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The internship practicum report explores current research on the plausibility of incorporating technology based on guided inquiry into K-12 classrooms to increase student science achievement. Part of the practicum report is browser-based software designed for teaching an ecosystems unit and includes the materials for use in a guided inquiry classroom. Can browser-based science instruction designed along a guided inquiry approach increase student achievement in science education and be quantified when compared to didactic classroom methods? The practicum report and the materials developed are designed to provide a means for the eventual testing of technology infused guided inquiry against traditional didactic teaching in the K-12 science classroom and begin to answer this question.

SECONDARY SCIENCE CURRICULUM:

DEVELOPING A BROWSER-BASED

CONSTRUCTIVIST ECOSYSTEM

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SECONDARY SCIENCE CURRICULUM:

DEVELOPING A BROWSER-BASED

CONSTRUCTIVIST ECOSYSTEM

INTERNSHIP PRACTICUM REPORT

Presented to the Graduate Council

of the University of North Texas

Health Science Center at Fort Worth

in Partial Fulfillment of

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MASTER OF SCIENCE

By

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Section I. Overview of Secondary Science Education in the U.S.

There is no doubt that K-12 education in the United States is in crisis. Many popular articles written about education decry the state of the schools and call for someone to provide an answer to the crisis. The research literature is comprised of opposing theories on how to improve education (AAAS, 2003; Barron, A. E., Kemker, K., Harmes, C., & Kalaydjian, K, 2003; Belmont, J. M., 1989; Goodstein, D., 2001; Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S. M., & Wood, W. B., 2004; Lederman, N. G., & Flick, L. B., 2004; Martin-Hansen, 2002; Mikropoulos, T. A., Katsikas, A., Nikolou, E., & Tsakalis, P., 2003; Papanastasiou, E. C., Zembylas, M., & Vrasidas, C., 2003; Richardson, V., 2003; Rop, C. J., 2002; Scheider, R. A., 2003; Schulz, L. E., & Gopnik, A., 2004; Vermette, P., & Foote, C., 2001; Zehr, M. A., 1998). They range from increasing standardized testing and teacher accountability to initiating development of student-centered schools. Opposing camps each state that they support the "correct" theory for education without an extensive tested body of research to support their claims. What is the answer? How do we, as good scientists, quantify the research? Many science education theorists are unified behind inquiry education, primarily because the sciences as a whole are home to scientific inquiry as a process (Martin-Hansen, 2002). As long as inquiry is a part of the discourse, the realization of meaningful research on the impact of inquiry education in the classroom is ever closer.

Science education is in a period of change. Current research on student achievement in the United States confirms suspicions that current systems of science teaching employed in the classrooms are not working for today's youth (Barron, Kemker, Harmes, & Kalaydjian, 2003; Martin et al., 2000; Mullis et al., 2003). In most cases, schools are still relying on lecture and teacher-driven techniques, termed didactic, to teach science (Jorgenson & Vanosdall, 2002) and the results have left the United States far behind other industrialized countries in achievement scores (Mullis et al., 2003). These other countries use student driven approaches to educate such as constructivist pedagogy (Education, 2002). In an attempt to change this progression of further defeat in the technology age and to provide credibility for changing teaching methods, the efficacy of teaching modalities such as constructivism need to be tested and compared to didactic teaching in the United States.

Statistics from the Third International Math and Science Survey (TIMSS) show that science achievement of students in the United States declined as they progressed through the educational system from 1995 to 1999 (Martin et al., 2000). The TIMSS assessment tested science achievement in four subject areas: biological science, chemistry, earth science, and physics. Science achievement was assessed in six primary areas:

"• depth and breadth of content area knowledge;

• understanding and use of technical vocabulary;

• context of problem (progressing from practical to more abstract);

• knowledge of scientific investigation;

• complexity of diagrams, graphs, tables, and textual information; and

• completeness of written responses." (Martin et al., 2000)

According to the 1995 TIMSS report, U.S. students in fourth grade were 2nd in international science achievement (Smith, Martin, Mullis, & Kelly, 2000). The same students from the fourth grade in 1995 had fallen to 18th in international rank by 1999 (Martin et al., 2000). A report to be released in late 2004 on the 2003 results will allow analysis of these students in the 12th grade. The same report should also show the efficacy of recently enforced national standards in U.S. science achievement. The decline in science achievement by U.S. students shown by the TIMSS assessments has been reproduced by studies funded by the Department of Education, carried out by the National Assessment of Educational Progress (NAEP), and reported through the National Center for Educational Statistics (NCES) (Education, 2002). The studies conducted in 1996 and 2000 focused on student achievement in the sciences in 4th, 8th, and 12th grades in the United States. While student science achievement scores did not change significantly from the 4th to the 8th grade, there was a significant drop in achievement from the 8th to the 12th grade. Verification of the TIMSS results through a second agency leads to the conclusion that student achievement in the sciences needs to be looked at closely and that a dangerous downward trend in science achievement must be turned around in the United States secondary science education.

There is evidence of other factors within the U.S. educational system that may enforce this downward trend in science achievement. In a cross-national study, students from Canada, the U.S. and Australia were surveyed about their attitudes toward and understanding of the subject of science (Griffiths & Barman, 1995). The results of the study showed that students from the U.S. viewed science strictly as process, without necessarily understanding the overall picture or the implications of science. Correlated to this finding, the students overwhelmingly believed that science as a whole does not change and that once a discovery is made it cannot be modified. The conclusion drawn from these findings was that U.S. students lack an understanding of the basic nature of science and, perhaps more importantly, do not appreciate the nature of scientific research. It is possible that their lack of understanding leads to frustration and disinterest in science, a condition which must be kept in mind when directing students to future career choices or simply expecting their participation as scientifically aware citizens in an increasingly technological world. Thus, the challenge becomes how to make science both understandable and interesting so that students stay engaged, and possibly involved, in the discipline (Goodstein, 2001).

With the future of science critical to the U.S. as an academic field, in defense, and for technological and medical advances, student interest in science as a career choice becomes a critical component of science education. Studies have shown that student interest in academic subjects may be set early in the elementary years. A 1999 study by Joyce and Farenga looked at the relationship between informal and formal science experience and student interest in further science study or career (Joyce & Farenga, 1999). The results suggest that there is a link between those students who experience science related interactions early in life and those who will go on to choose a career in science. Furthermore, the rigor and number of science and mathematics courses taken in high school have been shown to correlate, not only to a student's choice of science as field of study, but also career choice (Trusty, 2002). This information is important to curriculum designers and to the educators implementing the curriculum. Students with a deeper understanding of a subject seem to be more likely to continue study of that subject. The burden of implementing this research then lies on the elementary generalist, i.e. the elementary school teacher, who may have only a minimal science background (Goodstein, 2001). It is imperative that elementary teachers become better trained and more proficient in teaching science because evidence points towards the need for elementary classrooms to be scientifically stimulating for students to enter future science careers. In addition, science stimulation at home is crucial to this time period in student development. It follows that education must not allow for an open system of science illiteracy to propagate itself through the generations, where science illiterate parents and educators will produce students that are science illiterate.

Section II. Developing a Constructivist Curriculum

One technique to turn U.S. declining science achievement around may already have been found in an educational design that is not new, but seldom utilized throughout K-12 public schools in the United States today (Jorgenson & Vanosdall, 2002; Wirt et al., 2004). Constructivism is an educational approach that requires students to use their prior knowledge in order to understand and appreciate increasingly complicated new concepts (Vermette & Foote, 2001). This approach results in students that truly understand and retain concepts, not students that merely memorize information for tests. It should follow that constructivism would be in place in every classroom across this country. There are a number of rationales for why this is not the case.

Lecture style, or didactic, teaching is the basic style of education in America today. In more than 80% of U.S. classrooms today, teachers are still engaged in didactic teaching (Jorgenson & Vanosdall, 2002). Most classrooms that a researcher would walk into might have the teacher at the front of the class lecturing and a classroom full of students sitting in uniform rows. The students may or may not be looking at textbooks and taking notes. Lecture, memorization, and reading are the cornerstones of the didactic pedagogy. The didactic classroom is teacher led with little to no input from the students (Everett, 2001).

Didactic teaching has a twofold problem. It relies on textbooks for information transference to the students. Textbook publishers, particularly of grade 8-12 science texts, have come under scrutiny recently due to increasing editorial mistakes and published misinformation (Raloff, 2001). Writers for these textbooks report that the publishers edit to the extent that the authors are unable to recognize their own work in the finished product. According to Raloff, who interviewed textbook reviewers from AAAS, the American Academy for the Advancement of Science, the problem is furthered by the trend of individual states choosing a list of textbooks that are designed along the state standardized tests as opposed to the cognitive needs of the students.

So, why is the percentage of teachers relying on textbooks still so high? There are indications that lack of teacher training in technology and resource funding for technology in the classrooms may be contributing to this trend of continuing textbook reliance (Irving, 2002). According to a 2001 nationwide survey on classroom internet usage, schools are spending 55% more on hardware and 30% more on software than they are on technical teacher training. Teachers that still rely on textbooks often state that they are unsure of their own technical skills, that the software available to them is unacceptable for the students they are teaching, or that the technology they have available to them is not adequate to give up on textbooks, even those with known problems (Irving, 2002; Zehr, 1998).

The second problem encountered with didactic teaching in the classroom is the question of how the student obtains, integrates, and retains information in the classroom. The research on this topic lies in the realm of cognitive and developmental psychology. The generic science experiment is concerned with cause and effect. If variable A is changed, what happens to variable B? Research shows that children as young as age four understand causal relationships and even build on prior knowledge instinctively (Schulz

& Gopnik, 2004). This is an innate characteristic that does not have to be learned, just utilized by a skilled educator to help the child gain the most out of the educational context. In further studies it was found that children need instruction on how to use active memory strategies (Belmont, 1989). Education today, in 2004, requires students to use active memory strategies. From the time children are in first grade, they are being taught to be educated. It might be easier if we simply taught the way they learned instead of fighting an inherent learning ability.

Constructivism necessitates inquiry. There are a variety of different definitions of inquiry learning in use in the educational literature and it is important to define the one that will be used in this project. These definitions are based on the literature (Martin-Hansen, 2002). The development of the browser-based module within constructivist theory is based on **guided inquiry**. Guided inquiry is a type of learning in which the instructor gives the students a topic and allows the students to then develop their own questions and discussion about that topic. The resources for finding information have to be available to the students and the instructor should be well trained in the subject area and included on that resource list. Guided inquiry is distinguished from **open inquiry** where the students are encouraged to develop the opening topic and then follow their own path of knowledge development. Open inquiry requires immense resources and highly trained personnel, not only at the subject level, but also at the theory level so that the instructor does not interfere with student learning. Both of the above are further distinguished from **structured inquiry**, which is completely teacher driven. This model is similar to the didactic model, but instead of straight lecture, structured inquiry includes the teacher asking students questions regarding the material. This type of inquiry differs from the other types of inquiry in that the instructor is usually looking only for answers included in the presentation, not for causal relationships developed by the students. Inquiry may be able to answer a number of educational theory questions in the classroom. As opposed to 80% of classrooms in general still using didactic approaches to teaching, science classrooms show different numbers with 31% of the science classrooms studied in a National Center for Educational Studies (NCES) report having student-conducted and student- reported experiments (Wirt et al., 2004).

Using a guided inquiry approach as an extension of constructivism allows the science educator to develop learning labs that are more open ended than the cookbook labs that currently make up most of the secondary science laboratory curriculum. The labs that are available in textbooks and on the World Wide Web, give students a recipe to follow in order to get them to a predetermined conclusion for the experiment. This type of inquiry is the perfect example of structured inquiry. In guided inquiry laboratory exercises, the students have to develop their own hypotheses, experimental protocols, come to conclusions based on collected data, and write up reports themselves. The instructor is there as a guide, not a lecturer. The biggest strength in using this model in science education lies in the fact that this exercise more accurately represents the work of the career scientist and follows the practice of scientific inquiry. Research suggests that students not only learn science concepts better through this method than through lecture, but interest in science increases (Norris, Sullivan, & Poitot, 2003). In addition, the move towards a guided inquiry education falls within the AAAS protocol for Project 2061

(AAAS, 2003), allowing educators already moving in this direction to lead the curve and provide mentorship to an academia that is struggling with the concept of change (Handelsman et al., 2004).

It is important to differentiate between inquiry as pedagogy and scientific inquiry in practice. Inquiry has been defined in a variety of pedagogical forms previously; structured inquiry, open inquiry, and guided inquiry. These learning theories are important across all disciplines and it may be true that it is comparatively easy to put inquiry into practice in the sciences.

Scientific inquiry is the process through which scientific discovery is made (Lederman & Flick, 2004). Most often in the classroom scientific inquiry is achieved via the formulation of a hypothesis, running an experiment, and coming to a conclusion. One of the goals of scientific inquiry in the classroom is an understanding of the nature of science (AAAS, 1993). This deserves a review of the nature of science as a concept. This is a difficult concept to master, especially for those educators whose primary background may not have been in the sciences. The nature of science is a dynamic process of discovery that one undergoes while engaging in scientific inquiry (Lederman & Flick, 2004). Achieving an understanding of the nature of science is an appropriate goal of the AAAS, because it could lead students to a lifelong love of the discipline.

Section III. Technology and Science

The educational browser-based module that has been developed as part of the internship practicum report was constructed using guided inquiry as the basic pedagogy. For this reason, it is important to evaluate the literature regarding technology in the science curriculum and technology in K-12 education in general. This background will be the basis of this section. More specific information on the browser software and the curriculum design will be in the next section entitled "The Ecosystem Module".

Many researchers within K-12 education are examining the changing needs of students in the sciences and the best ways to reach students by utilizing technology based inquiry based teaching methods. A report in *Science* recently stated that students learning physics through a technology based inquiry approach at a number of institutions functioned better at a variety of key science competencies than their peers who were taught through traditional lecture formats (Handelsman et al., 2004). The American Association for the Advancement of Science (AAAS) set out to improve science literacy and education in 1989 with the launch of Project 2061. This series of science education reviews and reform goals is the most extensive set of national science standard recommendations in the United States and requires that educators use both inquiry based teaching methods and the incorporation of technology in classroom science lessons (AAAS, 2003). Such high regard by this respected body of scientist places inquiry education at the top of the list of preferred science education methodologies.

It is important to note that the move towards technology is not being advocated as a jump into the unknown. An evaluation of research done on technology in science education presented in the *Journal of Science Education and Technology* examines a variety of reports for and against the use of computers in the classroom (Papanastasiou, Zembylas, & Vrasidas, 2003). Included are reports from the Program for International Student Assessment (PISA) and the Third International Mathematics and Science Survey (TIMSS). Both reports strongly suggest that the use of computer technology in the classroom needs to be closely scrutinized within curriculum design. The authors conclude from the data that as long as computer use is facilitated by teachers that understand the software and the theory behind their use, meaning that computers should not be used for drill and practice, then computers in the classroom improve student achievement. This warning comes back to the issue of teacher training and software preparation presented in Section II regarding the initial move from a didactic pedagogy to guided inquiry. In order for education to proceed into a new era of technology facilitated guided inquiry, the foundations of both trained professionals and a technological infrastructure must already be laid.

There are model success stories where such foundations were present. An example is a research study conducted in the Mount Sinai School District of New York focused on whether or not a web-infused curriculum affected students' achievement on the New York Global History Regents exam in 2000 (Scheider, 2003). The district served a relatively homologous white upper-middle class student population at the time of the study. Three new computer labs were constructed in the high school and the study was performed there. The students were then taught through a fully infused web-based curriculum. Based on comparison to scores from the previous four years, it was concluded that the improvement in performance that the students showed that scores on the Global History Regents exam had significantly improved. Although the topic was not science, the similarity in study format allows for a good view at what testing of a browser-based module versus didactic teaching might look like. It should be noted, however, that only one class of students was studied for the dependent variable.

The response of educators to technology is a factor that must be taken into account when assessing the success or failure of technology in the classroom. The teachers are ultimately the individuals who will employ the technology. The *Journal of Biological Education* published a study regarding the response of pre-service teachers to software on virtual environments in biology; the specific environments investigated were photosynthesis and plant cell biology (Mikropoulos, Katsikas, Nikolou, & Tsakalis, 2003). The study analyzed the comfort level of the pre-service, or student, teachers with the software and how they were able to manipulate it as an indicator of student performance. The researchers concluded that the pre-service teachers were excited about the software in the classroom and that the software in connection with hands-on laboratory exercises would be more effective for student learning than lecture with hands-on laboratory exercises. Research shows that teachers in the classroom are using computers, but most still use them only at the level of problem solving. The level of full student centered and student led technology integration has yet to be achieved (Barron et al., 2003). Even teachers who responded that they used computers in the classroom regularly often ended up answering that student computer work was routine drill and practice when questioned further (Bell, 2001).

According to the "No Child Left Behind" Law, which requires all states to monitor student achievement in core subjects for consideration of federal education dollars, Title II, Part D allows for grants to be available to states that can show full integration of technology into the various curricula. Even with federal money available to reward technology integration, Texas is opting for the graduation requirement of a technology class instead (Barron et al., 2003). This choice on the part of the state is particularly interesting because student achievement scores in Texas science classrooms are below the passing rate already and if technology can be shown to increase student achievement in science, this choice would be antithetical not only to student achievement, but to state educational funding as well (TEA). The Texas Education Agency reported the 2002-2003 10th and 11th grade TAKS scores in late 2004. The 10th grade students take a benchmarking TAKS exam to allow educators a view at where the students are and where tutoring needs to be focused before the 11th grade exit level TAKS exam required for graduation from Texas schools. If students do not pass a section of this exit level examination, then they are required to retake that section until they pass before they can graduate from a Texas public high school. In 2002-2003 10th grade students were required to answer 56.4% of the science section correctly to pass and only 69.6% of the Texas students were able to achieve this goal. Of more concern were the 11th grade students who only needed to answer 49.1% of the science content answers correctly to pass and a mere 67.9% of Texas students were able to pass this section of the exit level

TAKS exam. It is possible that a technology infused curriculum based on the constructivist teaching methods could increase these passing rates, but the software needs to be fully developed and tested.

The issue of moving to a student centered technology classroom based on guided inquiry raises some questions. The foremost question regards what happens to the teacher when a classroom becomes student centered, with the students engaged in interactive lessons on computers. A well designed software package should allow the students to use the computer on a level where the student would rely primarily on that software to proceed through the lessons. The instructor would then be allowed to take a guidance role in the classroom where student achievement and academic needs could be focused on rather than straight classroom mechanics and discipline. There are cases cited in the literature where students have been able to learn at their own pace using computer based lesson packages (Bennett, 2002). Most of the students described in these situations were at-risk. Authorities permitted them to be taught using the software designed by companies like Plato Learning, Inc. and Scientific Learning. Results of these studies are reported here using the Texas students because this report centers on testing a browser in Texas schools. Using the computers, the Texas students turned their 69% TAAS test (the predecessor to the TAKS test) pass rate in 1998 into an 83% pass rate in 2000. According to reports on the Texas Education Agency's website (TEA), the exit level (10^{th} grade) TAAS scores for all students during the same time period went from 72% to 80%. It is clear that further study is needed, but the preliminary results are promising.

The literature review gives an idea of where U.S. student science achievement currently rests internationally and an idea of how technology and different instructional methodologies might play in advancing that achievement. Can browser-based science instruction designed along a guided inquiry approach increase student achievement in science education and be quantified when compared to didactic classroom methods? This question has yet to be answered and is the basis of the browser included in this practicum report.

Section IV. The Ecosystem Module

In order to answer the question of whether or not a technology infused constructivist curriculum is more efficacious than a didactic model in increasing student science achievement, a testing tool must be developed for use in the regular classroom. The browser module included with this practicum report is a first step in the direction of testing tool development and it also provides a model for further development along this software line.

The Fort Worth Independent School District (FWISD) utilizes a 2003-2004 Biology Scope and Sequence (Appendix A) that is the guideline for development of the browser-based curriculum that is the cornerstone of this project. This document outlines the units to be covered by Fort Worth biology teachers and the time teachers should spend on each unit. It is designed so that all of the state mandated topics tested by the Texas Assessment of Knowledge and Skills (TAKS) test will be covered. The TAKS test is the standardized test designed in response to the federal "No Child Left Behind" Law. The chosen unit, "Interactions within Ecosystems," is a good choice for the developmental module for a number of reasons. This unit is the final unit in the Scope and Sequence, which means that it is the most likely unit to of the curriculum to be diluted due to lack of teacher preparation time, coverage time, or a mixture of both. By providing a complete module with worksheets, educator notes, and assessment tools, teacher preparation time is nearly eliminated. There is also some flexibility in the module schedule itself, as long as adequate time for reflection is allowed.

Due to the structured approach given in the lesson plans, there is little likelihood for the class to get "off-topic" and there is time built in for extra discussion, while still conforming to the time requirements of the district's unit guideline. The unit on ecosystems reviews many of the topics already covered throughout the year to allow for review of past concepts in a contextual format. This also allows the ecosystem unit to be completely browser based without the need for hands on lab technique; one of the main concerns that a science educator might have with moving to a browser based curriculum.

The length and scope of the unit allows the ecosystems module to conform to the Texas Essential Knowledge and Skills (TEKS) requirements for 10^{th} grade benchmarking and 11^{th} grade graduation testing requirements. The TEKS are the State of Texas mandated skills resulting from the federal government "No Child Left Behind" Law, which was designed to increase the educational achievement of American students ("TEKS for Secondary Science," 1998). The ecosystem unit used for this module is based on TEKS Chapter 112: Science, Subchapter C: High School, Rule §112.43: Biology, 12(A, B, D, E) as defined below.

> (12) Science concepts. The student knows that interdependence and interactions occur within an ecosystem. The student is expected to:
>
> > (A) Analyze the flow of energy through various cycles including carbon, oxygen, nitrogen, and water cycles;
> >
> > (B) Interpret interactions among organisms exhibiting predation, parasitism, commensalisms, and mutualism;

(D) Identify and illustrate that long-term survival of species is dependent on a resource base that may be limited; and

(E) investigate and explain the interactions in an ecosystem including food chains, food webs, and food pyramids ("TEKS for Secondary Science," 1998).

The Curriculum

Included is an overview of the proposed curriculum for a 10 day computer-based learning module. The focus remains on interactions within ecosystems as required by the Fort Worth ISD Scope and Sequence and conforms to TEKS A, B, D and E. The module will contain the computer software, instructions for the teacher on guiding the lessons, information regarding how to lead reflections, and the final assessment with answer key. All module materials, except the browser software, can be found in Appendix C. The software, found on the inside of the back cover of the practicum report, runs best on Internet Explorer 5.0 or higher, which is downloadable free from the internet should another browser program be in use and will require the use of Macromedia Flash Player, also downloadable from the internet at www.macromedia.com. Included in the browser software is an assessment review (Appendix B). There are fourteen questions from released TAKS tests, which may be used for student practice. The review is provided to give the students experience on TAKS questions and to review information on ecosystems. Although the final assessment for this unit will not be a multiple choice exam, the review should aid the students in viewing the information comprehensively.

Day 1 – Introduction to module format. Students put into groups of four.

- The students will learn about dependent interactions by playing with the following at the tables:
  - setting up Jenga© blocks on top of each other until they tumble
  - working with keystones in bridges
  - using tensegrity models to understand inter-relationships.
- The students should come up with similarities between methods listed above in order to understand balance and dependency.

Day 2 – The Pond Project (Appendix B)

- The Pond Project looks at energy flow in ecosystems and conforms to TEKS 12A ("TEKS for Secondary Science," 1998).
- Students go to the computers.
- This first lesson focuses on the conversion of light energy to chemical energy in plants and the subsequent use and storage of this chemical energy by animals in the form of ATP. An overview of glycolysis, the Kreb's cycle, and the electron transport chain are included.
- Students are asked to predict results throughout the lesson.

Day 3 – Reflection on the Pond Project

- Students should be given time at the beginning of class to write about their understanding of The Pond Project in their journals. This type of reflection through journaling is critical for knowledge reinforcement. Reflection is where the connections are made in the brain and is built specifically into the curriculum to round out the process of understanding the material (Richardson, 2003).

- Student help groups will meet to discuss energy flow and clear up any misconceptions they may have regarding the lesson.
- The class will meet as a whole for full discussion of what they have learned so far including questions that may further their study of the topic. The instructor should direct the students to further resources as required for self study to satisfy student interest. It is best if these resources are available in the classroom either through the internet or an accumulated set of current reference books.

Day 4 – Living and Eating Together (Appendix B)

- Living and Eating Together examines interactions among organisms and conforms to TEKS 12B ("TEKS for Secondary Science," 1998).
- Students go to the computers.
- This lesson is set up so that there are four main relationships to study: predation, parasitism, commensalism, and mutualism.
- The students are introduced to these interactions and then required to use prior knowledge to navigate through the browser and learn more about the different relationships.

- Questions are interspersed in the lesson that come from released TAKS tests in order to begin getting the students used to answering these types of questions.

Day 5 – Reflection on Living and Eating Together

- Students will be given time at the beginning of class to journal about their understanding of Living and Eating Together.
- Student help groups will meet to discuss the interactions of organisms and clear up any misconceptions they may have regarding the lesson.
- The class will meet as a whole for full discussion of what they have learned so far including connections between relationships and energy transfer and should have the freedom to ask questions that may further their study of the topic. The instructor should direct the students to further resources as required for self study to satisfy student interest. It is best if these resources are available in the classroom either through the internet or an accumulated set of current reference books.

Day 6 – Back to the Pond (Appendix B)

- Back to the Pond investigates and explains interactions between organisms and conforms to TEKS 12E ("TEKS for Secondary Science," 1998).
- Students go to the computers.
- This lesson specifically examines the food chain and the food web. It is organized to introduce the simple idea of the food chain and allow students to recognize that relationships among organisms are more complex than can be

explained by the food chain alone. The lesson is designed so that the students will realize on their own using inquiry based methods of discovery and interaction with the browser components that the food web is a more realistic indicator of organism, and therefore energy, interactions before anything is hinted to or explicitly stated in the lesson.

Day 7 – Reflection on Back to the Pond

- Students will be given time at the beginning of class to write their thoughts on Back to the Pond
- Student help groups will meet to discuss interactions among species and clear up any misconceptions they may have regarding the lesson.
- The class will meet as a whole for full discussion of what they have learned so far. At this point the integration of energy, relationships, and the food web should be coming together for the students. The instructor should have a very good idea of how the class as a whole and the individual student understands the concepts explored. Reference materials should still be available to the students for self study.

Day 8 – Survival of a Species (Appendix B)

- Survival of a Species studies biomes (fulfills TEKS 12C) and examines how long-term survival depends on a resource base (fulfills TEKS 12D) ("TEKS for Secondary Science," 1998).
- Students go to the computers.
- The lesson follows a beaver to see how environmental factors affect it.

- Many different environmental factors have been included in this lesson from human pollution and encroachment on habitat to natural effects on food. Students have the opportunity to look at each one of these effects individually and see the response of the beaver to the change in its environment.

Day 9– Reflection on Survival of a Species

- Students will be given time at the beginning of class to write their thoughts on Survival of a Species.
- Student help groups will meet to discuss biomes and long term survival and clear up any misconceptions they may have regarding the lesson.
- The class will meet as a whole for full discussion of what they have learned so far. This will be the last meeting of the whole class before the comprehensive assessment. Any issues that are still unclear should be dealt with at this time. As with all other lessons, reference materials should still be available to students for self study.

Day 10 – Assessment of ecosystems unit

- The final assessment for this unit is comprised of six short answer questions. The structure of the test is to assess critical and analytical thinking levels and avoid the mere regurgitation of material. If possible, regurgitation of material will be impossible with this unit because learning will depend completely on the level of engagement of the individual student. The ability of the students to answer the questions depends on the time each student has taken to understand the information presented both at the time of the group discovery and during the reflection periods. The exam will be timed at 40 minutes. TAKS questions have already been asked and answered throughout the module so practice and experience, which is required by most Texas school districts, will have been completed.

Section V. Limitations to Using the Module and Future Studies

While research as cited in sections I-III has shown that the constructivist approach to science education can be more beneficial to students than the traditional didactic approach, very few schools or school districts have implemented curricular reform to reflect the research. It may be difficult to find a school, or teachers, that are willing to work with the browser-based module because it is technology intensive and a method that many may not be comfortable with.

There is also the problem of practical implementation of the curriculum. In order to actually use this curriculum design effectively, the entire class would need to have access to individual computers. There are few schools in the FWISD that have this type of technology base. Each individual school would have to write a grant asking for technology funds outside of technology classrooms. It is possible that the presence of the software would create a reason for schools to seek out the funding for computers, but the efficacy of the browser-based curriculum might have to be proven before funding agencies would release money.

Future study will include proceeding from the development of the browser to a study arm. Movement to study will need Institutional Review Board (IRB) approval based out of a university because the students at the level of biology in Fort Worth are less than 18 years of age. The study design needs to include classrooms with the appropriate technology or access to technology and teachers capable of following the guided inquiry approach along with classrooms that follow didactic methods to use as controls. Coordination of these classrooms requires parent and student consent along with district cooperation. The ecosystems browser can be used as a pilot study that would not require as much time or as many resources as a fully integrated curriculum because it only focuses on one unit. With positive results, more funding could be acquired to develop and test a fully integrated year long curriculum for quantitative analysis. Then the question of the efficacy of a technology integrated inquiry based curriculum as compared to the current didactic methods used in many classrooms could be answered.

Appendix A

Fort Worth ISD Biology Scope and Sequence

APPENDIX A

Biology
Scope and Sequence
2003-2004

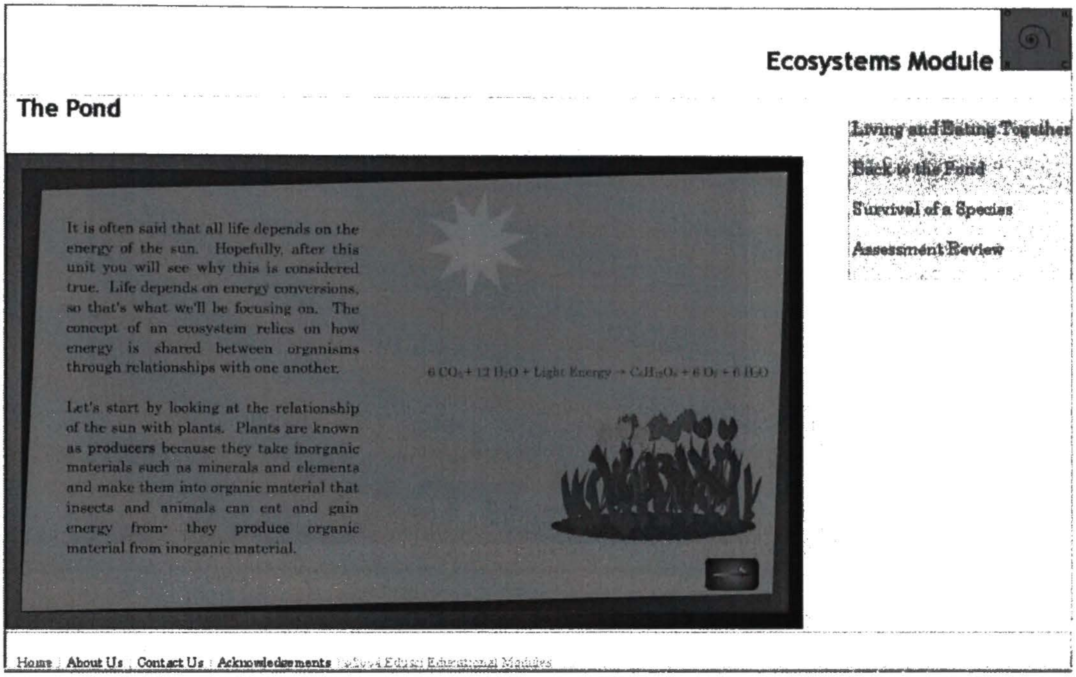
TEKS	Unit	Time
1A,1B; 2A-D; 3A-F	Nature of Science Safety, Process Skills, Lab Management, Experimental Design, Characteristics of Life **District Six Weeks Assessment – 8/22-10/3**	25 Days
9A,9C; 4A,4B; 5A; 9B	Cellular Biology Biochemistry, Cell, Cellular Processes **District Six Weeks Assessment – 11/3-11/14**	25 Days
6A-6F	Genetics DNA, Protein Synthesis, Mitosis vs Meiosis, Genetic Variation, Mutations **District Six Weeks Assessment – 12/8-12/19**	35 Days
7A, 7B	Theory of Biological Evolution Evidence, Natural Selection	10 Days
8A-C	Taxonomy Applications of Taxonomy, Characteristics of Kingdoms(6 Kingdoms, 3 Domains)	5 Days
4C, 4D; 11D	Viruses vs Bacteria Viral Structure and Function, Viral Roles in Disease, Bacterial roles in maintaining health and disease. **District Benchmark Assessment – 3/1-312**	15 Days
5B,5C; 10A-C; 11A-C; 12C; 13A,13B	Living Systems Includes Plants and Animals – Growth and Development, Functions of Systems, Homeostasis	40 Days
9D; 12A, 12B, 12D, 12E	Interactions within Ecosystems Relationships, Limiting Factors, Cycles, Energy Flow	10 Days

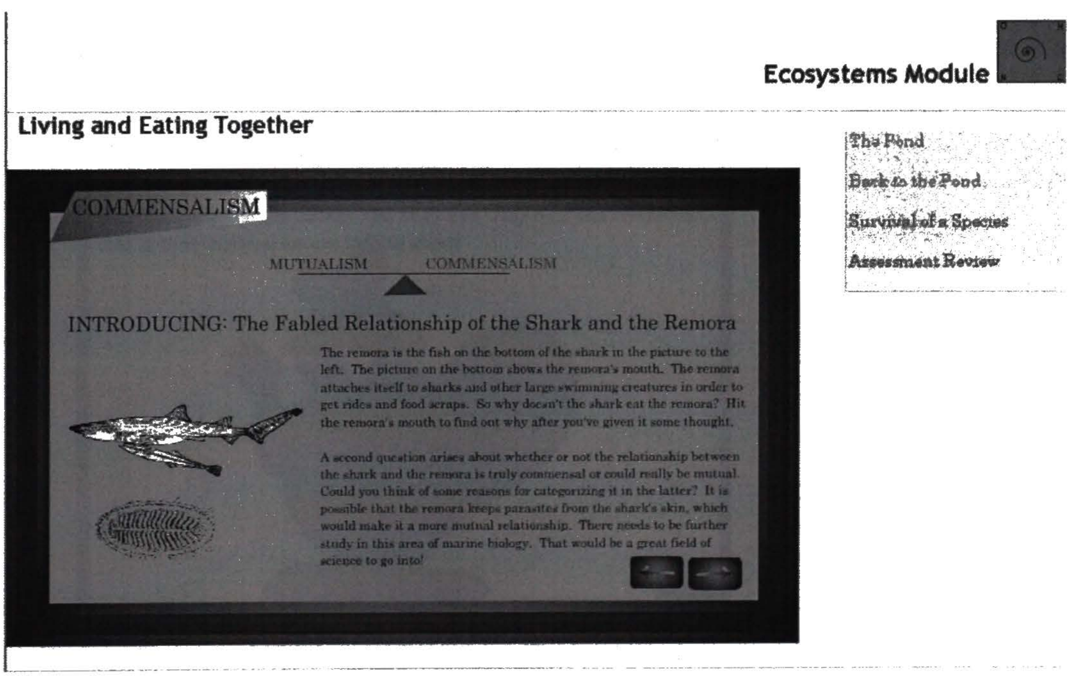
Note: The time allotted to complete each unit is based on a traditional school schedule – 45-50 minute classes. According to the district assessment calendar dated 7/30/2003, schools will be given a two week window to administer the assessment. One class period for each assessment has been factored in to the unit time schedule.

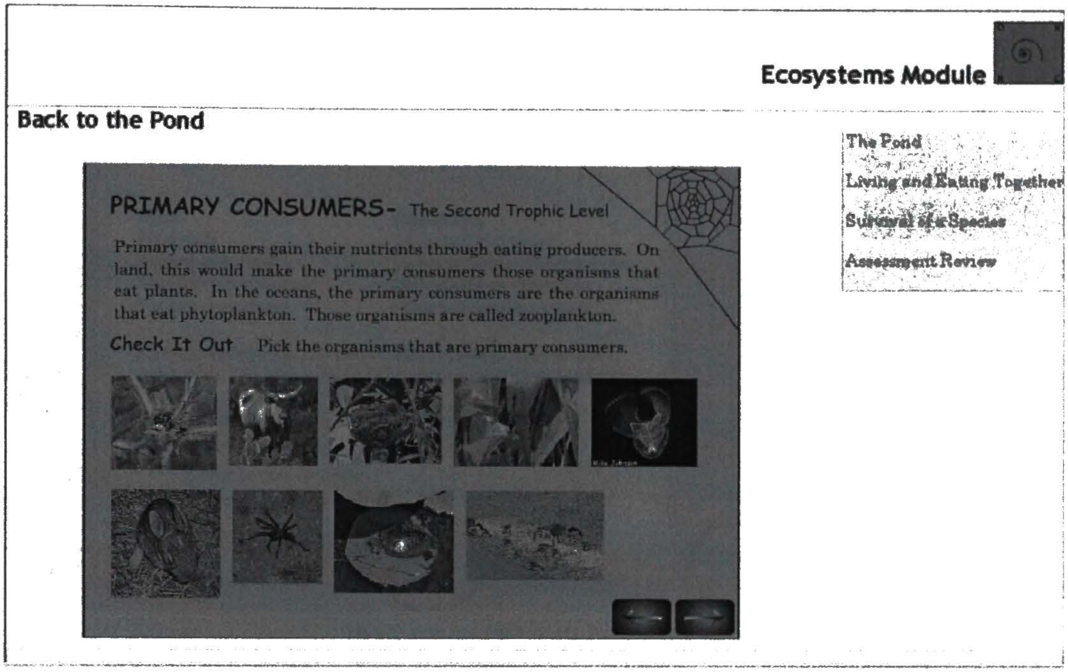
Appendix B

Browser Page Samples

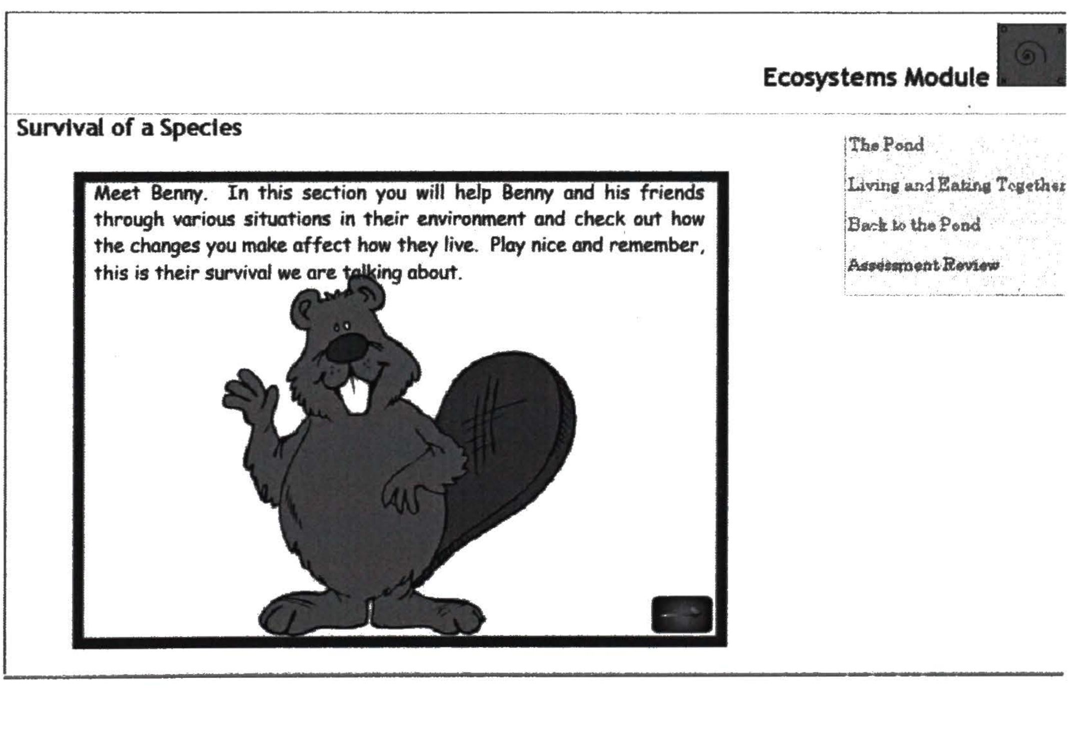
APPENDIX B


Ecosystems Module
The Pond
Living and Eating Together
Back to the Pond
Survival of a Species
Assessment Review
It is often said that all life depends on the energy of the sun. Hopefully, after this unit you will see why this is considered true. Life depends on energy conversions, so that's what we'll be focusing on. The concept of an ecosystem relies on how energy is shared between organisms through relationships with one another.
Let's start by looking at the relationship of the sun with plants. Plants are known as producers because they take inorganic materials such as minerals and elements and make them into organic material that insects and animals can eat and gain energy from· they produce organic material from inorganic material.
$6 CO_2 + 12 H_2O$ + Light Energy $\rightarrow C_6H_{12}O_6 + 6 O_2 + 6 H_2O$
Home | About Us | Contact Us | Acknowledgements

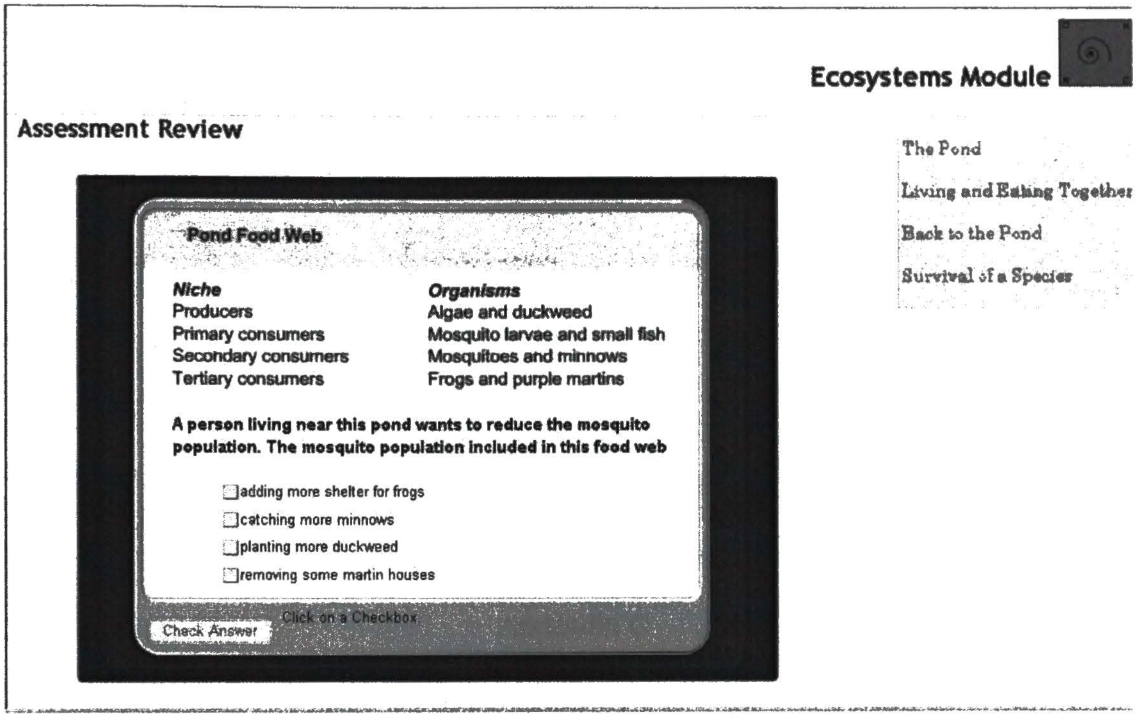

Ecosystems Module
Living and Eating Together
The Pond
Back to the Pond
Survival of a Species
Assessment Review
COMMENSALISM
MUTUALISM
COMMENSALISM
INTRODUCING: The Fabled Relationship of the Shark and the Remora
The remora is the fish on the bottom of the shark in the picture to the left. The picture on the bottom shows the remora's mouth. The remora attaches itself to sharks and other large swimming creatures in order to get rides and food scraps. So why doesn't the shark eat the remora? Hit the remora's mouth to find out why after you've given it some thought.
A second question arises about whether or not the relationship between the shark and the remora is truly commensal or could really be mutual. Could you think of some reasons for categorizing it in the latter? It is possible that the remora keeps parasites from the shark's skin, which would make it a more mutual relationship. There needs to be further study in this area of marine biology. That would be a great field of science to go into!



Ecosystems Module
Back to the Pond
The Pond
Living and Eating Together
Survival of a Species
Assessment Review
PRIMARY CONSUMERS- The Second Trophic Level
Primary consumers gain their nutrients through eating producers. On land, this would make the primary consumers those organisms that eat plants. In the oceans, the primary consumers are the organisms that eat phytoplankton. Those organisms are called zooplankton.
Check It Out Pick the organisms that are primary consumers.



Ecosystems Module
Survival of a Species
The Pond
Living and Eating Together
Back to the Pond
Assessment Review
Meet Benny. In this section you will help Benny and his friends through various situations in their environment and check out how the changes you make affect how they live. Play nice and remember, this is their survival we are talking about.


Ecosystems Module
Assessment Review
The Pond
Living and Eating Together
Back to the Pond
Survival of a Species
Pond Food Web
Niche
Producers
Primary consumers
Secondary consumers
Tertiary consumers
Organisms
Algae and duckweed
Mosquito larvae and small fish
Mosquitoes and minnows
Frogs and purple martins
A person living near this pond wants to reduce the mosquito population. The mosquito population included in this food web
adding more shelter for frogs
catching more minnows
planting more duckweed
removing some martin houses
Check Answer
Click on a Checkbox

Appendix C

Ecosystem Module Materials

APPENDIX C

The Lessons

Note: Each student will need a journal and a pen to complete this unit. A laboratory notebook with numbered pages would be preferable. Students should date the pages and have the teacher sign them in order to re-create a true lab bench feeling. The data/reflections put in the journals will be a reflection of the students' inquiry into ecosystems and as such should be treated with the respect of true scientific work.

DAY 1

Introduction- The purpose of this lesson is to introduce the students to the concept of interdependence and balance. Proposed materials for this lesson include Jenga© blocks, a model bridge with a removable keystone, and/or a tensegrity model.

Instructions to Instructor- Split the students into their lab groups. Give the students the model materials and instruct them to study the interdependence of the materials. If asked for a definition of interdependence, say

- balance each other,
- fit with each other, or
- work with each other.

Give the groups 10-15 minutes for this exercise. When the groups are finished, have the students write down their thoughts about the exercise in their journals.

Direct them to answer the following:

- Where there similarities between the models; what were they?
- What was the guiding principle behind how the models worked?
- Were these models important to science?

Come back to the whole class and discuss their thoughts regarding the above questions.

Goal of the Exercise- The goal is for the students to notice the similarities between the different situations and to see the interdependence within each situation. It is important for each group to come up with these concepts with minimal to no guidance from the instructor.

DAY 2- The Pond Project

Standards Covered- TEKS 12A

Introduction- The purpose of this lesson is to introduce the students to the concept of energy flow within ecosystems. There is a review of photosynthesis (light energy to chemical energy) and polysaccharides, but most of the lesson is concerned with glycolysis, the Kreb's cycle, the electron transport chain and the storage of ATP.

Instructions to Instructors- Students should proceed immediately to the computers. They will be able to interact in their lab groups throughout the lesson and should be allowed the freedom to explore with the understanding that they will have at least 25 minutes up to whatever time you allot for the computer lesson.

Goal of the Exercise- This exercise is intended to take the students through a step-by-step visual study of energy conversion so they can better understand the basis of energy movement from one organism to another. This should give the students some basics for understanding the complexities of relationships that will be coming up in the next couple of lessons.

DAY 3- The Pond Project Reflection

Introduction- Reflection is a critical aspect of guided inquiry. It allows students to tap into the knowledge that they gained from the previous day and reinforce it if needed. Additionally, students using this module will be writing in a laboratory notebook and following procedures of data compilation as done on the lab bench.

Instructions to Instructors- Students should go to the computers in order to have access to the program and any information they might have missed during the previous day. They should be well-informed that the laboratory notebook will be signed off on. Then instruct the students to compile their reflections of the current lesson and any connections they might have made to previous lessons or other information. You might give them a format to use such as the following:

- Date Teacher Signature
- Reflections
    - Current Lesson
    - Connections to other lessons
- Additional information
- Student Signature

Goal of the Exercise- The goal is to reinforce the lessons learned up to this point and allow the students to clarify any points they might have missed. In this type of guided inquiry process it is better to direct the students to where answers to questions might be rather than outright answer the question itself. This allows the students to become more independent thinkers and learners.

DAY 4- Living and Eating Together

Standards Covered- TEKS 12B

Introduction- This lesson looks at the relationships between species including predation, parasitism, commensalism, and mutualism.

Instructions to Instructors- Students should proceed immediately to the computers. They will be able to interact in their lab groups throughout the lesson and should be allowed the freedom to explore with the understanding that they will have at least 25 minutes up to whatever time you allot for the computer lesson.

Goal of the Exercise- The goal of this lesson is to reinforce energy flow and set up the students for the discussion of food chains and food webs.

DAY 5- Living and Eating Together Reflection

Instructions to Instructors- Reflection should be encouraged in the same manner as before.

DAY 6 – Back to the Pond

Standards Covered- TEKS 12E

Introduction- The concepts of marine and terrestrial food chains are introduced and give way to the more complex idea of the food web in this lesson.

Instructions to Instructors- Students should proceed immediately to the computers. They will be able to interact in their lab groups throughout the lesson and should be allowed the freedom to explore with the understanding that they will have at least 25 minutes up to whatever time you allot for the computer lesson.

Goal of the Exercise- In step-wise manner, students are guided through the food chains to see that ecosystems rely more on concept of food web for interdependence. The lesson ends with the understanding that the cycle of the ecosystem starts again with the detritivores, or decomposers, that are responsible for breaking organic (biotic) compounds back down to their inorganic (abiotic) components.

DAY 7- Back to the Pond Reflection

Instructions to Instructors- Reflection should be encouraged in the same manner as before.

DAY 8- Survival of a Species

Standards Covered- 12D and 12C (partial)

Introduction- This lesson uses a fictitious beaver to explain some basics about beavers and their habitat. Students are able to click on buttons and see how different variables impact the beaver's environment.

Instructions to Instructors- Students should proceed immediately to the computers. They will be able to interact in their lab groups throughout the lesson and should be allowed the freedom to explore with the understanding that they will have at least 25 minutes up to whatever time you allot for the computer lesson.

Goal of the Exercise- This final exercise consolidates the previous lessons and reinforces the principles of ecosystem balance and energy flow.

DAY 9- Survival of a Species Reflection

Instructions to Instructors- Reflection should be encouraged in the same manner as before.

Special Note: There is an assessment review included on the browser that is made of released TAKS ecology questions from the 2002 and 2003 tests. The students can use extra time to review these questions. They have been included as a review of information and to give the students experience with the type of questions that will be on the TAKS exam. These are not the type of questions that will be on the assessment for this unit.

DAY 10

Introduction- This is the day allotted for the assessment. The assessment was designed to assess comprehension, not memorization, so the questions are short answer and open to some interpretation. Obviously this leaves some discretion up to the teacher.

Instructions to Instructors- Students should be given as much time to complete the assessment as possible without access to the computer or their journals. It is suggested that the journals be turned in as part of the assessment grade, although only counted for completion (perhaps 2 points per day). Journals should be returned to the students.

Goal of the Exercise- The goal of the assessment is to insure that the students have grasped the concepts important for the understanding of ecosystems. The assessment will show competency in the TEKS by default due to the structure of the browser.

Ecosystems Assessment

Please write your name and the date at the top of the page. Write clearly and answer all questions fully. Most importantly, relax and enjoy describing what you have learned!

1. When converting light energy to chemical energy, a plant undergoes a process called photosynthesis. Why is photosynthesis important in an ecosystem? (15pt)

   - *it's the first energy conversion into usable energy from the sun*
   - *plants require photosynthesis to exist and without plants (producers), an ecosystem will eventually fail*

2. When a top predator (quaternary consumer) eats, we know that it will get very little of the original producer's energy from the bottom of the food chain. Why then is the predator able to continue living? (15pt)

   - *the quaternary consumer does not limit its prey to tertiary consumers and the lower down the food chain it feeds, the more energy it consumes*
   - *top predators also bring down large primary consumers so energy consumption will be large due to the size of the prey*
   - *top consumers conserve energy by maintaining territories in groups and only being active to hunt, defend, and reproduce*

3. Explain the relationship between the cow and the cowbird. (10pt)
   - *this is a commensal relationship where the cowbird stays on or near the cow and as the cow stirs up insects in the grass as it eats the cowbird feeds on them*

4. A beaver lives on a river. Upstream the local electrical cooperative needs to build a new dam for more power generation. Explain how the construction of the new dam will affect the beaver living downstream. (10pt)
   - *the dam will limit the water flow downstream and most likely dry up the area where the beaver's current lodge is so that it will have to build another or move on*
   - *beavers eat a lot of water plants and tubers that live near the water so when the river changes to a stream the beaver might run out of food while the ecosystem undergoes a change*

5. An Orca whale swims in the ocean looking for food. It comes upon a sea lion hiding in some seaweed. Will the Orca attack the sea lion or munch happily on the seaweed? (10pt)
   - *Orca whales are actually carnivorous dolphins, also called killer whales and will hunt and kill the sea lion*

6. In Indonesia a major volcano erupts and spews ash into the atmosphere for two weeks. The jet stream carries the ash over the western portion of the United States, causing the sun to be blocked out for over a month. Describe what might happen to the ecosystem in the northwestern rainforest of the United States during this time period. (20pt)

   - *without the sun to provide light energy the plants will begin to die off and the ecosystem as a whole will begin to deteriorate*

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