not test this hypothesis as he did not collect any data in the Experiment phase. He skipped over the Experiment phase and went right to the analysis widget. The student claimed the data did not support the hypothesis but had no data to submit as evidence. Based on this, the student did not show an understanding of the scientific method. He did not test his hypothesis as the scientific method describes, which gave him no data to interpret or use as evidence to support or refute his hypothesis. Once again, despite prior knowledge of the content, the student did not follow the scientific method in working in the microworld.

Embedded Post-questions

In the first open response question the student received a score of 0. His answer showed no understanding of the relationships in the ecosystem and was incorrect. This showed that he did not have understanding of the ecosystem in the microworld despite having a high prior knowledge score.

Due to logging error, the answer to the second open response question was not recorded.

Post-Test

The student scored 6 out of 10 on the multiple choice and 2 on the open response question giving him a total post-test score of 8 out of 12. This was lower than his pretest score, but not drastically. He answered the open response well, showing an understanding of the content and a willingness to participate. His scores showed no gain as they were not higher than those of his pretest.

Student 110962

Pretest

Student 110962 scored a total of 9 out of 12 points on the pretest. She scored 7 points on the multiple choice questions and received a full 2 points on the open response. This high score and understanding in the open response shows the student has prior knowledge of the content.

Problem Scenario 1

Microworld

The student did not go to the Explore phase of the microworld. She hypothesized correct that “if the ecosystem has more seaweed then it will be stable” showing that she did read and pay attention to the directions. Her hypothesis maximized the solution and therefore received the full 3 points.

The student did not scan the baseline in the Experiment phase. She started by testing her hypothesis and only adding seaweed, showing she was controlling for variables. However after this first distinct scan, she then added many of the each of the other organisms into the ecosystem, showing she was no longer controlling for variables. For the third scan, she also did not control the variables, as she took out many organisms she had added in the previous scan and added more of another. She scanned this condition twice, giving her two identical scans.

She then moved on to the analysis phase, but decided she needed to go back to the experiment to gather more data. She continued experimenting, having a total of three more scans, all of which were distinct and controlled for variables.

Once again she moved onto the analysis phase and decided she needed to go back to the Experiment phase to gather more data. The student ran three more trials, the first not controlling for variables and the other two were distinct scans controlling for variables.

Finally she moved on to the analysis phase and stated that her data did support her hypothesis. She chose three trials as evidence. These trials however did not support her claim as they were trials in which she was not testing the hypothesis, but instead was manipulating other variables. This showed that she had little understanding of the scientific process. Although she did make a hypothesis and then start by testing it while controlling variables, she did not control for variables the whole time and after the first trial no longer was testing the hypothesis. Even though she had high prior knowledge of the content, she did not show full understanding and execution of the scientific method.

Embedded Post-questions

The student received a full 2 points on the open response questions showing that she did have an understanding of the content. Of the four multiple choice questions, the student answered two correctly. This could be interpreted the student not being able to apply prior knowledge to the multiple choice questions based on the microworld interactions, as she did show high prior knowledge in the pretest. However, since these questions tested different knowledge than the pretest, it is also possible that the student did not have the knowledge in order to correctly answer the questions.

Problem Scenario 2

Embedded Pre-question

Due to computer error, no answer was logged for this question.

Microworld

The student started by exploring in the Explore phase of the microworld. She once again did not scan the baseline. Her first two scans were distinct, showing control for variables, however her other two scans showed no control for variables as she manipulated more than one organism.

With the hypothesis widget, the student hypothesized “if the ecosystem has more small fish then the shrimp population will be at its highest.” This hypothesis is partly correct and good, as the ecosystem would need both more small and large fish to maximize the shrimp population so she received 2 points. This partially correct hypothesis shows that she is using her prior knowledge to build the hypothesis.

In the first trial the student did not control for variables, as she removed seaweed and added small fish. Her next trial both controlled for variables and tested her hypothesis as she added more small fish. Of her final three trials, only one of them was distinct, controlling for variables. None of them tested the hypothesis as she was manipulating organisms other than the small fish.

The student then moved onto the analysis widget and stated that her data did not support her hypothesis. She submitted three trials as evidence of this; however, they did not support her claim as the data did support her hypothesis. This shows that she does not have full understanding of the scientific method. She did not scan the baseline and only occasionally controlled for variables in her experimenting. Also, she only tested her hypothesis for a couple trials and then started to manipulate other variables instead. Her analysis of her data was also incorrect showing that she doesn't understand how to interpret the data. Despite having prior content knowledge, she showed little understanding and execution of the scientific method.

Embedded Post-questions

Due to computer error, the first open response question was not recorded.

The student received a full 2 points on the second open response. This shows she was able to apply her prior knowledge to the ecosystem of the microworld and indicates an understanding of the content of the microworld.

Posttest

The student received the full 2 points on the open response and 5 points on the multiple choice questions giving a total post test score of 7. Her answer to the open response was complete showing that she understood the content and had a willingness to participate. The score was lower than the student's pretest score showing that she did not have any gains after the microworld.

Student 110969

Pretest

Student 110969 scored a total of 5 out of 10 points on the pretest. He scored 5 points on the multiple choice questions and received 0 points on the open response. This score shows that he has limited prior knowledge of the content as he did not answer the open response correctly but was able to answer half of the multiple choice questions correctly.

Problem Scenario 1

Microworld

The student did not go back to the Explore phase. He hypothesized “if the ecosystem has more big fish, fewer small fish, fewer seaweed and fewer shrimp then the ecosystem will be stable.” This is incorrect, as the student was told to hypothesize “if the ecosystem has more seaweed then it will be stable.” This shows the student did not pay attention to the instructions that were given. Also this hypothesis does not stabilize the ecosystem, as more seaweed would be needed in order for anything to survive, so the student received a score of 0.

In the Explore phase the student did not scan the baseline. He did a total of eight scans, only one of which was distinct where he only added one organism. This shows that he did not control for variables in most of his experimenting. After his first four trials, he moved onto the analysis phase where he said he needed more data, which prompted him back into the Experiment phase. He then conducted his last four trials, in which the one distinct trail was carried out. None of his 8 trials tested the hypothesis.

Using the analysis widget the student claimed that his data supported his hypothesis. He submitted five of his trials as evidence of this. The trials he selected, however, did not support his claim. As he did not test the hypothesis, he did not have trial data that was able to support it. This shows that the student had no understanding of the scientific method as he neither tested the hypothesis nor controlled for variables during his experimentation. He also had little prior content knowledge as seen on the pretest, showing that his understanding of the content and scientific method were both low.

Embedded Post-questions

The student received a 0 for the open response. His answer did not address the questions and showed no understanding and little effort. He correctly answered 1 out of 4 of the multiple choice questions. This shows he had little understanding of the microworld and the content.

Problem Scenario 2

Embedded Pre-question

The student showed little effort in his response and did not completely answer it. He did however give a partial response, and received 1 out of 2 points. This shows that he did not understand the content, as his answer was not complete and his thoughts were incorrect.

Microworld

In the Explore phase of the microworld, the student did not scan the baseline. He added and removed many different organisms and then scanned it, giving him one trial in the Explore phase.

The student then moved to the hypothesis widget and hypothesized that “if the ecosystem has fewer big fish, more small fish, more seaweed and fewer shrimp, then it will be stable.” This hypothesis does not maximize the solution and is not a good hypothesis, showing he did not or was unable to use prior knowledge in making it. It does however stabilize the ecosystem and therefore the student received a score of 1.

While in the Experiment phase the student manipulated three of the four organisms at once and then scanned. He scanned this same configuration a total of four times, giving him four total trials. He did not test the hypothesis or control for variables, as he only tested one set of conditions in which many things were changed.

With the analysis widget, the student claimed the data supported his hypothesis. He then added all four of his trials as evidence of this. The trials he selected were all the same and did not support his claim, as he did not test the hypothesis. Based on this, the student did not show an understanding of the scientific method. He did not test his hypothesis or run different distinct trials that controlled for variables. This showed once again, that in addition to little prior content knowledge, he did not understand or follow the scientific method.

Embedded Post-questions

The student received no points for both of the open response questions. He did not address the questions in his answer and instead just wrote very short, unconnected information. This shows little effort as well as no understanding of the microworld and its content.

Posttest

The student received a total score of 2 on the posttest, correctly answering two of the multiple choice questions and receiving zero points on the open response. The student was unmotivated to answer the questions most likely because he had already seen them in the pretest. Because of this he did not put in much effort, as seen through is two word open response answer. He did not show gains as this score was lower than his pretest score.

Student 110963

Pretest

Student 110963 scored a total score of 4 out of 12 on the pretest. He received 2 out of 10 points for the multiple choice and the full 2 points on the open response. This low score suggests the student may have little prior knowledge of the subject.

Problem Scenario 1

Microworld

The student went back and explored the ecosystem in the Explore phase of the microworld rather than making a hypothesis and going to the Experiment phase. In this he did not scan the baseline. Of the 11 scans that were made, only four were distinct, so the student did not seem to fully grasp the proper procedure for experimentation. He was able to stabilize the ecosystem during this Explore phase.

The student then moved onto the hypothesis widget and hypothesized that “If the ecosystem has fewer big fish and more shrimp, then it will be stable.” This is incorrect and is given a score of 0. As the directions told them to hypothesize that more seaweed was needed, he either did not read the directions or chose to disregard them. The student did not act upon his hypothesis, adding more seaweed rather than shrimp, which caused him to stabilize the ecosystem.

The student only scanned once outside of the Explore phase, and thus performed only one trial in the Experiment phase of the microworld. He did not test his hypothesis and did not collect corresponding data to be used in the analysis phase. He submitted his only trial as evidence of his claim that his data supports his hypothesis, though it did not. Based on this the student did not show understanding of the scientific method of observing, hypothesizing, testing, and then interpreting the data. He did all his testing before making the hypothesis, did not do any experiments in which he could gather data to interpret, and did not scan the baseline. He has not shown prior knowledge of the subject, as seen through his pretest score, and he did not show understanding of the scientific method while doing this problem scenario.

Embedded Post-questions

The student got a score of 1 on the embedded open response question. His answer did not fully answer the questions and showed little understanding gained from the problem scenario that had just been completed. He also scored only 1 of 4 points on the embedded multiple choice questions. This shows that the he did not have prior vocabulary knowledge to apply to the food web shown in the microworld.

Problem Scenario 2

Embedded Pre-question

For the open response pre-question the student received a full 2 points. His answer as to what his thoughts were on predator/prey relationships was complete and satisfactory, showing sufficient understanding of the subject.

Microworld

The student went back and explored the ecosystem in the Explore phase of the microworld rather than making a hypothesis and going to the Experiment phase. In this he did not scan the baseline. Of the forty-nine scans at were made, thirty-nine were distinct, indicating that the student seemed to somewhat grasp the proper procedure for experimentation, however, the number of scans was abnormally high. This may indicate that the student was fooling around, and did not have a clear understanding of the aim of his experimentation. The student then made the hypothesis that "if the ecosystem has more small fish, then it will be stable." This will stabilize the ecosystem and is a valid hypothesis, but is not the ideal hypothesis that more small fish and more big fish are needed which would maximize the population of the shrimp, so a score of 2 was given.

The student did in fact test this hypothesis, but only scanned once in the Experiment phase. The student claimed his one trial did support the hypothesis and he submitted this trial as evidence. Still, this trial followed his hypothesis and stabilized the ecosystem, so it can be thought to support it. He did not test his hypothesis quite as the scientific method describes, which gave him insufficient data to interpret or use as evidence to support or refute his hypothesis, but his activity may have been merely misplaced in the Explore phase. Despite poor performance thus far, the student showed signs of greater understanding in working in this microworld.

Embedded Post-questions

In the both of the open response questions the student received a score of 0. His answers were merely mashed keys resulting in gibberish that showed no understanding of the relationships in the ecosystem. This showed that he was not motivated to answer the questions properly, despite much effort invested in the preceding microworld activity. However, it is possible that the gibberish answer is due to a logging error.

Posttest

The student scored 3 out of 10 on the multiple choice questions and 0 on the open response questions giving him a total posttest score of 3 out of 12. His multiple choice score was slightly higher than on his pretest. His open response score was lower, although that can be attributed to lack of interest or logging error, since it contained key-mashed gibberish. His scores show a slight drop, not providing us with any evidence of learning from the procedure.

Student 110972

Pretest

Student 110972 scored a total score of 4 out of 12 on the pretest. He received 3 out of 10 points for the multiple choice questions and 1 point on the open response question. This low score suggests the student may have little prior knowledge of the subject.

Problem Scenario 1

Microworld

The student went back and explored the ecosystem in the Explore phase of the microworld rather than making a hypothesis and going to the Experiment phase. However, he did scan the baseline. Of the twenty scans that were made, only six were distinct, so the student did not seem to fully grasp the proper procedure for experimentation. He did not stabilize the ecosystem.

The student then moved onto the hypothesis widget and hypothesized that "If the ecosystem has more seaweed, then it will be stable." This is correct, and precisely what the directions told them to hypothesize, earning a score of 3. The student did not act upon his hypothesis however, which prevented him from stabilizing the ecosystem. The trial he submitted had resulted in only seaweed remaining, with all other species having died off.

The student only scanned once outside of the Explore phase, and thus performed only one trial in the Experiment phase of the microworld. He did not test his hypothesis and did not collect corresponding data to be used in the analysis phase. He submitted his only trial as evidence of his claim that his data supports his hypothesis, though it did not. The student did not show understanding of the scientific method of observing, hypothesizing, testing, and then interpreting the data because of this. He did all his testing before making the hypothesis and then did not do any experiment in which he could gather data to interpret. He has not shown prior knowledge of the subject, as seen through his pretest score, and he did not show understanding of the scientific method while doing this problem scenario.

Embedded Post-questions

The student got a score of 1 on the embedded open response question. His answer did not fully answer the questions and showed little understanding gained from the problem scenario that had just been completed. He also scored only 1 out of 4 on the embedded multiple choice questions. This shows that the he did not have prior vocabulary knowledge to apply to the food web shown in the microworld.

Problem Scenario 2

Embedded Pre-question

For the open response pre-question the student received a 1 out of 2. His answer as to what his thoughts were on predator/prey relationships was incomplete and not entirely satisfactory, showing some understanding of the subject.

Microworld

The student went straight to making a hypothesis and going to the Experiment phase. In this he did not scan the baseline. The student made the hypothesis that "if the ecosystem has more seaweed, then it will be stable." This will not stabilize the ecosystem, and is completely incorrect, as the ideal hypothesis would be that more small fish and more big fish are needed, so it was scored 0. He added a number of seaweed to the ecosystem and scanned that as his only trial, indicating that the student did not quite grasp the proper procedure for experimentation. It is curious that this would have been the correct hypothesis and scan for the previous microworld, and perhaps the student assumed that the answer would be the same, though the approach was insufficient regardless. This indicates a poor understanding of and attention to the problem.

The student did in fact test this hypothesis, but only scanned once. The student claimed the data did support the hypothesis, but had only one trial, which he submitted as evidence. This trial followed his hypothesis, but did not stabilize the ecosystem, so it did not support it. Based on this, the student did not show any more understanding of the scientific method than before. He did not test his hypothesis as the scientific method describes, which gave him insufficient data to interpret or use as evidence to support or refute his hypothesis. However, he may have made the assumption that this microworld had the same correct hypothesis as the previous one, and thought that the correct hypothesis was all that mattered, though it was not even correct for this microworld. The student showed no signs of greater understanding in working in this microworld.

Embedded Post-questions

In the first open response question the student received a score of 1. His answer was insufficient and showed little understanding of the relationships in the ecosystem. This would be consistent with his data so far. A logging error prevented his second open response answer from being recorded.

Posttest

The student scored 3 out of 10 on the multiple choice questions and 1 on the open response questions giving him a total posttest score of 4 out of 12. His scores show no change, providing us with no evidence of any learning from the procedure.

Student 110966

Pretest

Student 110966 scored a total score of 6 out of 12 on the pretest. He received 5 out of 10 points for the multiple choice question and 1 point on the open response question. This medium score suggests the student may have some prior knowledge of the subject.

Problem Scenario 1

Microworld

The student went straight to making a hypothesis and going to the Experiment phase. The student hypothesized that “If the ecosystem has more small fish, more big fish, more shrimp, and more seaweed, then it will be stable.” Only the amount of seaweed needed to be increased, and hypothesizing more of everything does not show proper understanding or effort, so the hypothesis was scored 0. The student did scan the baseline. Of the fourteen scans that were made, only six were distinct, so the student did not seem to fully grasp the proper procedure for experimentation.

The student tested his hypothesis, and subsequently stabilized the ecosystem. For some reason he submitted no trials, even though he had fourteen to choose from with relevant data. He also claimed that his data did not support his hypothesis, though it did. Based on this behavior, the student did not show full understanding of the scientific method of observing, hypothesizing, testing, and then interpreting the data. He continues to show some knowledge of the subject, as seen through his pretest score.

Embedded Post-questions

An error prevented the student's answer on the embedded open response question from being recorded, though he did score a full 4 points on the embedded multiple choice questions. This shows that the he had prior vocabulary knowledge to apply to the food web shown in the microworld.

Problem Scenario 2

Embedded Pre-question

For the open response pre-question the student received a full 2 points. His answer as to what his thoughts were on predator/prey relationships was satisfactory, showing sufficient understanding of the subject.

Microworld

The student went straight to making a hypothesis and going to the Experiment phase. In this he did not scan the baseline. The student made the hypothesis that "if the ecosystem has more big fish, more small fish, fewer seaweed, and more shrimp, then it will be stable." This is incorrect, as the ideal hypothesis would be that only more small fish and more big fish are needed, and such a setup could not stabilize the ecosystem, so it scores a 0. Out of ten scans, four were distinct, indicating that the student did not quite grasp the proper procedure for experimentation.

The student did in fact test his hypothesis, and stabilize the ecosystem. He also claimed the data did not support the hypothesis, but submitted no trials as evidence. Based on this, the student showed some understanding of the scientific method, but still did not understand that he had to submit trials as evidence. The student showed no clear signs of greater understanding in working in this microworld.

Embedded Post-questions

In both open response questions the student received a score of 2. His answers were sufficient and showed good understanding of the relationships in the ecosystem. This continues to show his good knowledge of the subject matter, and perhaps it was the scientific method or the microworld's interface that troubled him.

Posttest

The student scored 3 out of 10 points on the multiple choice and 2 points on the open response questions giving him a total post-test score of 5 out of 12 points. His scores show a slight decrease, however it is suspected that by this point the student had lost motivation due to repeated questions and long testing time, as was the case for most students in the experiment. It does however provide us with no evidence of any learning from the procedure.

Future Testing and Scaffolding

Learning from the data, there are a number of places where the microworld exercises could be improved. One significant finding was that students did not properly employ the scientific method during the activity. They need to be taught to scan the baseline and to make sure that their scans are distinct. Many students performed all of their experimenting in the Explore phase, so they should be reminded that data is not gained during the Explore phase, and encouraged to make a hypothesis and move on to the Experiment Phase after considerable time spent in the Explore phase. In addition, students should not be allowed to move on with the exercise before performing the expected tasks, in particular analyzing data without having gathered any data. A pedagogical agent named "Rex" was used to ensure that students entered substantial information for their open responses, and this agent could possibly be used to relate all the guidelines mentioned. Also, an inquiry pretest could be implemented to discover each student's preexisting knowledge of the scientific method, in order to compare it to their execution during the activity.

Another general problem was that students took wrong actions despite the instructions clearly contradicting such actions. For instance, the first microworld clearly states that the problem with the ecosystem is that it lacks seaweed, and that the students should hypothesize that more seaweed is needed, yet many ignored these instructions and made completely unrelated hypotheses. It seems that these students skipped over the instructions, likely due to lack of motivation. A suggestion to prevent this is to condense all instructions into their most crucial points, explaining what the student should be doing as simply as possible. The instructions couldn't be much more prominent than they already were, although the popup instructions for the current phase may have distracted from them. Perhaps they could be integrated more dynamically, through popups or some similar format, or the phase instructions could be made less intrusive. Hopefully future students can be better motivated somehow, such as by offering a minor reward for completion, or timing the activity so that it doesn't occur when the students are tired from school.

Lastly, there are technical errors to correct. A number of open responses weren't logged due to an error, crippling the data gathered. The pretest and posttest questions were also in different orders, so that should be corrected. Many students didn't understand that the posttest questions were meant to be a repeat of the pretest questions, so that could be made clearer as well. The trial performed resorted to showing an image of the ecosystem's food web on a nearby projector, but instead it should be included in the actual activity. These adjustments would allow for a more polished and official scientific exercise.

Conclusions

The ecosystem microworld was developed in order to assess the students' knowledge of ecosystems as well as their knowledge and ability to perform inquiry tasks. This was done by addressing the common misconception in food web ecology that organisms not directly connected in the web do not affect one another, while the students navigated the microworld following the steps of the scientific method.

Most of the students showed little to no understanding of the scientific method, as they did not follow the steps while experimenting. The scientific method includes the steps of exploring, hypothesizing, testing the experiment to collect data, analyzing the data, and then communicating the findings in relations. Students very rarely scanned the baseline to give the preliminary data. Also, they often did not test their hypothesis, giving them no conclusive data for analysis. When there was no analysis little was gained from the microworld and the students did not communicate their findings well. This all shows they were not able to use the scientific method in their inquiry task.

The students showed no gain in knowledge from the pre to posttest. Their posttest scores were either similar to or lower than their pretest scores. The students had already seen the posttest questions during the pretest and expressed that they did not want to answer them again. Therefore, the lower scores were concluded to be due to a lack of motivation. Also after doing the microworld experiments, the students appeared tired and unmotivated to do any more work. The students were taken from an afterschool program and had arrived for testing after a day of school. Due to going through a full day of school, they no longer wanted to do anything that had to do with learning, and that added to their lack of motivation.

In conclusion, the data show that in order for the students to succeed in this inquiry task, they need more knowledge of the scientific method. Also, as discussed above in the previous section, the data show many places in which more scaffolding and direction could be used in future testing as well as changes that could be made to the design. Implementing these changes would help ensure that useful data is gathered when the ASSISTment becomes implemented in school systems.

References

Alessi, S. (2000). The Application of System Dynamics Modeling in Elementary and Secondary School Curricula. Retrieved from http://depts.washington.edu/edtech/Alessi-System.pdf

Fadel, C., Honey, M., and Pasnick, S. (2007). Assessment in the Age of Innovation, *Education Week, Volume 26 (38)*, 34-40.

Gallegos, L., Jerezano, M. E., & Flores, F. (1994) Preconceptions and Relations Used by Children in the construction of Food Chains. *Journal of Research in Science Teaching, 31*(3), 259-272.

Gotwals, A. W., & Songer, N. B. (2006). Cognitive Predictions: BioKIDS Implementation of the PADI Assessment System. Retrieved from http://padi.sri.com/downloads/TR10_BioKIDS.pdf

Gotwals, A. W., & Songer, N. B. (2009). Reasoning Up and Down a Food Chain: Using an Assessment Framework to Investigate Students' Middle Knowledge. *Wiley InterScience*. Retrieved from http://sitemaker.umich.edu/songer/files/gotwals_songer.foodweb.pdf

Lennon, K. & DeBoer, G. E. (2008). Probing Middle School Students' Understanding of Ideas About Interdependence in Living Systems Through Content-Aligned Assessment. Retrieved from http://www.project2061.org/publications/2061connections/2008/media/5a_Kristen_NARST%20ID%20Poster%20Paper%20final.pdf

Massachusetts Department of Education. (2006). Massachusetts Science and Technology/Engineering Curriculum Framework. Retrieved from http://www.doe.mass.edu/frameworks/scitech/1006.pdf

Quellmalz, E. S., Timms, M. J., & Schneider, S. A. (2009). Assessment of Student Learning in Science and Games. Retrieved from http://www7.nationalacademies.org/bose/Schneider_Gaming_CommissionedPaper.pdf

Ruiz-Primo, M. A., and Shavelson, R. J. (1996). Rhetoric and reality in science performance assessments: An update. *Journal of Research in Science Teaching, 33*(10), 1045-1063.

Wilensky, U., & Reisman, K. (1998). ConnectedScience: Learning Biology through Constructing and Testing Computational Theories - an Embodied Modeling Approach. *Proceedings of the Second International Conference on Complex Systems*. Retrieved from http://ccl.northwestern.edu/papers/bio/short/

Appendices

Appendix 1a: Pretest

The diagram below shows the feeding relationships between populations of organisms in an area. The arrows point from the organisms being eaten to the organisms that eat them.

Using only the relationships between the organisms shown in the diagram, which of the following statements describes what will happen to the number of foxes if most of the worms are killed and why?

Comment on this question

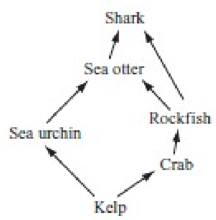
Select one:

- The number of foxes will decrease because there will be fewer worms to eat the robins and so more robins to eat the foxes.
- The number of foxes will decrease because there will be fewer worms for the robins to eat and so fewer robins will be available for the foxes to eat.
- The number of foxes will not change because the worms are killed, not the foxes.
- The number of foxes will not change because it is not connected to worms in the diagram.

Submit Answer

Appendix 1b: Pretest

Part of a food web for a marine kelp forest is shown below:



Which of the following statements correctly describes the transfer of energy that initially enters this system?

Comment on this question

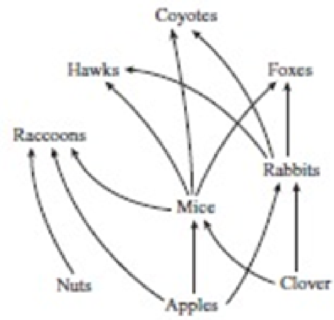
Select one:

- The sea urchin gets energy from the sea otter.
- The shark receives most of the energy that enters the ecosystem.
- The crab transfers less energy to the next trophic level than does the rockfish.
- The kelp converts energy into a form that can be used by other organisms.

Submit Answer

Appendix 1c: Pretest

The diagram below represents a food web:



Which of the following are consumers in this ecosystem?

Comment on this question

Select one:

- apples
- clover
- mice
- nuts

Submit Answer

Appendix 1d: Pretest

Which of the following lists identifies organisms that are producers in food webs?

Comment on this question

Select one:

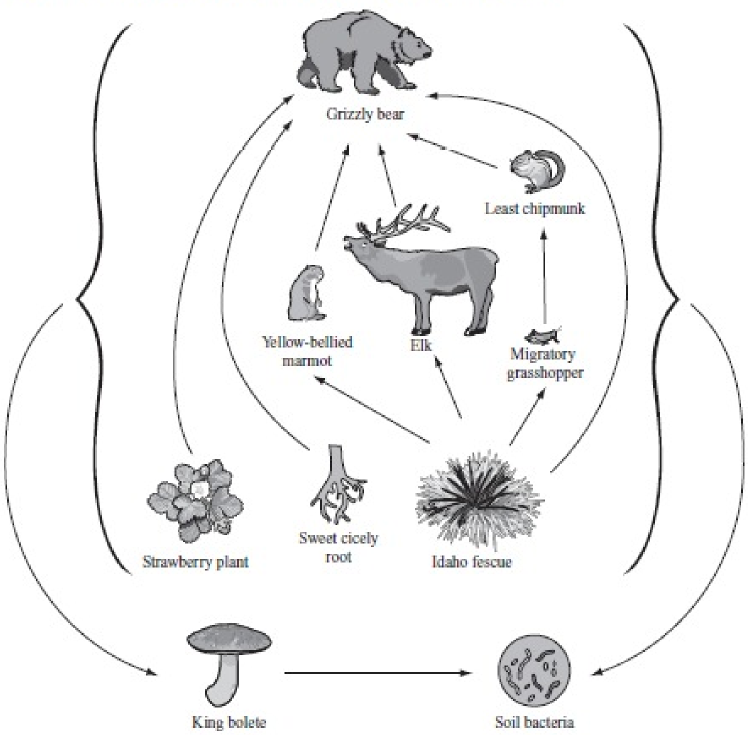
- algae, ferns, sunflowers
- mushrooms, bacteria, earthworms
- termites, red foxes, shrews
- woodpeckers, cardinals, grasshoppers

Submit Answer

Appendix 1e: Pretest

Which of the following organisms is a secondary consumer in this food web?

A partial food web for organisms in Yellowstone National Park is shown below.



Comment on this question

Select one:

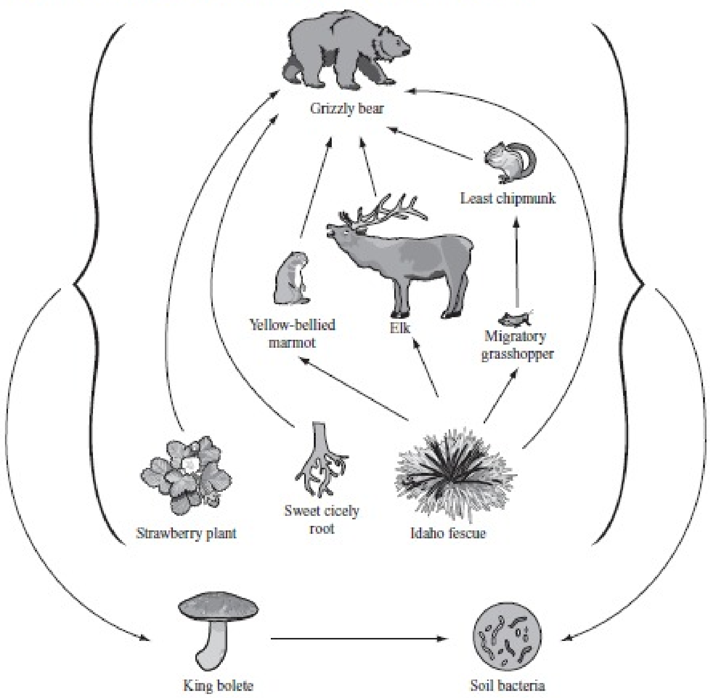
- yellow-bellied marmot
- strawberry plant
- least chipmunk
- king bolete

Submit Answer

Appendix 1f: Pretest

Consider the following food web:

A partial food web for organisms in Yellowstone National Park is shown below.



Assume the elk population in Yellowstone National Park increases. Discuss how this increase in elk will **most likely** affect each of the following populations:

Idaho fescue

migratory grasshopper

grizzly bear

Be sure to include specific reasons to support each of your responses.

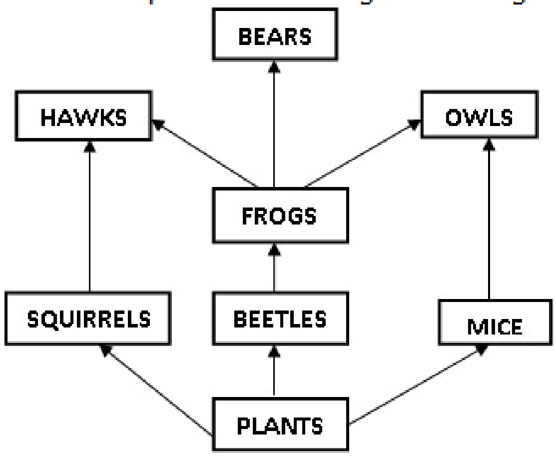
Comment on this question

Type your answer below:

Submit Answer

Appendix 1g: Pretest

The diagram below shows the feeding relationships between populations of organisms in an area. The arrows point from the organisms being eaten to the organisms that eat them.



Using only the relationships between the organisms shown in the diagram, which of the following populations of organisms could be affected if the number of frogs changes?

Comment on this question

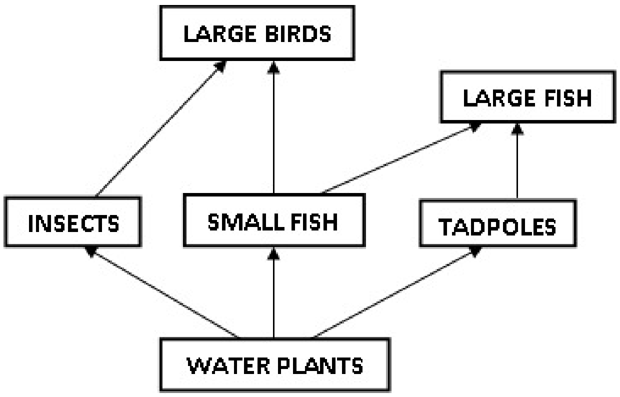
Select one:

- Only the frog population could be affected.
- Only the populations of plants, beetles, and bears could be affected.
- Only the populations of beetles, hawks, bears, and owls could be affected.
- The populations of all of the organisms shown in the diagram could be affected.

Submit Answer

Appendix 1h: Pretest

The diagram below shows the feeding relationships between populations of plants and animals in and around a pond. The arrows point from the organisms being eaten to the organisms that eat them.



More people than usual go fishing and take a lot of the large fish out of the pond. Using only the relationships between the plants and animals shown in the diagram, what is likely to happen to the number of insects and why?

Comment on this question

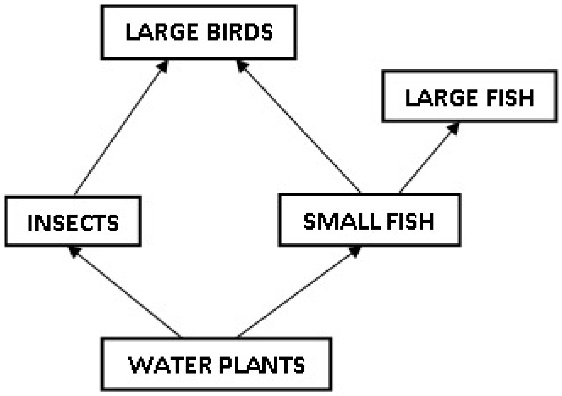
Select one:

- ○ The number of insects is likely to decrease because with fewer large fish to eat the tadpoles, there would be more tadpoles eating more water plants and fewer water plants available for the insects.
- ○ The number of insects is likely to decrease because with fewer large fish for the large birds to eat, the large birds would have to eat more insects.
- ○ The number of insects is not likely to change because large fish are not connected by an arrow in the diagram.
- ○ The number of insects is not likely to change because people took only large fish out of the pond.

Submit Answer

Appendix 1i: Pretest

The diagram below shows the feeding relationships between populations of plants and animals in and around a pond. The arrows point from the organisms being eaten to the organisms that eat them.



More people than usual go fishing at the pond this year and take a lot of the large fish out of the pond. Using only the relationships between the plants and animals shown in the diagram, what effect is this likely to have on the large bird population and why?

Comment on this question

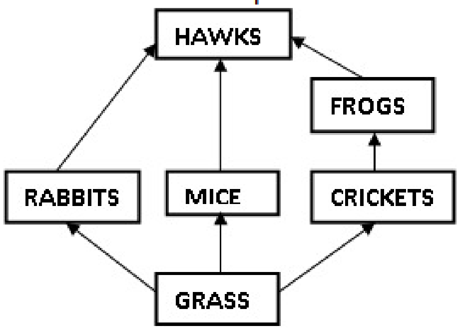
Select one:

- The number of large birds is likely to increase because there will be more small fish for the large birds to eat.
- The number of large birds is likely to decrease because there will be fewer large fish for the large birds to eat.
- The number of large birds is likely to stay the same because large birds and large fish are not connected by an arrow in the diagram.
- The number of large birds is not likely to change because they are higher in the diagram than the large fish, which means that the large birds will not be affected by changes below them in the diagram.

Submit Answer

Appendix 1j: Pretest

The diagram below shows the feeding relationships between populations of plants and animals in an area. The arrows point from the organisms being eaten to the organisms that eat them.



Most of the rabbits in this area are killed. If the number of hawks does not change, what could happen to the number of crickets and why? Use only the relationships between the plants and animals shown in the diagram.

Comment on this question

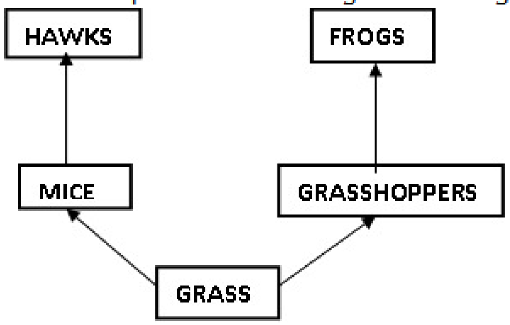
Select one:

- The number of crickets would decrease because fewer rabbits could result in a decrease in the number of individuals in all of the populations of organisms in this diagram.
- The number of crickets could decrease because with fewer rabbits for the hawks to eat, the hawks would eat crickets instead.
- The number of crickets could increase because with fewer rabbits for the hawks to eat, the hawks would eat more frogs, so there would be fewer frogs to eat the crickets.
- The number of crickets would not be affected by the number of rabbits because crickets are not connected by an arrow to rabbits in the diagram.

Submit Answer

Appendix 1k: Pretest

The diagram below shows the feeding relationships between populations of organisms in an area. The arrows point from the organisms being eaten to the organisms that eat them.



Using only the relationships between the organisms shown in the diagram, what will happen to the number of mice if most of the frogs are killed and why?

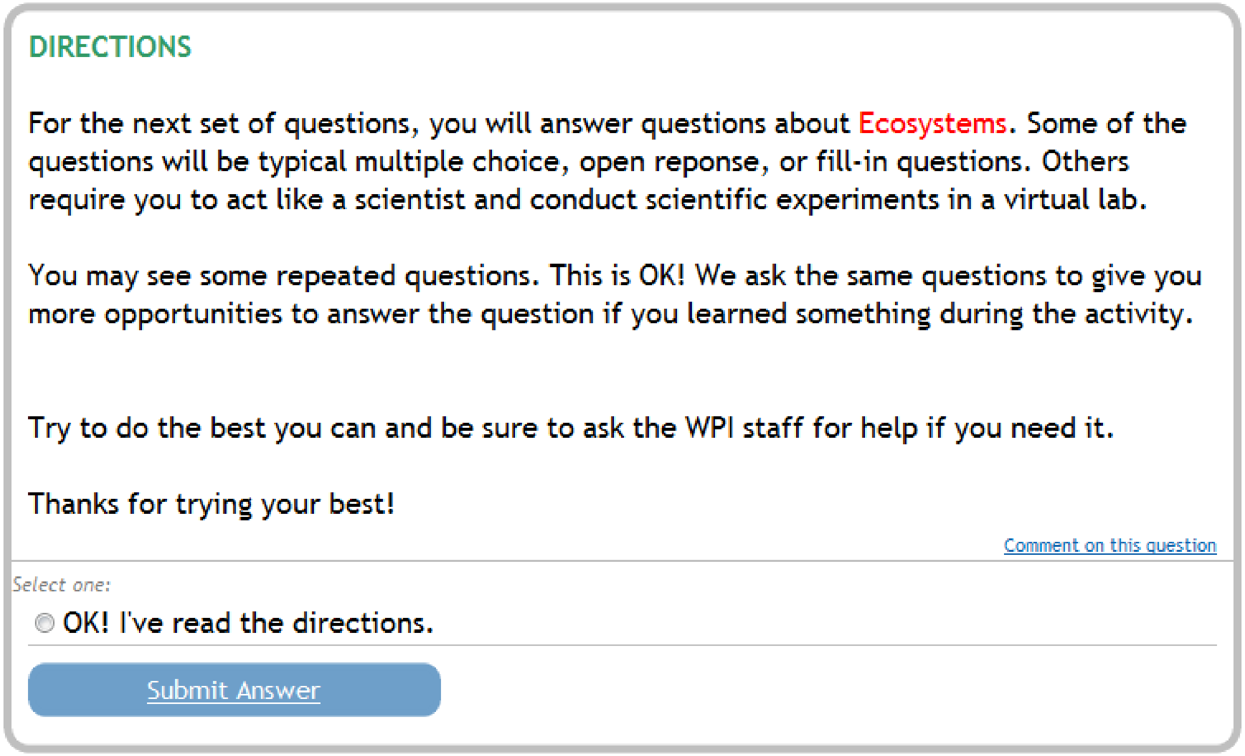
Comment on this question

Select one:

- The number of mice will decrease because the number of individuals in all of the populations of organisms in this diagram will decrease.
- The number of mice will decrease because there will be more grasshoppers to eat the grass, so there will be less grass available for the mice to eat.
- The number of mice will stay the same because there will be no effect on the number of individuals in the populations of organisms below the frogs in the diagram.
- The number of mice will stay the same because frogs and mice are not connected by an arrow in the diagram.

Submit Answer

Appendix 2a: Directions for Problem Sets



DIRECTIONS

For the next set of questions, you will answer questions about Ecosystems. Some of the questions will be typical multiple choice, open reponse, or fill-in questions. Others require you to act like a scientist and conduct scientific experiments in a virtual lab.

You may see some repeated questions. This is OK! We ask the same questions to give you more opportunities to answer the question if you learned something during the activity.

Try to do the best you can and be sure to ask the WPI staff for help if you need it.

Thanks for trying your best!

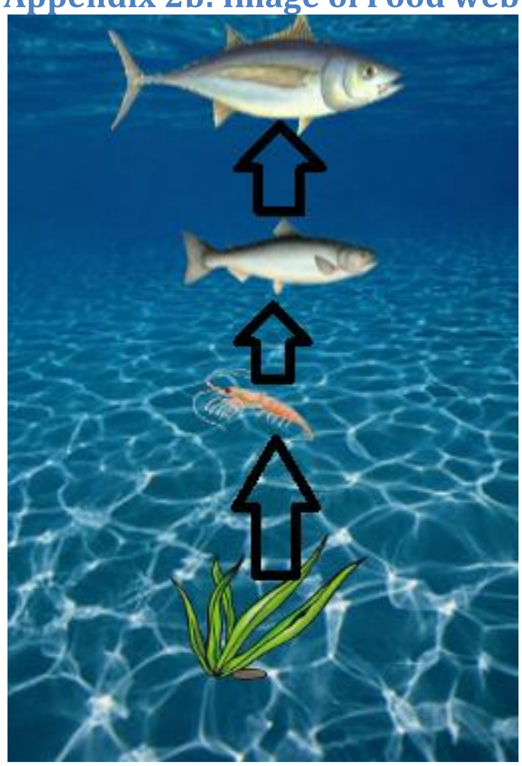
Comment on this question

Select one:

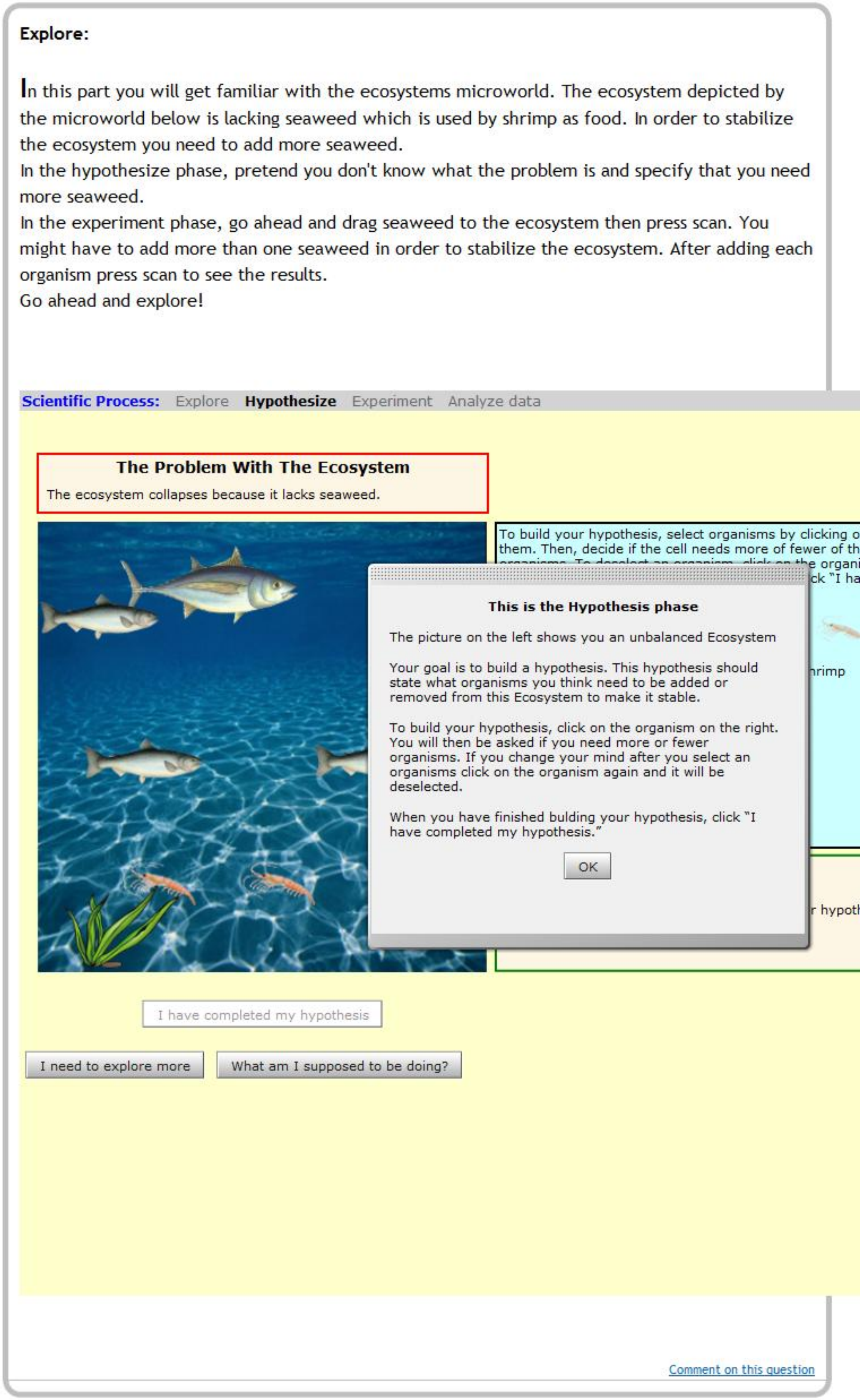
OK! I've read the directions.

Submit Answer

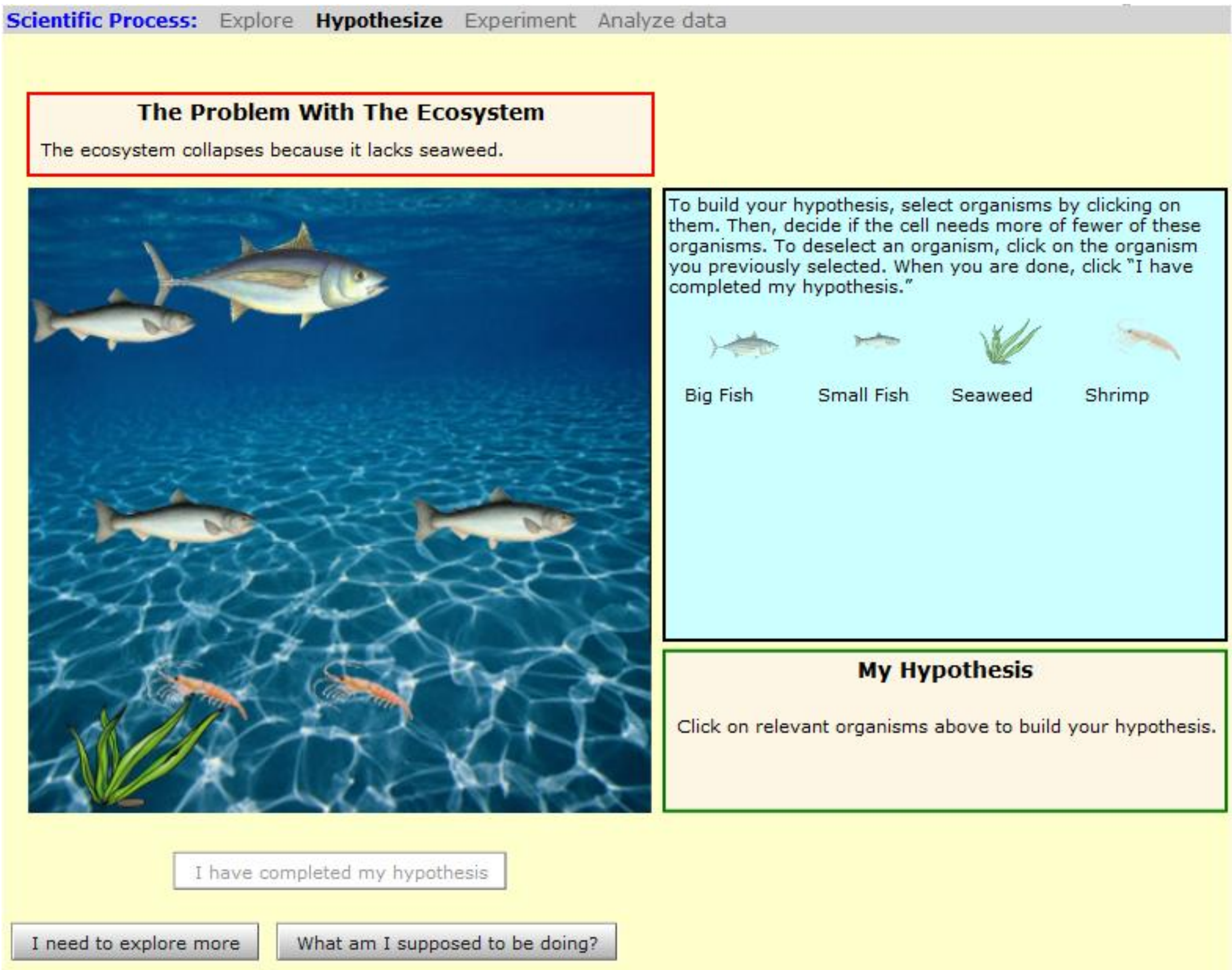
Appendix 2b: Image of Food web



Appendix 3a: Problem Set 1 Instructions and Hypothesis Phase Instructions



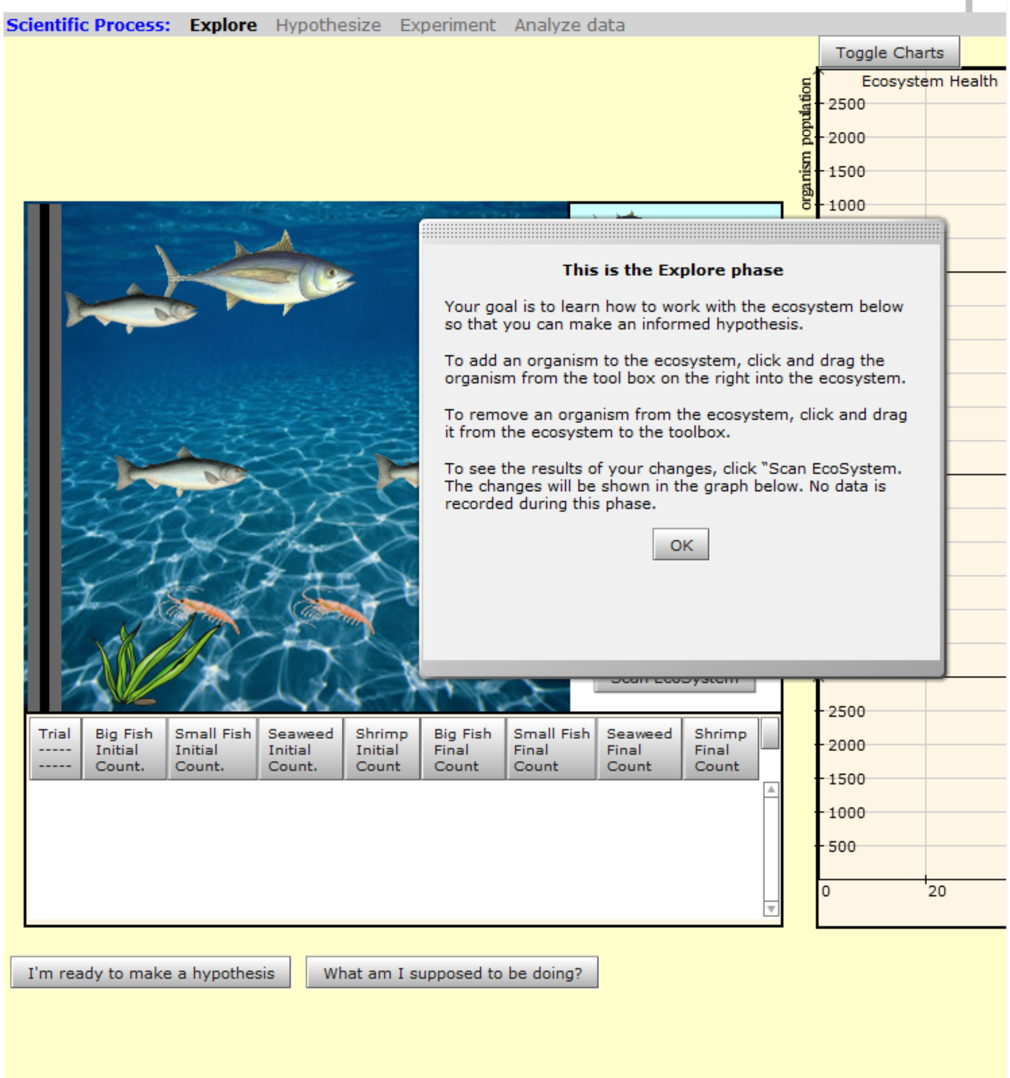
Appendix 3b: Hypothesis Phase Showing Initial Microworld for Problem Set 1



Appendix 3c: Problem Set 1 Instructions and Explore Phase Instructions

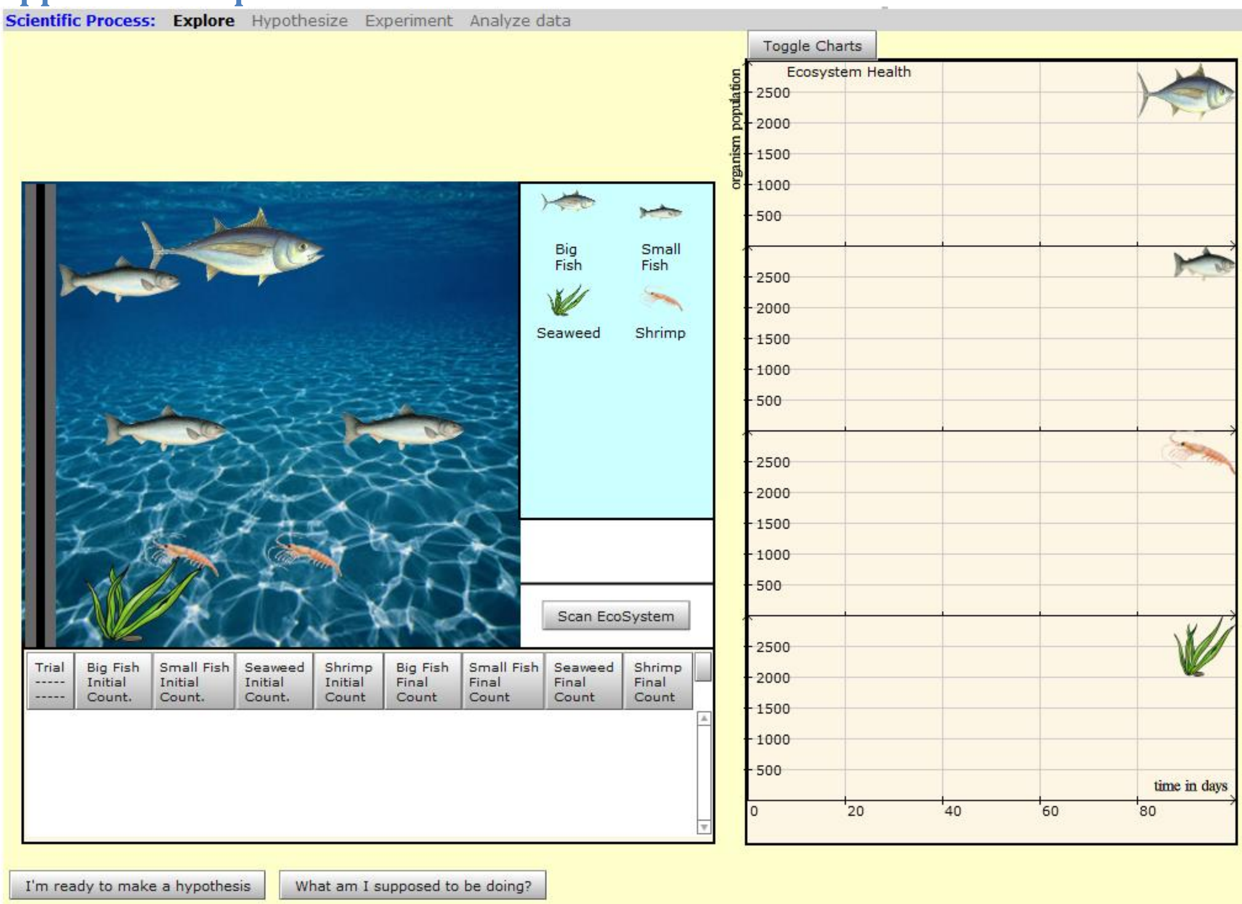
Explore:

In this part you will get familiar with the ecosystems microworld. The ecosystem depicted by the microworld below is lacking seaweed which is used by shrimp as food. In order to stabilize the ecosystem you need to add more seaweed.
In the hypothesize phase, pretend you don't know what the problem is and specify that you need more seaweed.
In the experiment phase, go ahead and drag seaweed to the ecosystem then press scan. You might have to add more than one seaweed in order to stabilize the ecosystem. After adding each organism press scan to see the results.
Go ahead and explore!

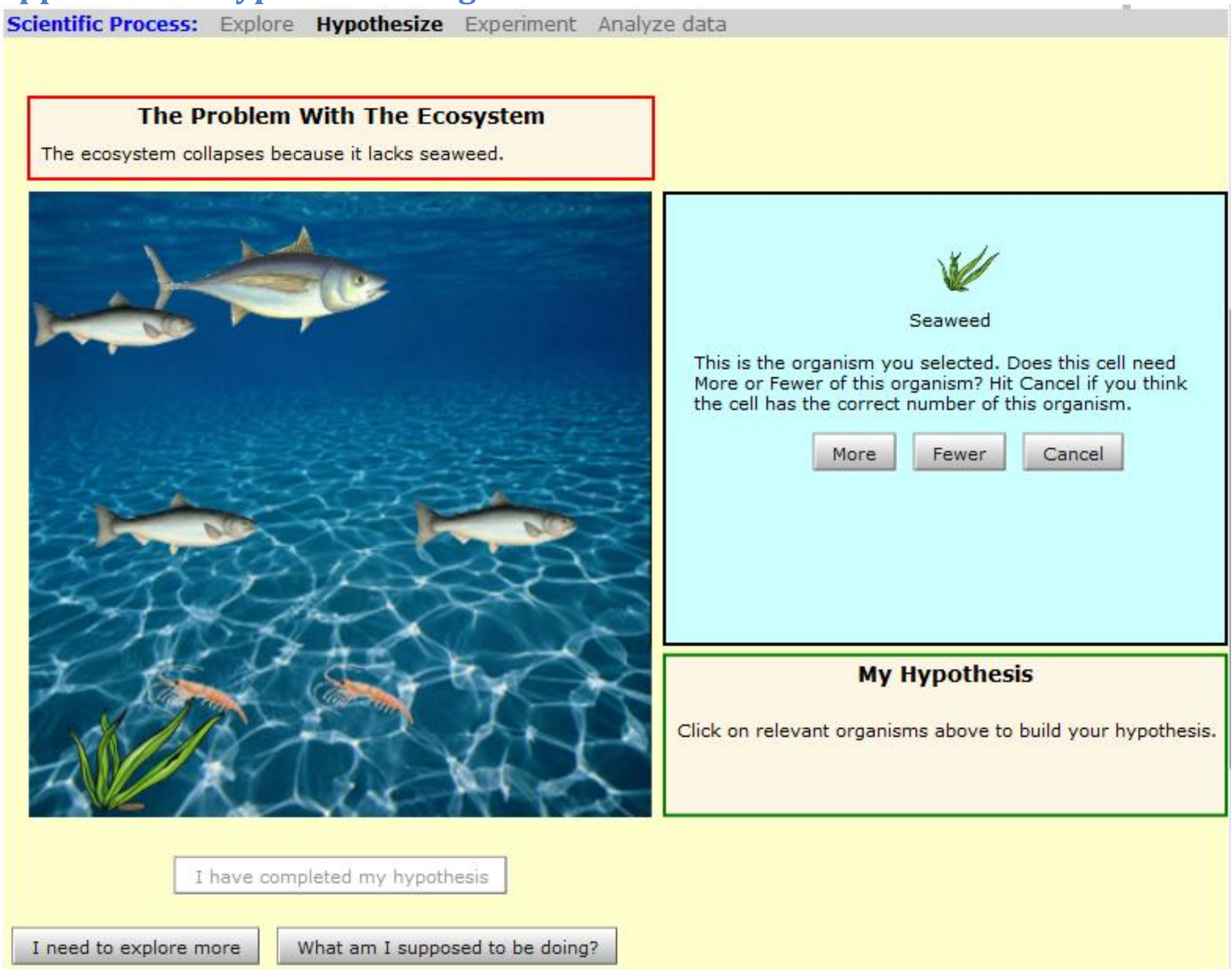


Comment on this question

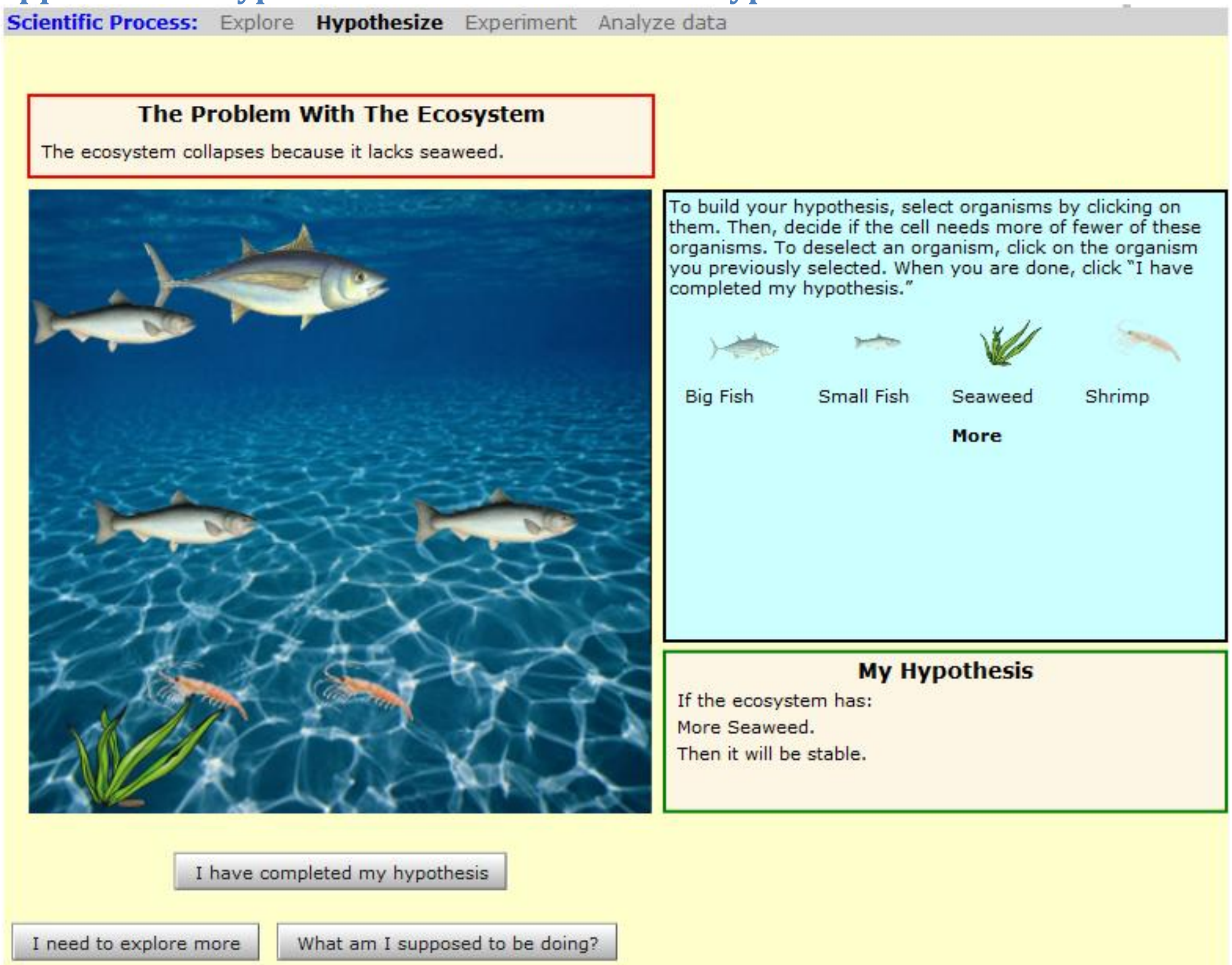
Appendix 4: Explore Phase



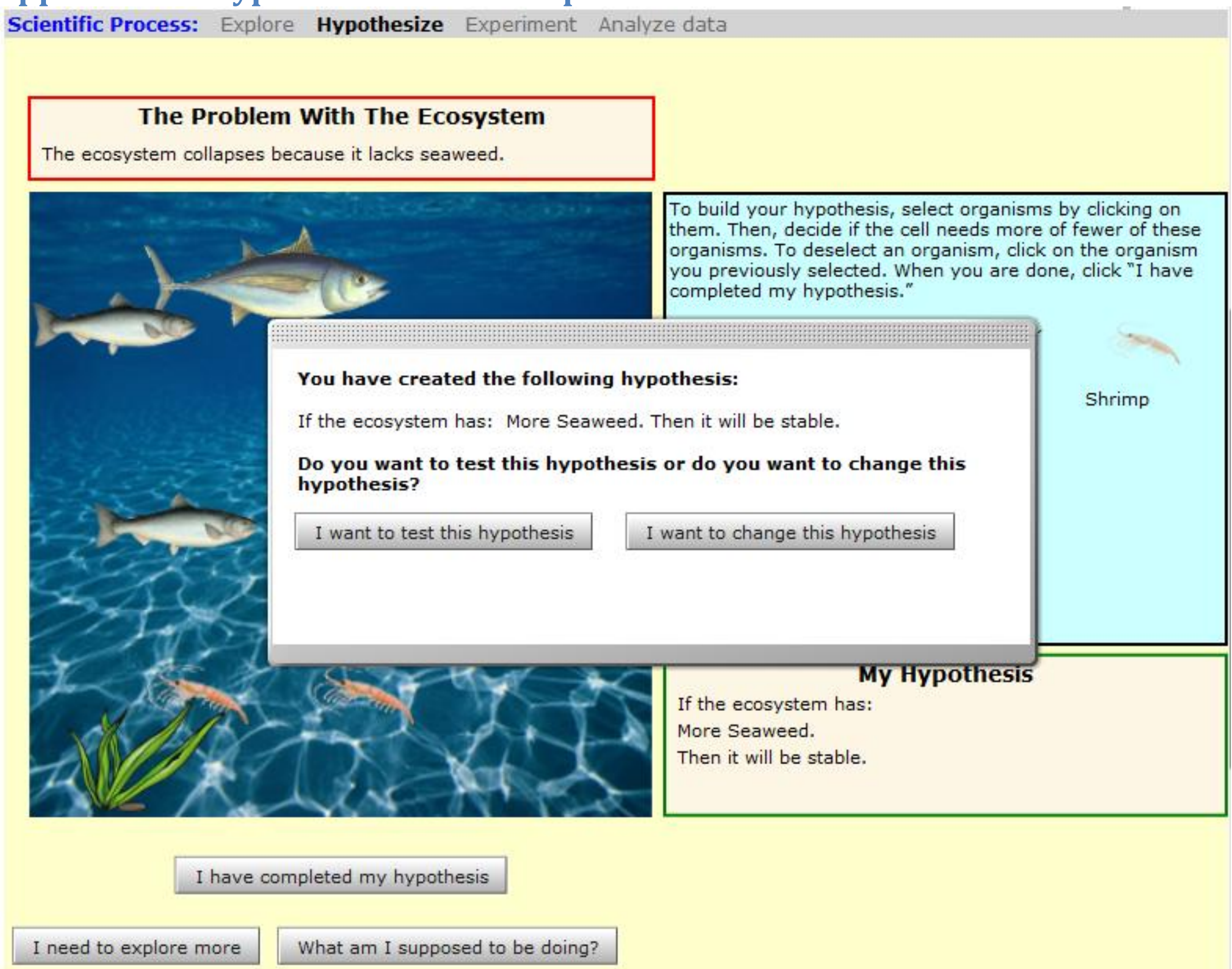
Appendix 5a: Hypothesis Widget



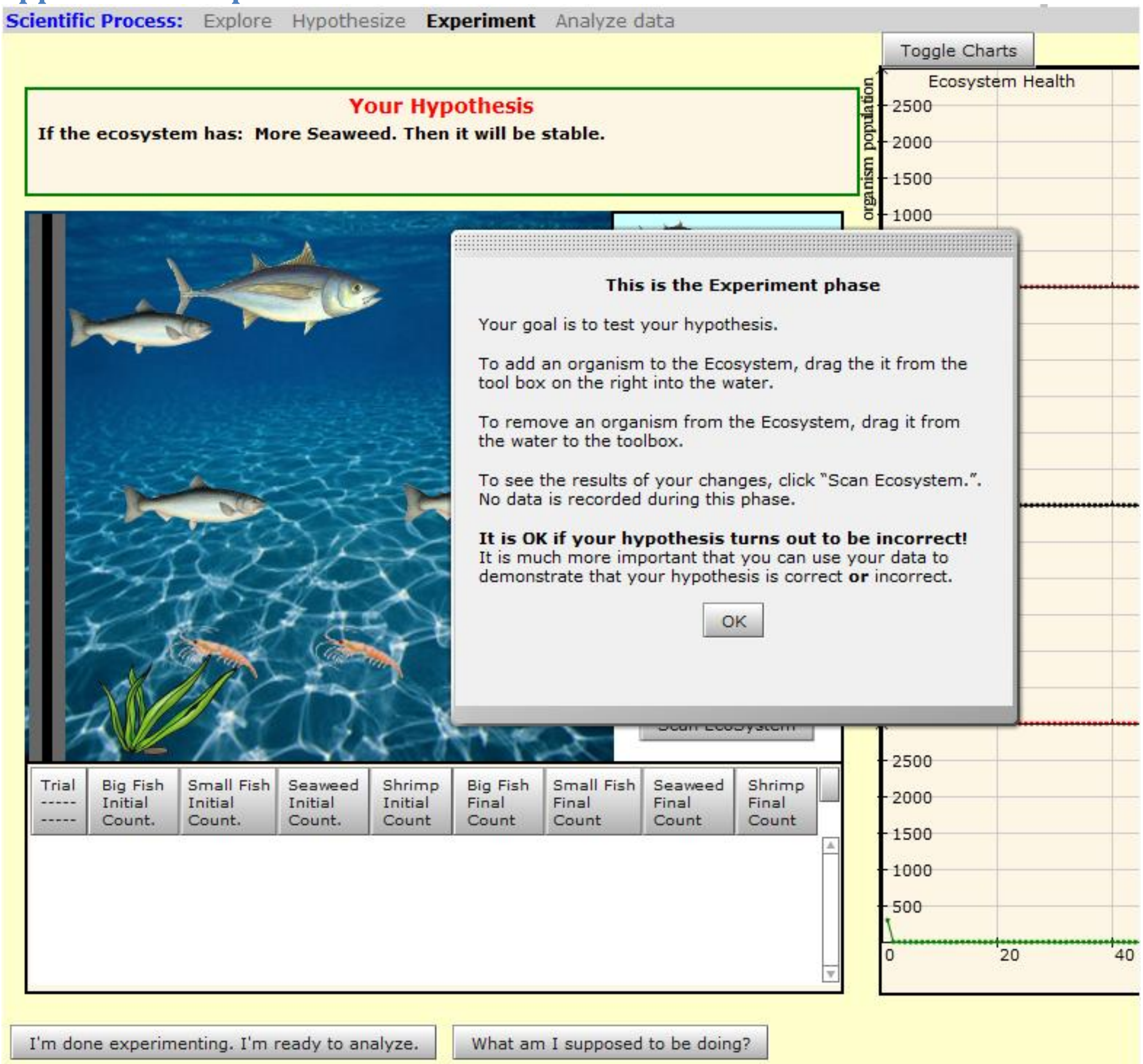
Appendix 5b: Hypothesis Phase with Formed Hypothesis



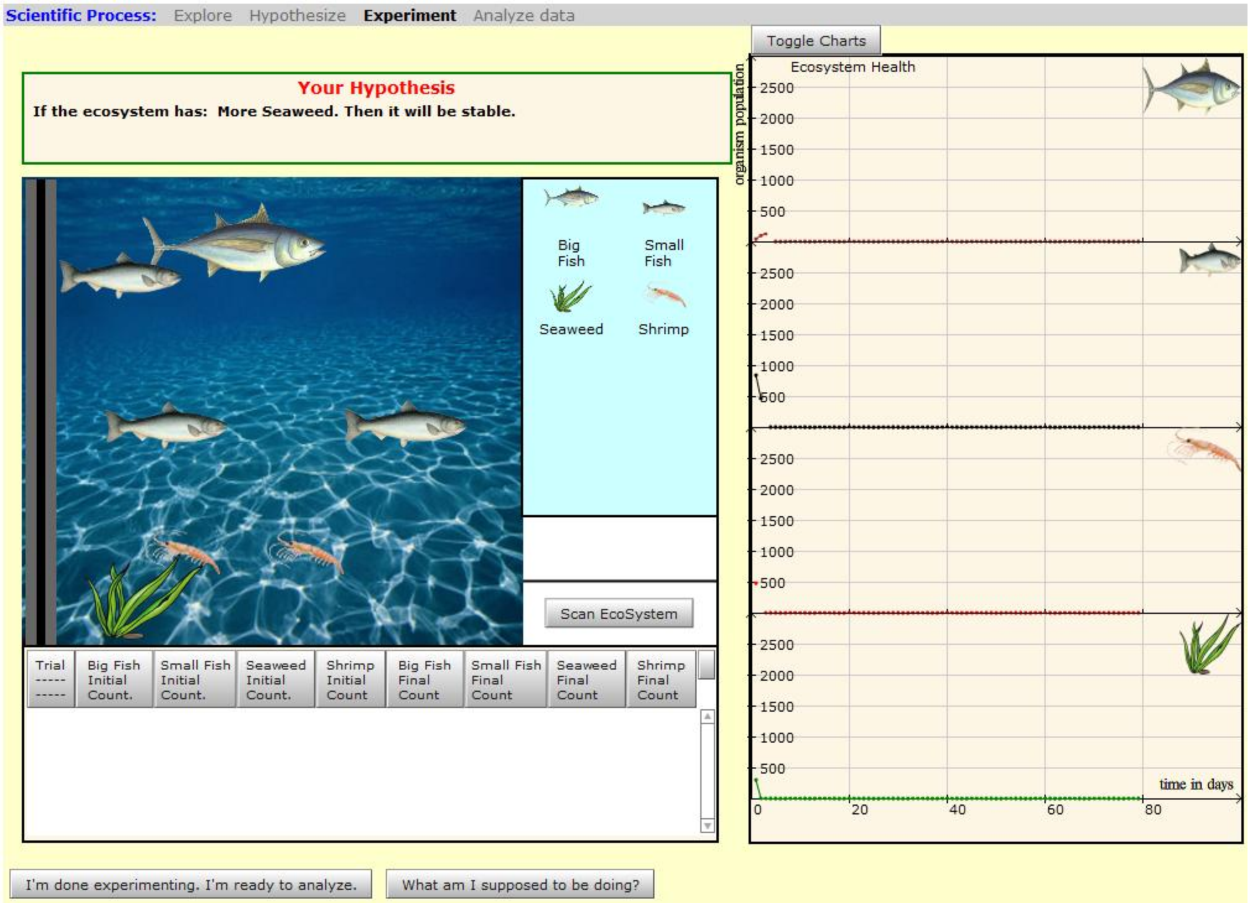
Appendix 5c: Hypothesis Phase Completion



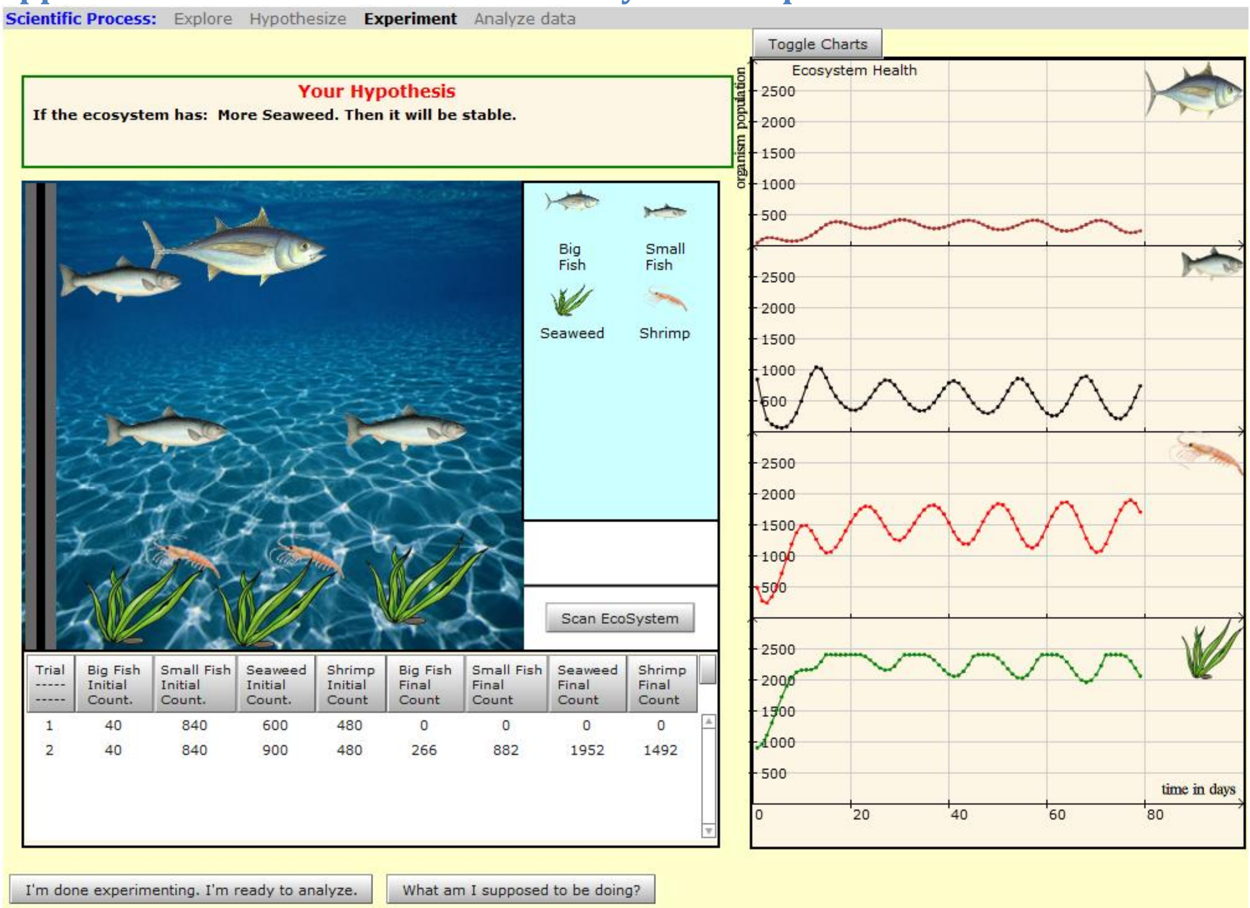
Appendix 6a: Experiment Phase Instructions



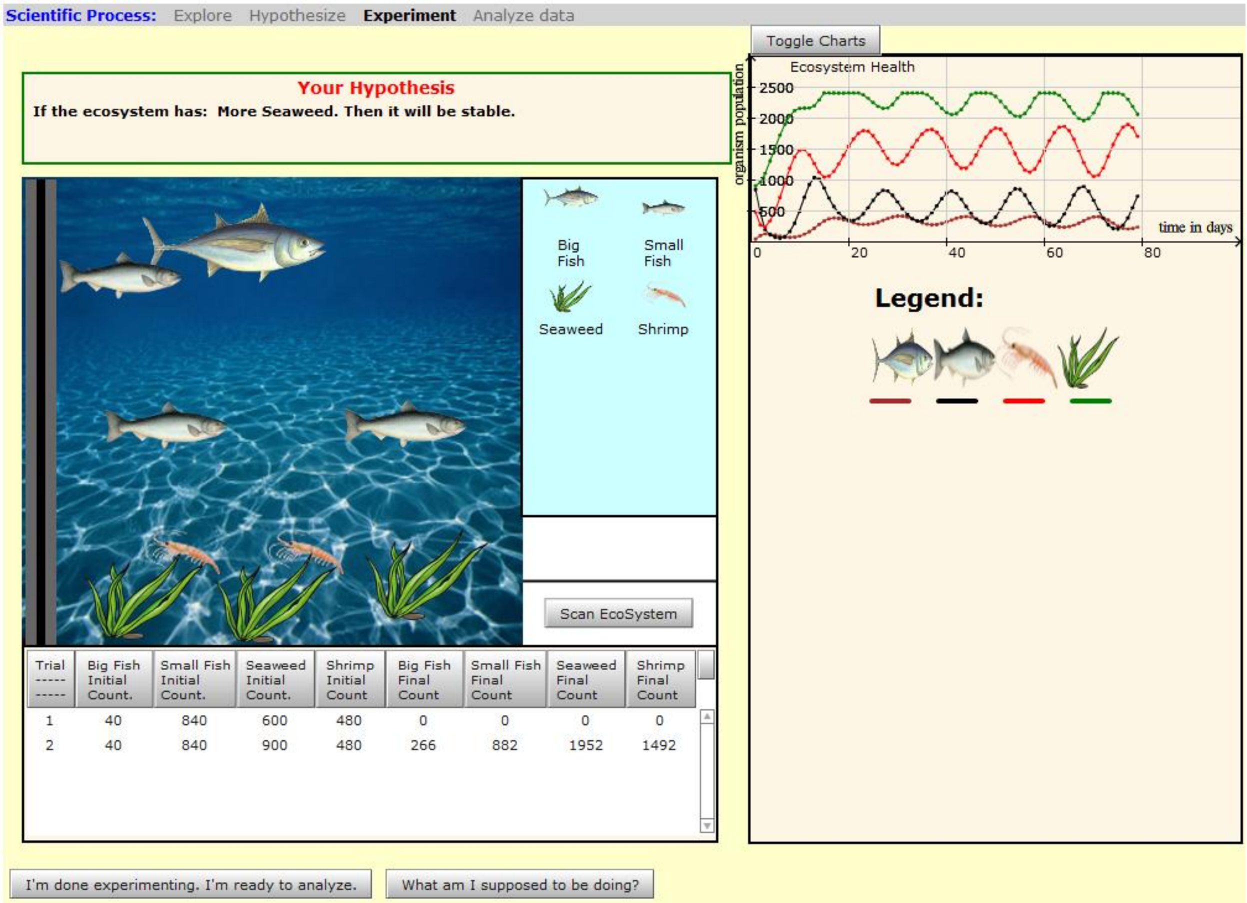
Appendix 6b: Experiment Phase



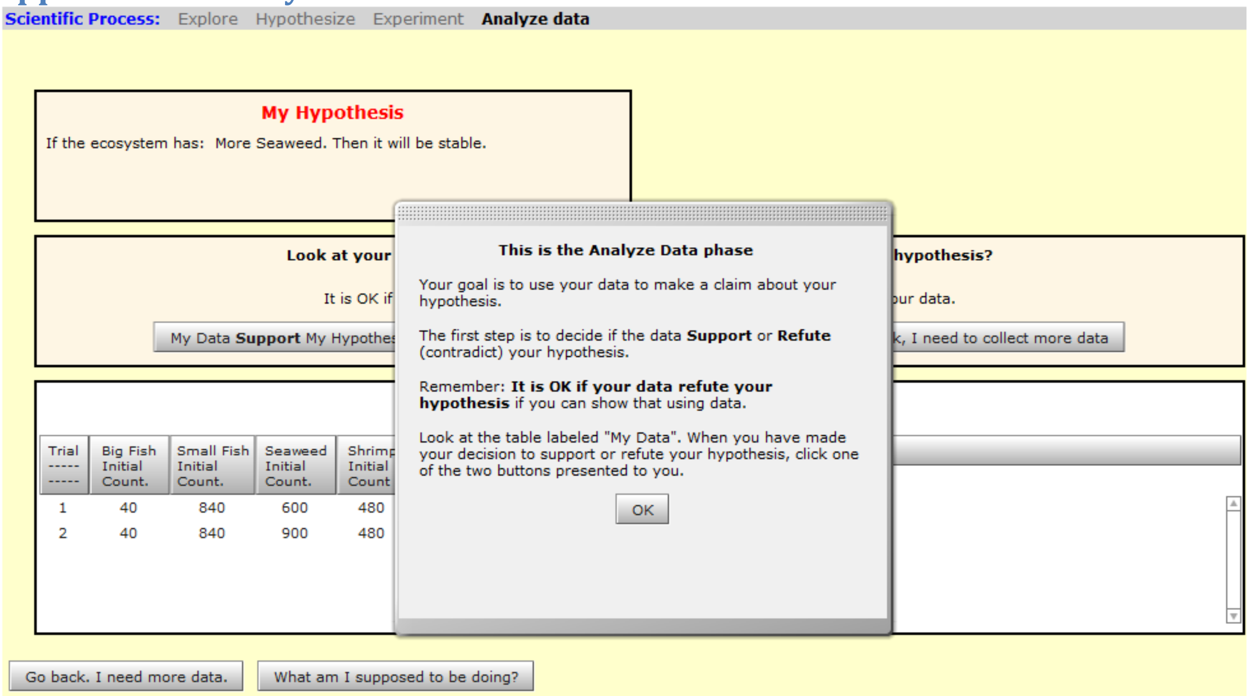
Appendix 7a: Problem Set 1 Stable Ecosystem Graphed after Scan



Appendix 7b: Graphs of Stable Ecosystem Collapsed Together



Appendix 8a: Analyze Data Phase Part 1 Instructions



Appendix 8b: Analyze Data Phase Part 1

Scientific Process: Explore Hypothesize Experiment **Analyze data**

My Hypothesis

If the ecosystem has: More Seaweed. Then it will be stable.

Look at your data below. Do the data support or refute (contradict) your hypothesis?

If you think need more data click 'Go back. I need more data.'

It is OK if the data contradict your hypothesis as long as you show that with your data.

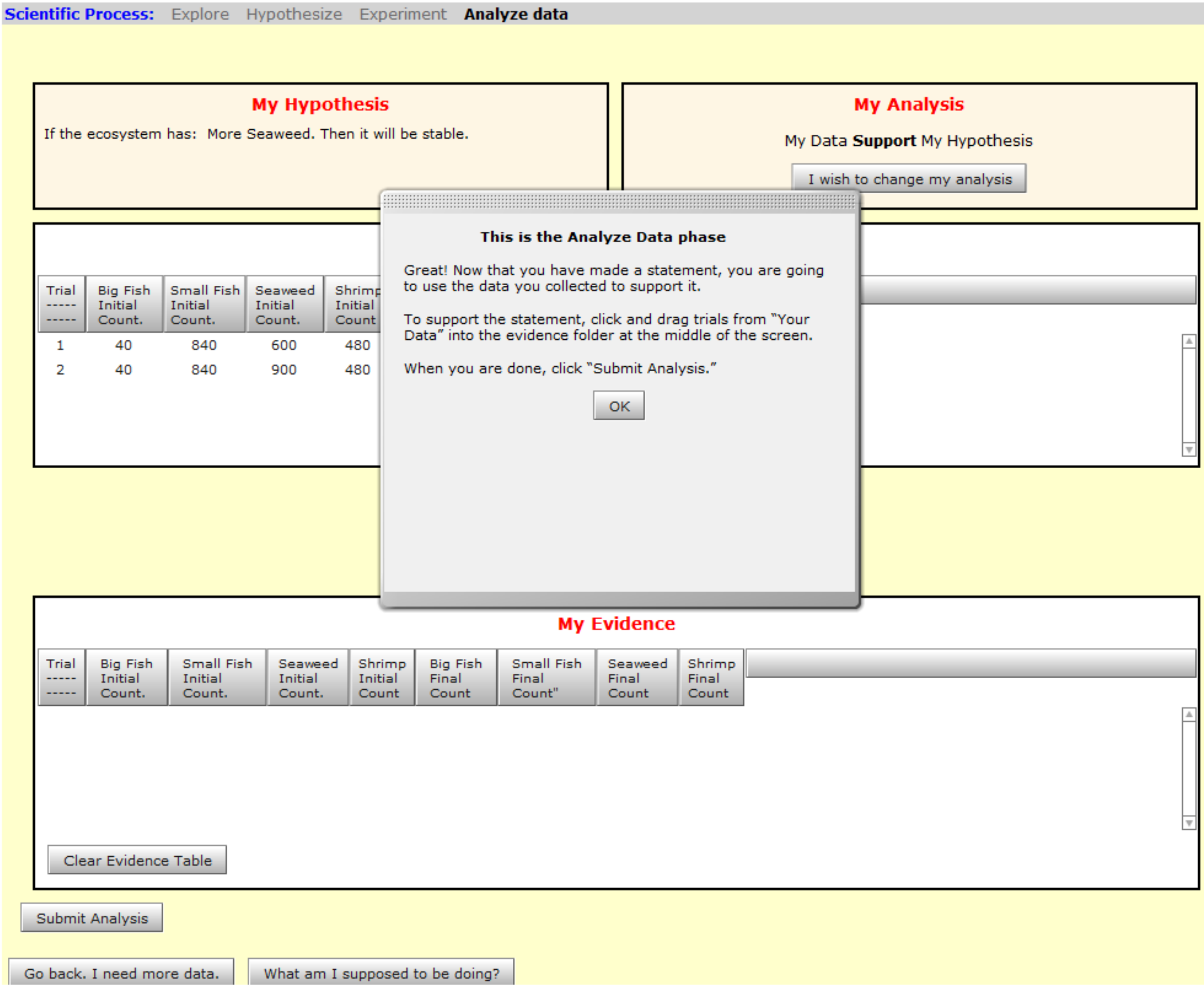
[My Data **Support** My Hypothesis] [My Data **refute** (contradict) My Hypothesis] [Go back, I need to collect more data]

My Data

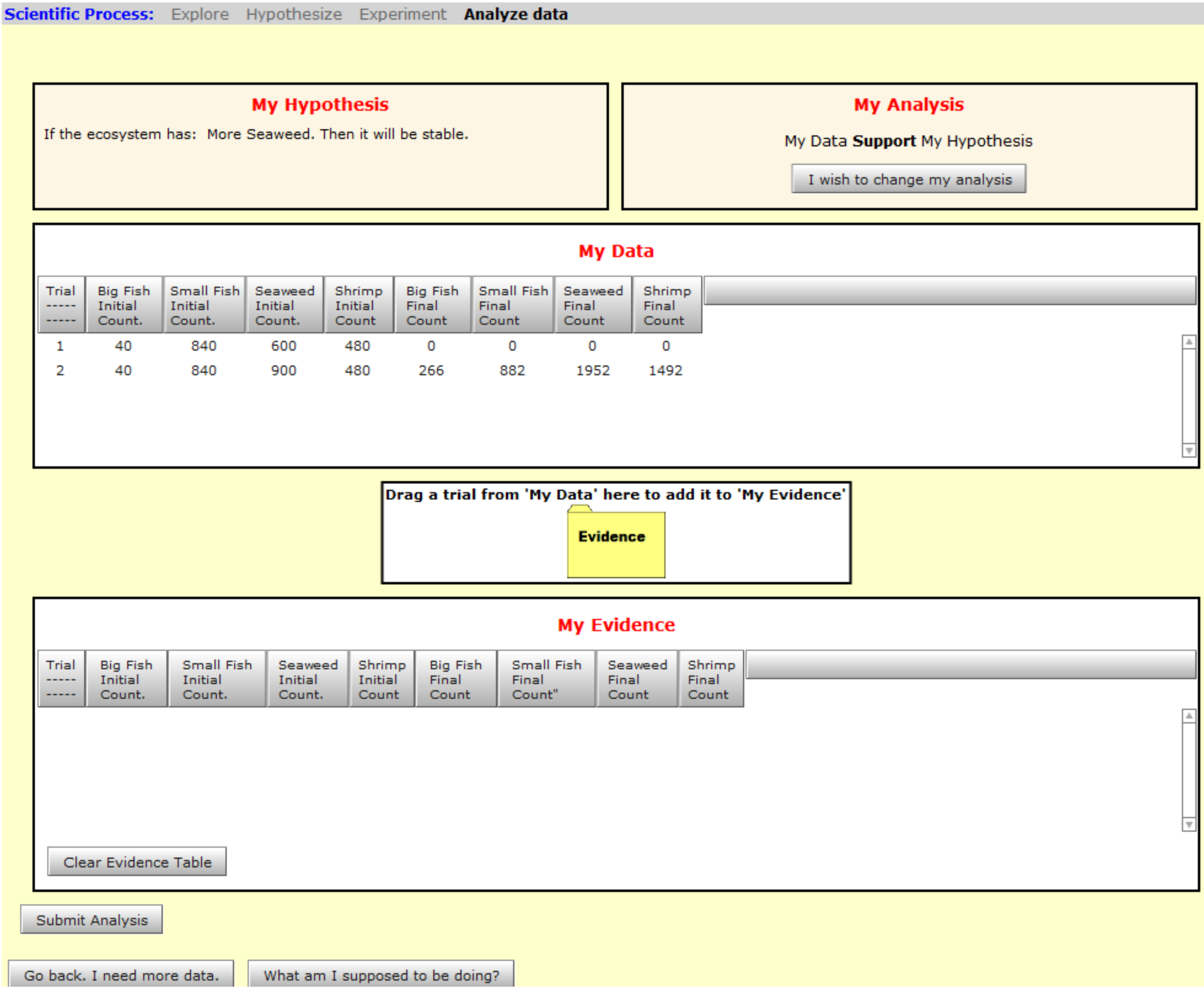
Trial ----- -----	Big Fish Initial Count.	Small Fish Initial Count.	Seaweed Initial Count.	Shrimp Initial Count	Big Fish Final Count	Small Fish Final Count	Seaweed Final Count	Shrimp Final Count
1	40	840	600	480	0	0	0	0
2	40	840	900	480	266	882	1952	1492

[Go back. I need more data.] [What am I supposed to be doing?]

Appendix 8c: Analyze Data Phase Part 2 Instructions



Appendix 8d: Analyze Data Phase Part 2



Scientific Process: Explore Hypothesize Experiment **Analyze data**

My Hypothesis

If the ecosystem has: More Seaweed. Then it will be stable.

My Analysis

My Data **Support** My Hypothesis

I wish to change my analysis

My Data

Trial ----- -----	Big Fish Initial Count.	Small Fish Initial Count.	Seaweed Initial Count.	Shrimp Initial Count	Big Fish Final Count	Small Fish Final Count	Seaweed Final Count	Shrimp Final Count
1	40	840	600	480	0	0	0	0
2	40	840	900	480	266	882	1952	1492

Drag a trial from 'My Data' here to add it to 'My Evidence'

Evidence

My Evidence

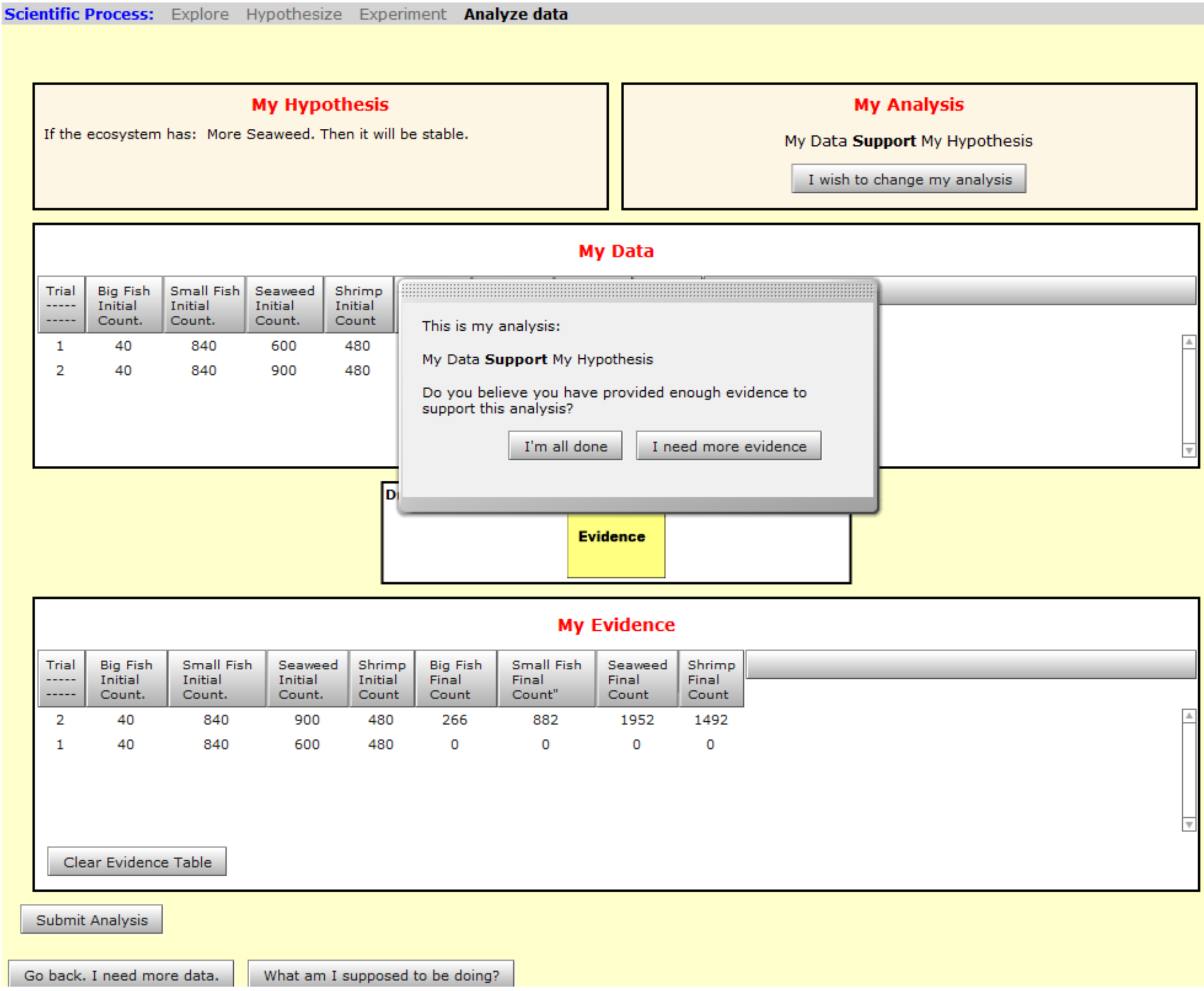
Trial ----- -----	Big Fish Initial Count.	Small Fish Initial Count.	Seaweed Initial Count.	Shrimp Initial Count	Big Fish Final Count	Small Fish Final Count"	Seaweed Final Count	Shrimp Final Count

Clear Evidence Table

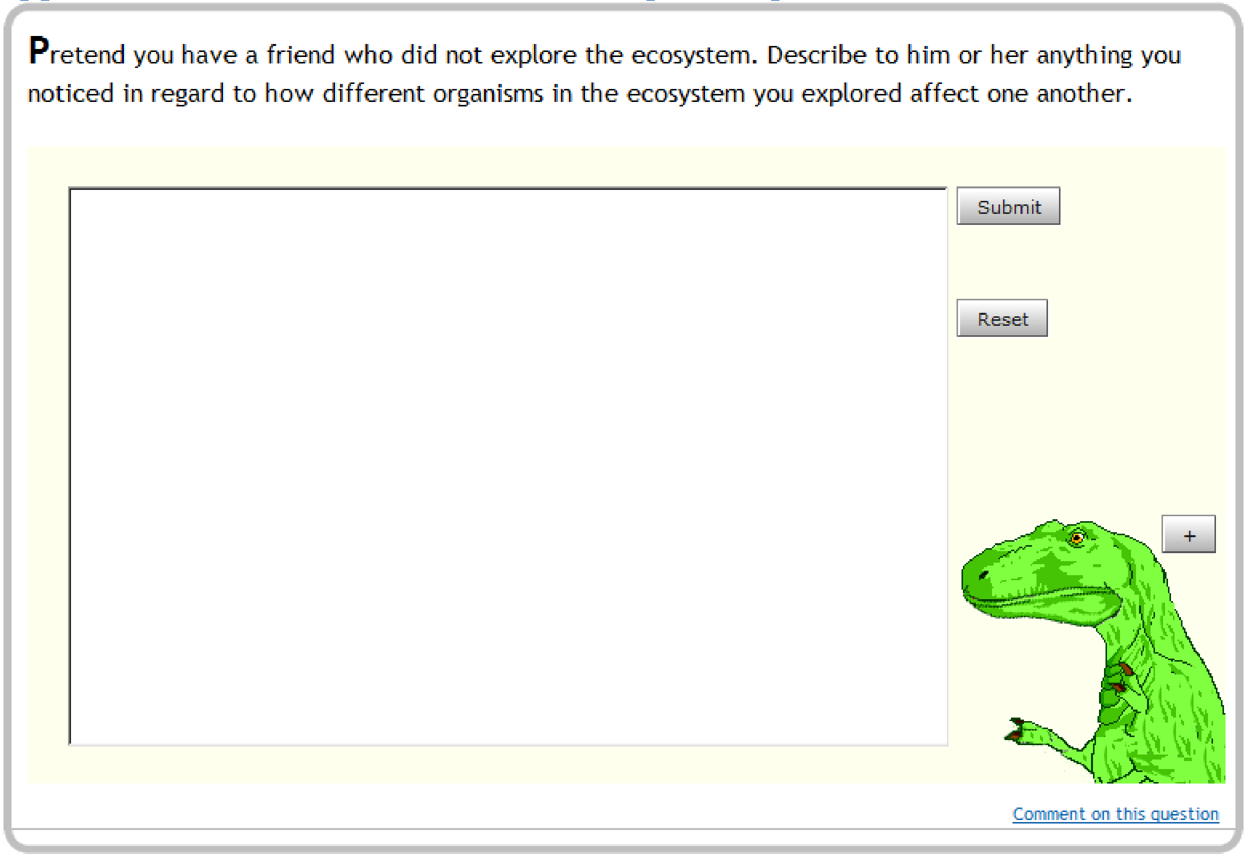
Submit Analysis

Go back. I need more data. What am I supposed to be doing?

Appendix 8e: Analyze Data Completion



Appendix 9a: Problem Set 1 Embedded Open Response Question



Appendix 9b: Problem Set 1 Embedded Multiple Choice Questions

Which of the organsims is/are the producer(s)?

Comment on this question

Select all that apply:

- [ ] Large Fish
- [ ] Small Fish
- [ ] Shrimp
- [ ] Seaweed

Submit Answer

Which of the organsims is/are the primary consumer(s)?

Comment on this question

Select all that apply:

- [ ] Large Fish
- [ ] Small Fish
- [ ] Shrimp
- [ ] Seaweed

Submit Answer

Which of the organsims is/are the secondary consumer(s)?

Comment on this question

Select all that apply:

- [ ] Large Fish
- [ ] Small Fish
- [ ] Shrimp
- [ ] Seaweed

Submit Answer

Which of the organsims is/are the tertiary consumer(s)?

Comment on this question

Select all that apply:

- [ ] Large Fish
- [ ] Small Fish
- [ ] Shrimp
- [ ] Seaweed

Submit Answer

Appendix 10: Problem Set 2 Embedded Prior Open Response Question

Shrimp Pond Used for Shrimp Farming
Courtesy of: U.S. National Oceanic and Atmospheric Administrationtion

Organisms that you will have available to add or remove to the shrimp pond ecosystem and the microworld that will follow.

A group of seafood farmers are concerned because the shrimp they are farming in their shrimp ponds are decreasing rapidly in numbers. The farmers are trying to develop a **natural and sustainable method of raising shrimp**, which involves **recreating the shrimp's natural ecosystem**. There is plenty of food for the shrimp (seaweed) and there are no predators. The farmers keep adding shrimp hatchlings, but the populations do not stabilize.

Before we move on to the microworld what are your thoughts on the relationships betwen predator and prey? How do predators affect their prey populations?

Submit

Reset

+

Comment on this question

Appendix 11a: Problem Set 2 Instructions and Hypothesis Phase Instructions

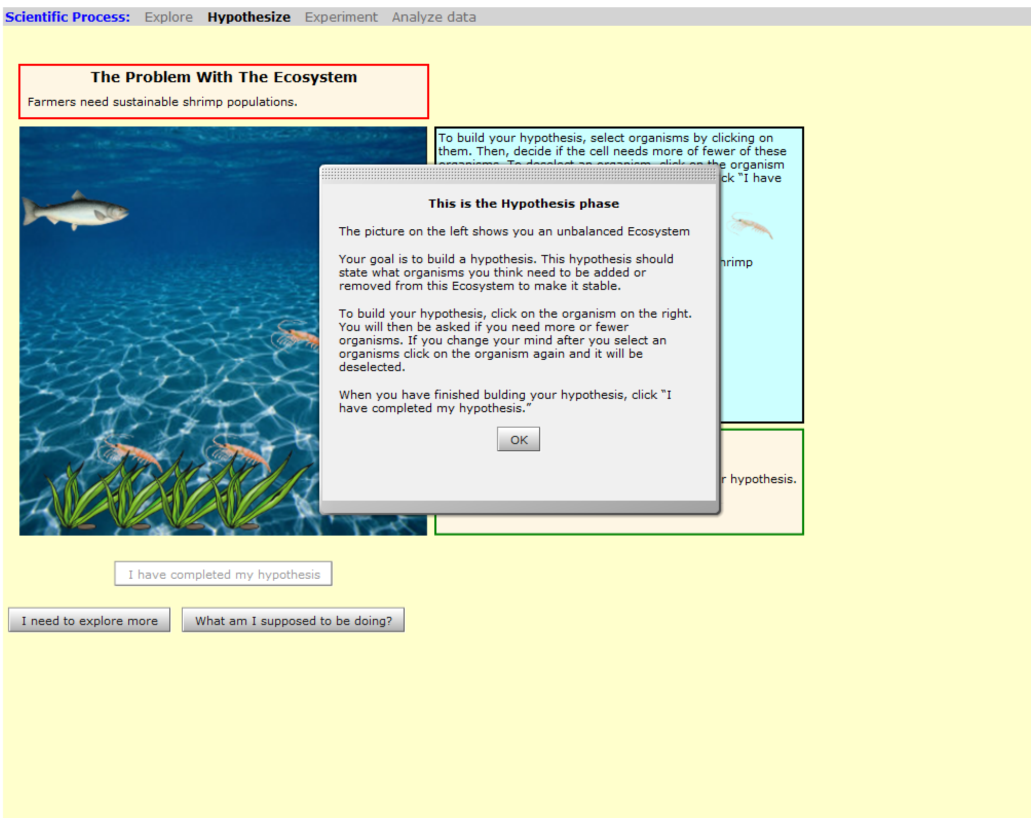
Please Read - Please Read - Please Read

Now it is time to stabilize the shrimp population in the shrimp pond. The tools you use to add or remove organisms to the pond are symbolic. That means that when you add one shrimp or one fish, many are added to the ecosystem (for simplicity lets say that when you add one, one hundred are added in reality).

1. In the first screen of the microworld you have to **hypothesize**, which in this case means: take a guess on what is the problem with the shrimp and how do we fix it. The "how do we fix it" part, is what you have to build as a hypothesis using the microworld hypothesizing tool.

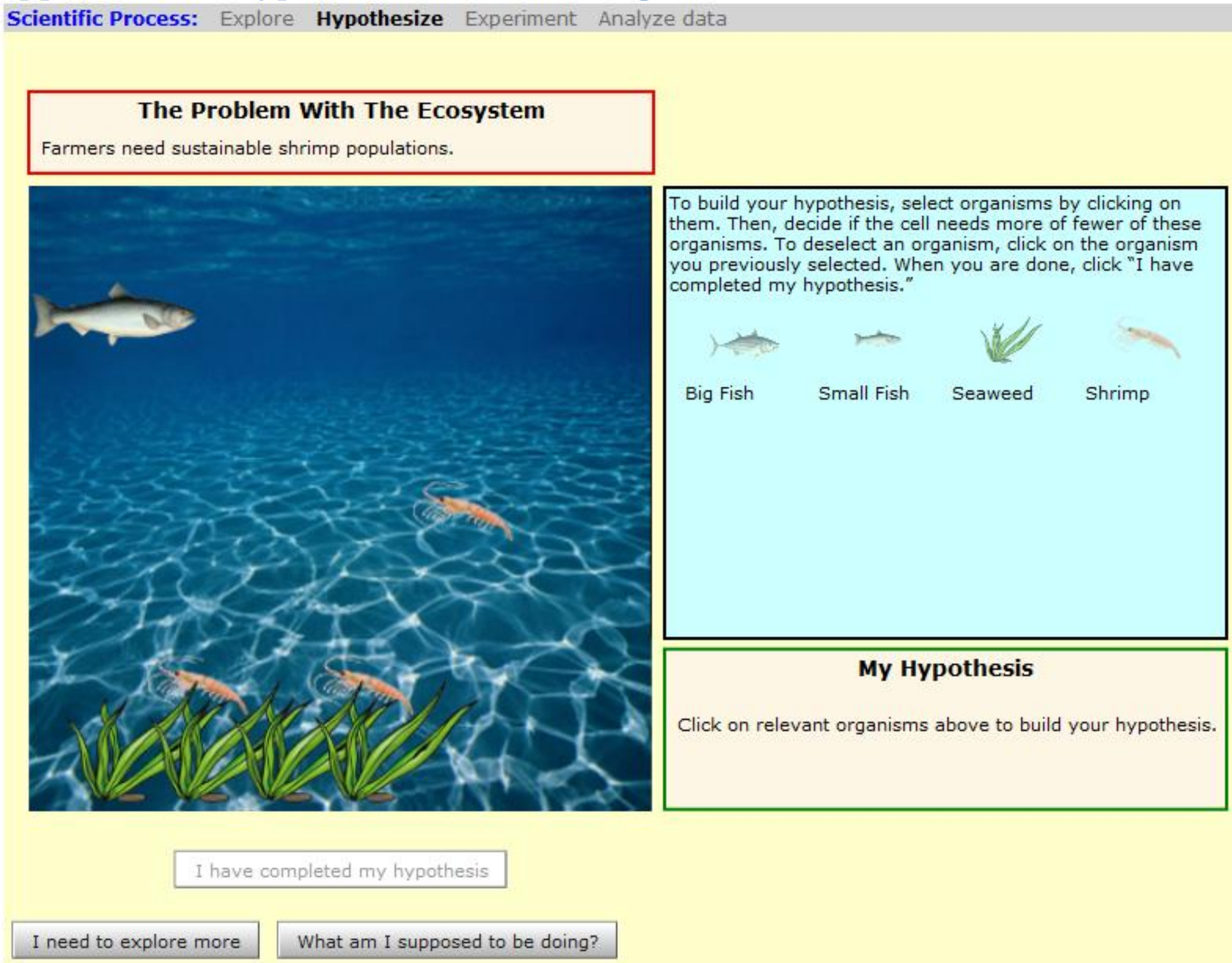
2. In the screen, after the hypothesis you have to **collect data to test your hypotheses**, which in this microworld means to add or remove organisms and hit scan. You will see that the graphs might change, and the table below the ecosystem will show the organisms numbers. Make sure the final shrimp numbers, are as high as possible. After all that is what the shrimp farmers are concerned with.

3. And finally one last thought: **Remember to change one thing at a time (control for variables)**: or you will not know for sure what caused the change in the shrimp numbers.



Comment on this question

Appendix 11b: Hypothesis Phase Showing Initial Microworld for Problem Set 2



Appendix 11c: Problem Set 2 Instructions and Experiment Phase Instructions

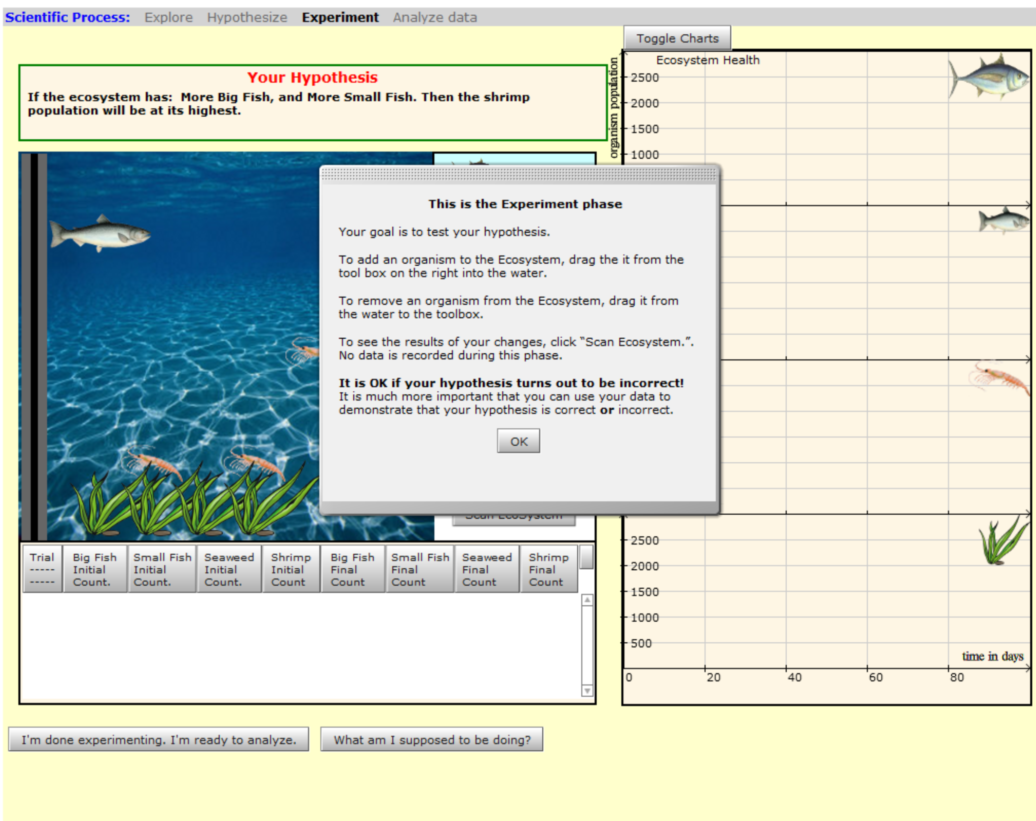
Please Read - Please Read - Please Read

Now it is time to stabilize the shrimp population in the shrimp pond. The tools you use to add or remove organisms to the pond are symbolic. That means that when you add one shrimp or one fish, many are added to the ecosystem (for simplicity lets say that when you add one, one hundred are added in reality).

1. In the first screen of the microworld you have to **hypothesize**, which in this case means: take a guess on what is the problem with the shrimp and how do we fix it. The "how do we fix it" part, is what you have to build as a hypothesis using the microworld hypothesizing tool.

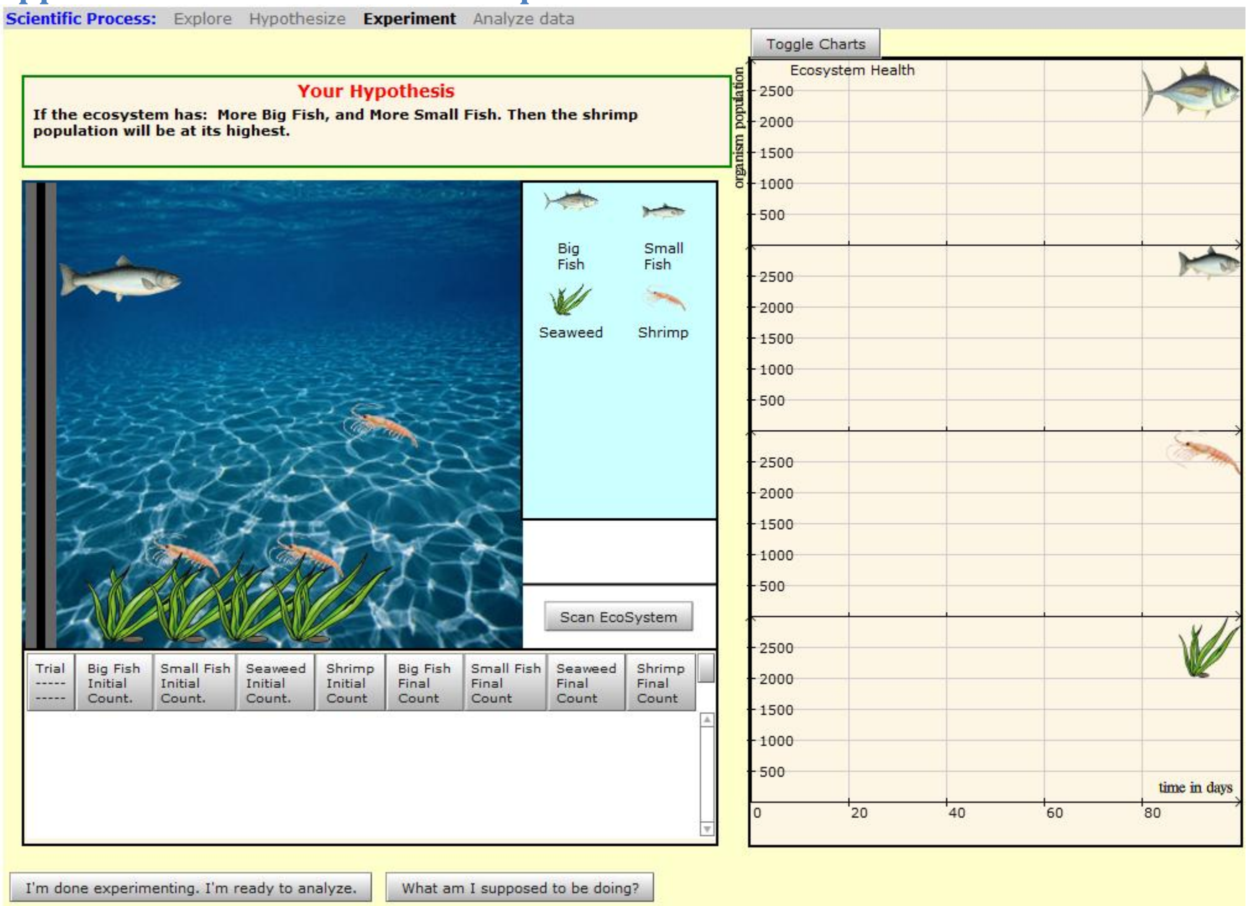
2. In the screen, after the hypothesis you have to **collect data to test your hypotheses**, which in this microworld means to add or remove organisms and hit scan. You will see that the graphs might change, and the table below the ecosystem will show the organisms numbers. Make sure the final shrimp numbers, are as high as possible. After all that is what the shrimp farmers are concerned with.

3. And finally one last thought: **Remember to change one thing at a time (control for variables)**: or you will not know for sure what caused the change in the shrimp numbers.

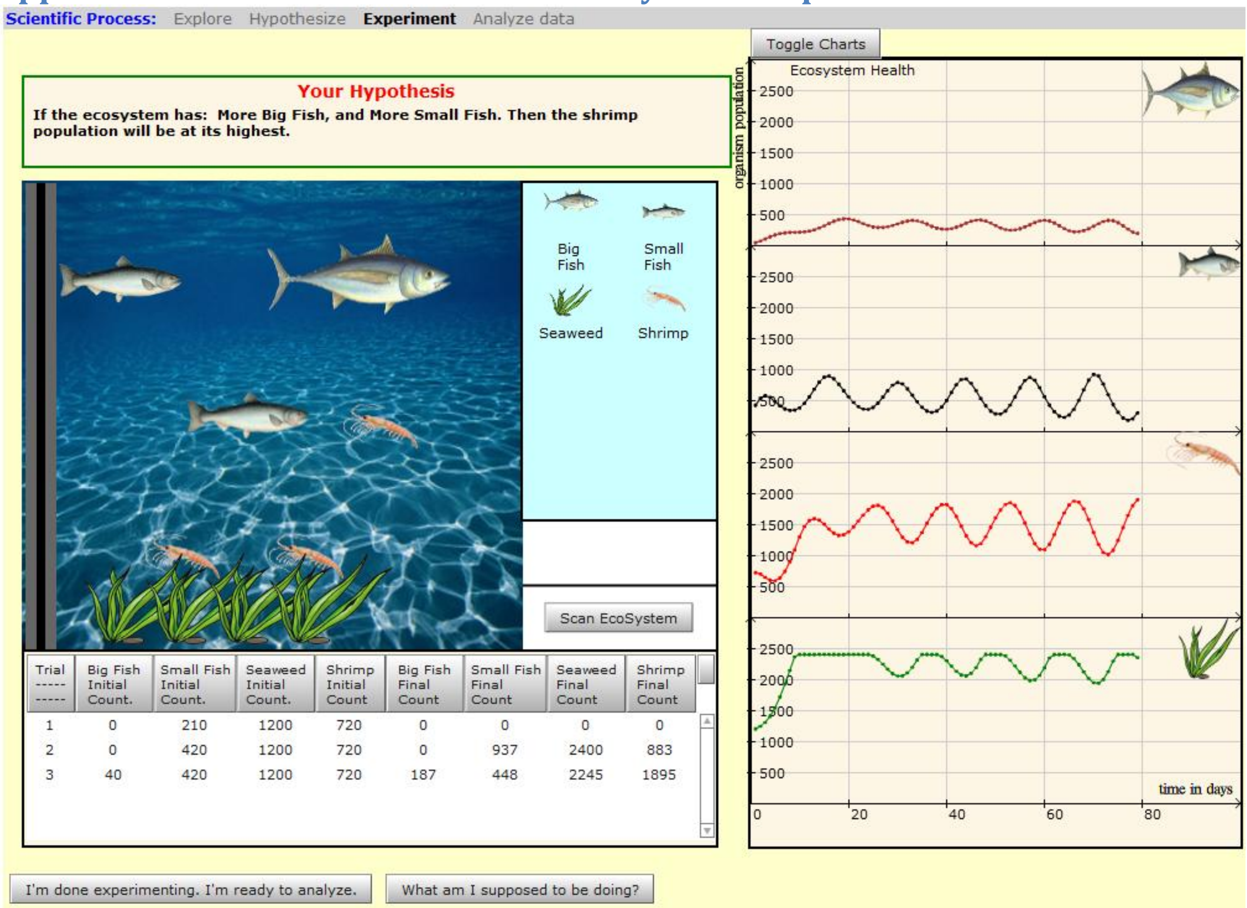


Comment on this question

Appendix 11d: Problems Set 2 Experiment Phase



Appendix 11e: Problem Set 2 Stable Ecosystem Graphed after Scan

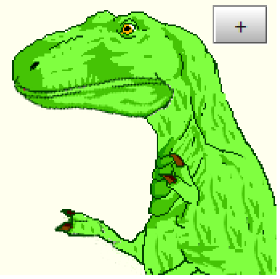


Appendix 12a: Problem Set 2 Embedded Subsequent Open Response Question 1

One of your friends is going to start an eco friendly shrimp farming business and wants to know the details of the experiment you just performed. Unfortunately he doesn't know anything about ecology or shrimp. What can you tell him about the role of predators in the shrimp farm ecosystem you experimented with? Was this an expected result?

Submit

Reset



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Comment on this question

Appendix 12b: Problem Set 2 Embedded Subsequent Open Response Question 2