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The Effectiveness of Using Problem Solving in Teaching Ecology

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Kari A. Hoikka

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THE EFFECTIVENESS OF USING PROBLEM SOLVING IN TEACHING ECOLOGY

By

Kari A. Hoikka

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ABSTRACT

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The purpose of this study was to show the degree of student learning in the area of ecology when using problem-solving techniques in teaching. During the unit on ecology, the students were given a more active role in the development of the unit. The students were presented with questions, then discussed the ideas being presented and decided what notes should be taken. The students were given problems to solve and designed their own procedures to solve the problems. The sample population was students enrolled in my biology classes at Mattawan High School. A pretest consisting of an objective portion, relating to concepts and terminology of ecology, and a subjective portion, relating to identifying a problem and designing an experiment to solve that problem, was administered at the beginning of the unit. The test also included three items that allowed students to rank their own perceived abilities in the areas of ecology, designing experiments and problem solving. The same test was administered as a posttest. Upon comparing the pretest and the posttest results, a substantial increase in objective scores was noted, and the data were supported by statistical analysis using a t-test. Subjective scores showed no significant increase.

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INTRODUCTION

STATEMENT OF PROBLEM AND RATIONALE FOR STUDY

The problem investigated by this study was whether or not a problem-solving approach to teaching ecology was effective. When using the terms "problem-solving approach," I am referring to a style of teaching in which the students take an active role in the learning process, and they decide, to a larger extent, the direction the lessons take. Students discover the content through questions presented by the teacher and through questions asked by the students themselves. This style was used in contrast to the more traditional style of teaching, in which the lesson is dictated by the teacher, and the students, while still involved, take a more passive role.

Mattawan High School, where this study took place, is located in the relatively rural area of Mattawan, Michigan, and has approximately 950 students. Students are from primarily middle class and upper-middle class families. Most students are Caucasian; there are less than 1% minorities at the high school. Education is a priority among the families and students of Mattawan High School. This is evident in the 98% graduation rate, with 85% of those graduates going on to further their education.

Originally, when this study was planned, I was teaching science at Allegan High School in Allegan, Michigan. At that time, the entire science department was working to improve our students' scores on Michigan's High School Proficiency Test (HSPT), especially in problem solving and constructing responses. It was felt that although many of our students had knowledge of the topics on the HSPT, they were having difficulty applying that knowledge. This was of great concern to me because, although standardized tests do not always tell the whole story, it was clear that our students were not able to communicate what they knew.

Other factors contributed to my choosing problem solving as a research topic. One very influential factor was the poor work habits that I was noticing more and more in my students. Students did not seem to know how to begin solving even simple problems. If the answer to a question was not in writing directly in front of them, they frequently would just give up. For example, if a student was asked a question during a class discussion and he or she did not know the answer, the response was usually, "I don't know," followed by silence. Very rarely was an attempt made to find the answer in a textbook or even to ask questions that might clarify what was being asked. "I don't know," became a far too common response.

Another contributing factor was centered around laboratory activities. I was finding that rather than being "investigations," many of the students were doing "activities." The students were active participants in completing the assigned tasks of the lab, but they did not seem to understand what they were actually doing or why they were doing it. I felt that although students were getting the hands-on experiences they needed, they were not getting the required elements that would help them personalize the processes and procedures.

If students could not personalize these activities, one major purpose for doing the activity was lost. Students would not be able to apply that knowledge to other areas, such as life skills and career paths. In fact, the ability to analyze, think independently and work as a member of a group to solve problems are all employability skills that are being sought in today's job markets (McTighe and Schollenberger, 1991). I felt that no matter what career each student chose, I should be able to help him or her prepare for that field. Including questioning and problem solving techniques incorporated into my courses seemed to be beneficial.

Once it was decided that my research would be geared around problem-solving methods of teaching, the actual topic had to be chosen. At that time, the science department at Allegan High School was attempting to branch out in terms of what courses were to be offered. After checking with the students, one topic that was suggested as a possible semester course was ecology. I also felt that this would be a good course to offer, and I agreed to teach the course. This posed a great opportunity to develop my research on problem solving in the classroom because the whole basis of ecology is the interactions of living things with their environments and the complications that can arise in the process. Teaching ecology through problem solving seemed to be the ideal research topic.

One complication did arise. I had just finished designing the investigations for the new ecology class when I was hired by Mattawan Consolidated Schools to teach biology. Although I did not have as much time to devote solely to the topic of ecology at Mattawan High School, I was still able to apply my unit to my new teaching assignment.

LITERATURE REVIEW

The goals of using problem solving and inquiry as teaching techniques are not based on new ideas. As early as 1896, John Dewey, a professor at the University of Chicago, conducted studies to show that students learn best when using their curiosity and their own experiences and when they are allowed to take responsibility for their learning (Anderson, 1994). In the 1930's, educators were working toward a goal of students becoming independent thinkers and learners. The National Education Association's Educational Policies Commission included in its 1937 report,"...all youth need to grow in their ability to think rationally, to express their thoughts clearly, and to read and listen with understanding" (McTighe and Schollenberger, 1991). Although at that time these objectives were clearly stated, a means of achieving these goals was not known to many teachers.

Teaching strategies to achieve these objectives were developed in the 1950's and 1960's, and continue to be revised today. The Biological Sciences Curriculum Study was one organization to outline techniques for including inquiry in science curricula (Chiappetta, 1997). The teaching methods proposed at that time centered around students' attitudes, thinking habits and reasoning skills. The general idea of inquiry-based teaching was that, by engaging students' curiosities about the natural world, their learning would be increased.

These ideas seemed to wane somewhat during the 1970's when the focus of science education instead became content. Textbooks were designed to include as many facts as could be squeezed onto the pages, and many states published lists of topics that should be taught in science classes. Learning processes of science were forfeited in preference to learning content.

It seemed what was actually needed was a combination of both strategies. In order for students to be successful in learning the processes of science, they must be familiar with content terminology and concepts. Conversely, learning content is enhanced by active learning procedures. An educational program that included a blending of these methods was needed.

Fortunately, the 1980's saw a shift toward a curriculum which combined content and processes. Two documents that were very influential in this shift were *Project 2061: Science for All Americans*, which was developed by the American Association for the Advancement of Science (AAAS) and "Essential Changes in Secondary School Science: Scope, Sequence and Coordination" (hereby referred to as SS&C) by Aldridge (1989). Some goals of *Project 2061* were that schools should direct students to become citizens who can think independently and critically and who can deal with problems using logic. It also encouraged educators to reduce the amount of curriculum and focus on other things, such as making the content relevant to students' lives outside of school (AAAS, 1997).

Aldridge supported all of these ideas and added that the curriculum should be coordinated to show unity among all of the disciplines of science, and the curriculum should be sequenced to match the learning abilities of the students (Anderson, 1994).

Today, many educators are working to achieve and maintain the standards set by Project 2061 and SS&C. Before designing my ecology unit, I studied two current models that appeared to have many positive attributes. One of these programs was Realistic Experiences Activate Learning (REAL), which was developed by Science and Math Investigative Learning Experiences (SMILE) at Oregon State University (1996). The framework, designed as an enrichment program for minority and disadvantaged students, consisted of seven steps designed to solve problems. The processes are listed below:

1. Background knowledge
2. Problem exposition
3. Data collection
4. Data analysis
5. Data synthesis
6. Solution presentation
7. Career information

(Bloomfield, et al, 1996)

Along with basic steps of problem solving, students enrolled in REAL also learned skills such as teamwork, creation and use of charts and graphs and giving presentations. Student participants rated the program very highly.

The other program was problem-based learning (PBL), which was initially developed for medical schools to show medical students how to solve medical problems. Developed by H.S. Barrows and R.M. Tamblyn, PBL consists of the following steps:

1. Problem is encountered
2. Problem is presented to student in real-life context
3. Student works to solve problem through reasoning and applying previous knowledge
4. Students research any areas necessary
5. Information and skills acquired from research are applied to problem
6. New learning that has taken place is internalized by student for future use

(Delisle, 1997)

Although this program was initially developed for medical schools, it is also a model being used at all levels of education. The goal of this program is to make students active learners with teachers serving as guides.

The role of the teacher in any problem-solving classroom must change from that currently viewed as acceptable or traditional in many schools. Traditionally, a teacher's role has been that of a marshal, controlling what is taught and how it is taught. For many teachers, a strong sense of comfort comes from knowing what each class of each day will bring, and it is difficult to hand over any amount of that control. But the role of a teacher in a problem-solving classroom becomes that of a facilitator. The teacher first must develop materials that will require students to pose questions and design experiments to answer those questions (Edwards, 1997). Once the materials are developed and students are working through the problems, the teacher's role becomes that of a guide. Guiding students while they work on solving problems allows them to increase independence and creativity (Delisle, 1997). Throughout the entire process teachers can keep students engaged in active learning by continuously raising questions, posing problems and pointing out discrepancies for the students to resolve (Costa, 1991).

The role of the student in an inquiry-based or problem-solving classroom must change also. Traditionally, students have been passive learners, reading and writing what they were told, memorizing facts and information and completing "cookbook" laboratory exercises. In problem-solving classrooms, students are taught to take an active role. They must learn to pose direct and relevant questions, to design experiments, to collect and analyze data, to make presentations and to work as part of a team. The team building skills that students develop are of universal value. Students bring together different backgrounds and , therefore, may see different aspects of the same problem (Delisle, 1997). In many cases, students improve their leadership skills and gain confidence when speaking in groups or to the class. Although changing students from passive to active learners is not always a smooth transition, most students would agree the change is a positive one.

One other aspect of the traditional classroom that must change if a problem-solving curriculum is adopted is assessment.

> "While it certainly does not make much sense to ask students to enter into a process of discovery, then use a negative grading system in which credit is deducted for 'errors,' neither does it make sense to simply ask students to grade themselves."
>
> (Settlage and Sabik, 1997)

Settlage and Sabik point out the importance of adjusting assessment techniques to meet the needs of a problem-solving curriculum. The key to assessment seems to be to have a variety of tools with which to evaluate students. Laboratory reports, presentations, journal entries and assigning points based on active participation have all been suggested as means of grading in a problem-solving classroom. Rubrics for grading presentations and laboratory reports may partially be designed by students to give them an even greater sense of control over their learning. Ramona Lundberg, a chemistry teacher at Deuel High School in Clear Lake, South Dakota, reports the following benefits to having students assist with designing rubrics:

> "Students are more comfortable and realize their opinion is valued. Students are more successful because they know what is expected, and most are willing to work to meet those expectations. More hands-on activities that emphasize scientific inquiry are used."
>
> (Lundberg, 1997)

Inquiry and problem solving have their places in science classrooms around the world. Although they may be difficult to implement at first, the change would likely be for the better.

DEMOGRAPHICS OF CLASS

The study population consisted of 110 students enrolled in my five biology classes at Mattawan High School. Of those students, one was in ninth grade, 102 were in tenth grade and seven were in eleventh grade. Two students in the sample population qualified for special education services. All students were given the option to participate or to be exempt from the study. Those who chose to be exempt from the study still participated in the unit and completed all of the activities. The only difference between the participating and nonparticipating students was that only the participating students' scores were used in the data analyses. The parent notification letter found in Appendix A was sent home with all students, and the letters were returned regardless of the participation preference.

Although biology was not a required class, it was chosen by most students to partly complete their two-year science requirement at this school. As ninth graders, most students took physical science, which was a year-long class that surveyed such topics as chemistry, forces and motion, and rocks and minerals.

IMPLEMENTATION OF UNIT

I began teaching the ecology unit on May 8, 1998. It was the last unit to be covered before the end of the school year. I felt this would be a good time and place in the biology curriculum for a few reasons. The most important reason was that ecology brings together all other facets of biology. It combines knowledge of plants and animals, genetics, cells, basic chemistry and evolution. As the students had studied these topics already, I felt they could bring more into our discussions and investigations of ecology. Also, I wanted to keep the students focused on school, something that becomes especially difficult in May, and I hoped a few trips outdoors might spark some interest. I also anticipated nicer weather in May than in some other months in Michigan. For all of these reasons, I chose to teach ecology as the last unit of the school year.

Choosing this time of year to teach ecology did have some drawbacks. One problem was keeping students on task, as summer was approaching. A minority of students felt as though their grades could not be altered too much in the last three weeks of school, so they quit working. The biggest problem I faced was the continuous stream of class interruptions due to the end-of-the-year activities. Being new to the school, I was not aware of how much instructional time would be lost during these weeks. The loss of time greatly limited what I was able to accomplish. An outline of what was completed in the unit is given below. The outline shows what topics were taught during the three weeks of the ecology unit, and it states the activities that were completed each week.

Week 1

Topics:
- ecology and ecosystems
- biotic and abiotic factors
- biogeochemical cycles
- hypotheses and experimental design
- variable and control groups

Activities:
- pretest
- outdoor writing sessions
  1. ecosystems
  2. biogeochemical cycles
- begin "An Onion Conundrum"

Week 2

Topics:
- biogeochemical cycles
- groundwater
- food chains and food webs
- energy transfer within an ecosystem
- data collection and organization

Activities:
- observe and manipulate groundwater models
- continue investigation "An Onion Conundrum"
- prepare presentation

Week 3

Topics:
- succession
- oligotrophic and eutrophic lakes
- human impact on environment

Activities:
- outdoor writing session
  1. primary succession
  2. secondary succession
- presentations on "An Onion Conundrum"
- posttest

To start the unit on ecology, all students were given a pretest (Appendix B). The pretest consisted of an objective portion related to ecological concepts and terms and a subjective portion related to designing an experiment to solve a specific problem. The last three test items gave students an opportunity to rank their perceived abilities in ecology, designing experiments and problem solving. The choices ranged from one (no knowledge or skills) to five (very knowledgeable or skilled). The students were not assigned actual grades for the pretest, but they were given participation points for making a sincere attempt at the test. I felt that all students made an effort to complete the test to the best of their abilities.

As a way of introducing the topic of ecology, the students were taken to a small, wooded area on the school grounds. The questions, "What is ecology?" and "What is an ecosystem?" were asked to all students. After listening to several responses and not yet being told the correct answer, students were sent out around the school grounds to find and describe in detail any ecosystem they chose. This meant that within their small groups, students had to come to a consensus of what an ecosystem actually was. I let them choose their own groups, but they were limited to a maximum of three people per group. The students had to write in their notebooks anything that might be considered a part of their ecosystem. The notebooks were used throughout the school year as a tool in which to write notes, document thoughts, ask questions and record laboratory data. After all groups finished, a classroom discussion was held. This time, when the same two questions were asked, the answers were much more detailed. As a class, then, the students were able to decide on appropriate explanations for the concepts related to ecology and ecosystems. Although students could have been told the information in a lecture or found the terms in a book, this seemed to be a more memorable and worthwhile experience!

The days that followed included much the same approach as that first day outside. Rather than first lecturing students on certain topics and then expecting them to discuss it, the tables were turned. First, students discussed the topics, drawing on any previous knowledge or information they might have had. The teacher's role in these discussions was only to direct the students to the answers themselves. Notes were still given; however, rather than being something I prepared ahead of time and wrote on the board to be copied, I wrote what the students directed me to write. The students became more involved with the topics being discussed.

Another example of this process was the introduction of the biogeochemical cycles, such as the water cycle, carbon cycle and oxygen cycle. Again students were taken outside, and they were asked to draw on previous knowledge to introduce themselves to these cycles. The students were told to think about how these chemicals were traveling in cycles through nature and to write their thoughts on paper. They could have written paragraphs or notes, drawn diagrams or pictures. How they put the information on paper was not as important as the actual process of thinking about these concepts, but they had to document their thoughts in some way. Students who gave in to the standard, "I don't know," were told to look around and think about where carbon could be found around them or how oxygen gets into the air we breath and so forth. These prompts were the only bits of assistance that I offered. Grades were assigned on a scale of one to ten for participation. Students who worked 100% of the time received ten points, those who worked only half of the time received five points and so on. After twenty to thirty minutes, the students re-entered the classroom for a follow-up session. Along with students directing the notes that were given, some students also put their drawings and diagrams on the board to share. Many of the student illustrations were more complete and more relevant than those included in the textbook!

The laboratory investigation seemed to be the most challenging part of the ecology unit. In the investigation, students worked in groups to determine the answers to a specified problem. I allowed students to choose their own groups, and, in all but one class, I limited the group size to four students. In one class, I did not limit the group size because I was curious to see how the students would arrange themselves within groups. This turned out to be a mistake. Some groups were so large (six people) that some members sat idle. In the problem

"An Onion Conundrum," (Appendix C1), the problem was to figure out why Mr. Vidalia's onions were not taking root. The students had to determine what questions to ask Mr. Vidalia and what other scientific data they might need. In doing this, students not only needed to draw on previous knowledge, but they also needed to practice wording questions carefully and communicating clearly. Groups whose questions were vague or indirect spent a great deal of time trying to get any valuable information, while groups whose questions were well planned and direct were usually able to start experimenting sooner. Two examples are given below:

Example #1

Indirect Question: "Could there have been pollutants or contaminants in the water supply?"

Direct Question: "What factories or other sources of possible pollution are located on or near your water supply?"

Example #2

Indirect Question: "Do you fertilize or use chemical pesticides, herbicides or fungicides?"

Direct Question: "What chemicals do you apply to your onions and in what amounts?"

The indirect questions merely required yes or no responses, while the direct questions solicited responses with more valuable information. Most students caught on to this very quickly and revised their questioning techniques as needed. After gathering enough information about Mr. Vidalia and his onion crops, each group decided what they believed might be the problem.

Once the groups isolated variables to test, hypotheses had to be written. This seemed to be quite easy for most groups, but some found it necessary to conduct some research first. For example, a group determined that the amount of water added to the onions was the variable to target. Before a hypothesis could be written, the group had to determine what amounts of water would be too little, ideal or too much.

After writing the hypothesis, an experiment was designed by each group. I had to approve each experimental design before it could actually be set up, but I did not always correct mistakes that were noticed. In most cases, I allowed students to discover their errors on their own, the exceptions being those that could cause danger or needless use of valuable materials. When reading the experimental designs, the following criteria were looked for:

- written as step by step procedure
- included a large enough sample population
- described the testing apparatus to be used

- stated the length of time the experiment would run
- contained a control group

Once the designs were checked, the experiments were conducted.

The days that followed included data collecting and a fair amount of design problem solving. Some of the experimental designs did not work as planned and required modification. Evaporation of liquid samples, for example, was a factor that many did not anticipate. In my opinion, some of the best learning experiences came from the unanticipated problems experienced along the way.

When it came time to draw conclusions about the experiments and solve the "Onion Conundrum," I found three categories of conclusions.

Definite Conclusion Supporting Hypothesis

These were the ideal results, the results everyone hoped to see. In this case, the data definitely supported the hypothesis.

Definite Conclusion Refuting Hypothesis

These results usually caused disappointment initially. In this case, the data clearly showed that the hypothesis was not correct.

Many students needed help understanding just how valuable these results were. Being able to eliminate a variable, they learned, was a giant step in solving the problem.

Indeterminate Results

These results were probably the most confusing. In this case, some data seemed to support the hypothesis, while other data seemed to refute it. Usually, this type of result was due to a flaw in the experimental design or it was a problem that could have been eliminated by a larger sample size.

Any of these results were valuable in the learning process. All of them required the students to rethink the problem and to project their thoughts toward the future. Some groups were able to think toward steps to help Mr. Vidalia correct the problem, while others had to determine what steps they would take next to try to identify the problem.

The final requirement for the investigation was a presentation of the students' findings. The presentation provided students the opportunity to communicate what they had learned. This is a vital part of problem solving in any discipline. With this investigation, each group had to discuss how they isolated their variable (not all groups chose the same variable), how they tested their hypothesis and how they interpreted their data. They also had to either explain what variable they might test next, if they had not yet solved the problem, or what recommendations they had for the farmer. I evaluated each group's oral presentation according to the rubric in Appendix C1.

Overall, the laboratory investigation involved students in many different inquiry and problem solving activities. They learned to ask questions, isolate variables, write hypotheses, design experiments, collect data, draw conclusions and communicate findings. We started each class with a discussion session in which students could vent frustrations, ask questions and voice concerns about their project. Other students would respond, offering answers, suggestions and advice. Again, my role was that of a facilitator while students were actively involved in their learning processes.

The investigation, "An Onion Conundrum," was the only investigation completed during this unit. Two other ecology-based investigations following a similar pattern were also developed (Appendix C2 and C3). These were to be used as part of the semester long class that I was preparing for originally. Because of time constraints, these activities were not used in my teaching of ecology this year, but they will be used in my biology classes in the future.

The final assessment used to evaluate the entire unit was the same test as that given as the pretest. I chose to use the same test so that other variables, which might have appeared while designing a new test, would be eliminated. The students were not told in advance that the same test would be used. This time the actual grade achieved by each student was recorded as part of his or her class grade.

EVALUATION

OBJECTIVE ASSESSMENT

All of the students in the sample population were administered the same pretest and posttest which contained an objective portion with forty multiple choice questions. The focus of these forty questions was ecological terms and concepts. Upon comparing the results of this part of the pretest to the results of the posttest, I found that the students showed substantial improvement in their scores (Figure 1). The average number correct on the pretest was 19.77 or 49.4% while the average number correct on the posttest was 32.23 or 80.5%. A t-test showed these results to be significant at $t_{.05}$ with 120 degrees of freedom, as the test statistic was t=1.63. The statistical analysis supports the idea that students increased their knowledge of ecology significantly.

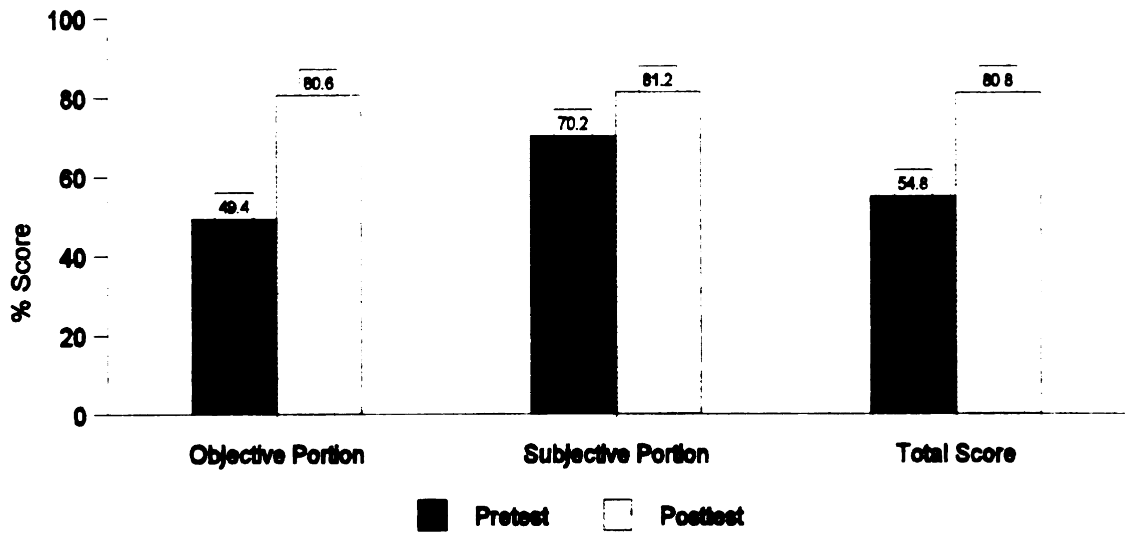


Figure 1-Mean Test Scores by Percentage

SUBJECTIVE ASSESSMENTS

The scores on the subjective portion of the pretest and posttest also showed improvement upon completion of the ecology unit (Figure 1); however, the improvement was less than that of the objective portion and was not found to be significant upon statistical analysis. The subjective portion of the test focused on identifying a problem, writing a hypothesis and designing a lab to test the hypothesis. The mean pretest score, out of 14 possible, was 9.83 correct or 70.2% compared to posttest results of 11.37 correct or 81.2%. When a t-test was completed, the test statistic was $t=0.403$ which shows that the increase in scores is not significant (at 120 degrees of freedom).

Questions 46-48 on the pretest and posttest also provided some subjective feedback from students. All of the results demonstrate that the students believed they improved in basic ecological knowledge, experimental design and problem solving. The average responses on the pretest and on the posttest are given for each item. All of the items use the following scale:

1=no knowledge or skills
2
3=average
4
5=very knowledgeable or skilled

46. Confidence in knowledge of ecology
pretest = 2.24
posttest = 3.5

47. Confidence in solving ecological problems
pretest = 2.9
posttest = 3.65

48. Confidence in ability to write hypotheses and design experiments
pretest = 2.99
posttest = 3.74

A final subjective measure of the success of the ecology unit was in the form of a student survey (Appendix D). Following the completion of the ecology unit, all students were given the to convey their thoughts on the unit. The students were directed to circle "1" if they definitely agreed with the statement closest to the 1, or circle "5" if they definitely agreed with the statement closest to the 5. All other numbers were to be used as middle ranges. The average response is given in parentheses next to each survey item. The written comments have been separated into pros and cons (Figure 2).

Rating of 1	Rating of 5	Average Response
simple	complex	2.9
easy to learn	difficult to learn	2.5
boring	interesting	3.7
impractical	practical	3.9
for scholars only	for everyone	4.0
worthless to society	valuable to society	4.1
worthless to me	valuable to me	3.7
did not affect my critical thinking skills	improved my critical thinking skills	3.7

Table 1-Average Responses on Student Survey

PROS	CONS
jogged memory of prior learning	needed more labs
easy to comprehend	don't use onions
fun unit	need more visual demonstrations
liked going outside	seemed like any other unit
got to move around more	hard to work outside
liked all of the lab time	too much writing
beneficial unit	monitor individuals better
interesting	didn't find it important
group projects were good	unit was boring
made me depend more on my own thinking and analyzing skills	needed more instruction and less independent work
better way of learning	difficult to learn
pretty cool chapter	should have taught unit earlier
should learn everything this way	experiments were boring
surprisingly interesting	didn't like having to use textbook
stimulated curiosity	some things weren't explained well
enjoyed being able to develop things for myself, not just follow directions	harder to learn than with lecture and notes
favorite unit of the year	hard to memorize terms
got us thinking on our own	biogeochemical cycles were hard
well organized, prepared and presented	note-taking was boring
everyone was a little more interested	unit was too short
it was fun being independent	didn't spend enough time on topics
interacting unit with everyday meaning	

Figure 2-Student Comments Regarding Ecology Unit

DISCUSSION AND CONCLUSION

The statistical analysis of collected data supports the idea that problem solving is an effective technique in teaching ecology; however, as educators know, the merits of any teaching program do not lie in test scores alone. Many practical implications must be considered as well. What follows is an analysis of both the positive and negative components of this unit. After considering all aspects, I concluded that using inquiry and problem solving to teach ecology was well worth the effort.

One of the most difficult aspects of implementing this unit was anticipating the unknown. It is easy to plan necessary lab materials and to prepare notes and information for topics that you know will be covered. It is much more difficult to try to anticipate questions that will be asked and to gather lab materials for procedures that have not yet been determined. A teacher who usually demonstrates a high level of organization and preparedness may need to show a greater degree of flexibility.

A very positive feature to planning for the unexpected was that I had to learn the content more deeply in order to be prepared for my students' questions. I also had to think through as many lab designs and strategies as possible in anticipation of the students' designs. Although this type of planning was very time consuming, a great deal of confidence and satisfaction came from knowing that I was so thoroughly prepared.

Another area of difficulty was maintaining the “controlled chaos” in the classroom, especially during the lab investigation. Rather than having all students working on the same procedure at relatively the same pace, various groups were carrying out different procedures at all times. It was difficult, therefore, to determine if all members of each group were on task as they should have been. I also quickly found that I needed to have alternate activities or assignments for students to work on while others worked with their laboratory procedures.

To help eliminate the problem of students not being on task, I will make a few minor adjustments when I next teach this unit. First, I would limit the group size to two or three people. Although this will require more supplies and materials, it helps assure that each student has work to do. I would also require that each student keep a journal of his or her daily contributions to hold each student accountable. The journal would be in addition to any comments recorded in the student’s lab notebook, as the lab notebooks are not collected and graded. Another adjustment I would make is to limit the amount of lab time allowed per class period. I allowed unlimited time in the laboratory, thinking that students would get more involved if they were not rushed. Unfortunately, time was wasted, so, in the future, I will limit laboratory time to 15-20 minutes per day. Any additional time needed would have to be scheduled by individual groups. This should encourage the students to work more efficiently. If these changes are made, the laboratory sessions will likely run more smoothly.

Another area that I need to improve is my teaching of actual problem-solving skills. As demonstrated by the subjective test results, the students did not show substantial improvement in this area. That may have occurred because I did not teach problem-solving techniques at a more complex level, but rather I taught just basic skills. I believe many of the students already had those basic skills and would have benefitted more from learning to build on them. The test scores showed students had knowledge of problem solving, but they did not substantially improve that knowledge.

Many unexpected benefits arose during the course of this unit. One of these benefits was the increased amount of student writing. Writing across the curriculum is a goal that many schools, including Mattawan High School, have in place. Without purposely trying to, I incorporated many more writing opportunities into this unit that I normally did. By documenting their own thoughts and ideas, creating questions, designing experiments, and preparing presentations, students ended up doing a large amount of writing. Although some students would disagree, I feel any writing opportunities are beneficial.

Another unexpected benefit was the depth of student involvement. Many students considered this to be the best unit of the class because they were active participants in the learning process. The level of confidence in their own abilities increased. They personalized the lab scenarios and worked almost competitively to determine who could figure out the ecology concepts first. Of course this did not apply to all students; some still felt that their learning needs were not being met. In most cases, these were the students who chose not to be active learners, but were more content to wait for someone to give them answers. As that did not happen much in this unit, some of those students became frustrated. To work though those frustrations, I spent some extra time working with those students, showing them how easy and satisfying it can be to think independently.

The most important benefit I received from using inquiry and problem solving while teaching ecology was how much more I enjoyed my classes. It was more fun to interact with my students in a spontaneous way than to simply be the person who supplies them with information. I learned more about the diverse backgrounds and personalities of my students in those few weeks than I had all year! Some of the monotony of teaching that usually becomes all too prevalent by May was replaced with curiosity and anticipation. My own enthusiasm likely contributed to the success of the unit.

Inquiry and problem solving are positive additions to a unit studying ecological concepts. It forces students to do some independent, critical thinking , and it asks students to draw on previous knowledge and look toward the future. The study of ecology would not be complete without some examination into the role of humans in our environment. After completing this unit, I am confident that my students have a better understanding of that role, and an increased ability to critique their own positive and negative environmental impacts.

APPENDIX A

STUDENT/PARENT CONSENT LETTER

Kari Hoikka
Biology Teacher
Mattawan High School
56720 Murray Street
Mattawan, MI 49071
668-3361 ext. 1107

May 1, 1998

Dear Parent/Guardian:

In the process of broadening my knowledge of the biological sciences, I have been participating in a Masters degree program with the Division of Science and Mathematics Education at Michigan State University. During the course of my studies, I have developed a teaching unity on ecology which I plan to use in the classroom this spring. I would like to include assessment data from my students in my final thesis. Your student will not be mentioned by name, nor identified in any way.

Although use of your student's data is voluntary and will not be reflected in your student's grade, it is important to the study. Your consent is important. Should you choose not to give your consent for your student's participation, no penalty will be assessed against the student. If you have questions or require further information, you may contact me at Mattawan High School and leave a message on my voice mail.

Sincerely,

Kari A. Hoikka
Biology Teacher

Student Name____
Student Signature____________________________Date________________

I, ____________________, have read and understand the situation involving assessment data being collected on my student at Mattawan High School. With full understanding that participation in the study is voluntary, and lack of participation would result in no penalties to my student, I:

___ give consent for my student to participate in the curriculum study in biology class at Mattawan High School.

___ do not give consent for my student to participate in the curriculum study in biology class at Mattawan High School.

Parent/Guardian Signature______________________________Date____________

APPENDIX B

ECOLOGY PRETEST AND POSTTEST

1. Which level of a food pyramid has the most biomass?
   A) top
   B) middle
   C) bottom
   D) all are equal
2. Which is a water pollutant commonly caused by decay of organic materials?
   A) ammonia nitrogen
   B) copper
   C) iron
   D) nitrate nitrogen
3. Which is a water pollutant commonly caused by synthetic fertilizers?
   A) ammonia nitrogen
   B) copper
   C) iron
   D) nitrate nitrogen
4. What occurs during the eutrophication of a lake?
   A) the lake gradually becomes cleaner
   B) the lake gradually contains more dissolved oxygen
   C) the lake gradually becomes deeper
   D) the lake gradually contains less dissolved oxygen
5. What is a watershed?
   A) area where there is only water, no plants
   B) depletion of groundwater
   C) area of land that drains into a particular body of water
   D) water which flows through a river
6. What is the primary role of decomposers in an ecosystem?
   A) fixing nitrogen
   B) photosynthesis
   C) producing water
   D) recycling of organic materials
7. In an ecosystem, what are autotrophs also known as?
   A) primary consumers
   B) producers
   C) secondary consumers
   D) decomposers

8. What is made up of a group of individuals of the same species living in the same area?

A) community
B) habitat
C) niche
D) population

9. What consists of the interactions between living and nonliving things in an area?

A) community
B) ecosystem
C) habitat
D) population

10. Which of the following is an abiotic factor?

A) amount of rainfall in a given area
B) amount of edible plants
C) number of primary consumers in a population
D) number of producers in a population

11. Which is NOT part of the oxygen cycle?

A) heterotrophs consume plants
B) heterotrophs exhale carbon dioxide
C) heterotrophs exhale water
D) heterotrophs inhale oxygen

12. During what process do trees and plants return water to the atmosphere?

A) condensation
B) precipitation
C) respiration
D) transpiration

13. Which of the following is a symbiotic relationship in which one organism benefits from, but does not harm or help, its host?

A) commensalism
B) intraspecific
C) mutualistic
D) parasitic

14. What is the process of adding undesirable amounts of heat/energy to a body of water?

A) biomagnification
B) eutrophication
C) succession
D) thermal pollution

15. Which of the following is an example of a herbivore?
A) deer
B) grass
C) wolf
D) vulture

16. What is the name of the process in which bacteria change nitrites and nitrates back into atmospheric nitrogen?
A) ammonification
B) denitrification
C) nitrification
D) nitrogen fixing

17. What would result if the primary consumer was missing from a food chain?
A) both producer and secondary consumer would die
B) producer would increase while secondary consumer decreased
C) neither the producer nor secondary consumer would be affected
D) producer would decrease while secondary consumer increased

18. What is the grouping of all organisms in a specific area?
A) community
B) ecosystem
C) habitat
D) population

19. What type of relationship exists between fungi and algae in a lichen?
A) intraspecific
B) commensalistic
C) mutualistic
D) parasitic

20. In the relationship between a wolf and a rabbit, what does the wolf represent?
A) autotroph
B) herbivore
C) predator
D) prey

21. What is ecology?
A) study of animals and their relationships with each other
B) study of living things and their relationships with their environment
C) study of plants and their relationships with each other
D) study of plant and animal interactions

22. What type of plants have nitrogen-fixing bacteria on their roots?
A) autotrophs
B) legumes
C) vegetables
D) weeds

23. Which is a way that consumers return carbon to the atmosphere?
  A) perspiration
  B) photosynthesis
  C) respiration
  D) transpiration
24. Which of the following is an example of succession?
  A) a farmer rotating his crops from year to year
  B) a pond slowly becoming a marshy field
  C) a developer planting new trees in a subdivision
  D) a river being dammed up into a lake
25. What is another name for a herbivore?
  A) primary consumer
  B) secondary consumer
  C) tertiary consumer
  D) predator
26. What type of organisms feed on both plants and animals?
  A) autotrophs
  B) carnivores
  C) omnivores
  D) herbivores
27. What is the exchange of energy and organic materials from one organism to another?
  A) biomagnification
  B) decomposition
  C) food chain
  D) succession
28. Of the air we breathe, approximately what percent is oxygen?
  A) .03%
  B) 20%
  C) 50%
  D) 75%
29. What is the most abundant gas in our atmoshere?
  A) carbon
  B) hydrogen
  C) nitrogen
  D) oxygen
30. Which is NOT a DIRECT part of the water cycle?
  A) evaporation
  B) photosynthesis
  C) precipitation
  D) transpiration

31. Which of the biogeochemical cycles is no longer efficient because of pollution?
A) carbon
B) nitrogen
C) oxygen
D) water

32. What is the niche of a honey bee?
A) a flower
B) a tree
C) class Insecta
D) producing honey

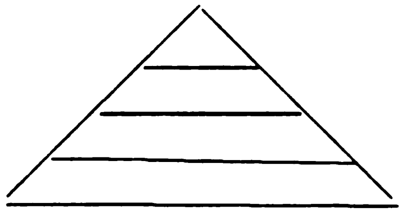
33. In a grassland, what do prairie-dogs, rabbits, and rattlesnakes have overlapping?
A) biomass
B) habitats
C) niches
D) populations

34. In what form is energy stored in an ecosystem?
A) chemical bonds
B) electrical fields
C) nitrogenous wastes
D) nuclear plants

35. Which body of water would most likely have the warmest temperatures, the most plant growth, and the least amount of dissolved oxygen?
A) fast-moving stream
B) one of the Great Lakes
C) eutrophic lake
D) oligotrophic lake

36. What is the mane for the zone of all living things on earth?
A) biosphere
B) community
C) ecosystem
D) population

37.-40. Refer to the food/energy pyramid below. Consider the top portion of the pyramid "a," followed by "b," "c," and "d" as the bottom section of the pyramid.



37. Which organisms are at trophic level "d"?
    A) carnivores
    B) consumers
    C) herbivores
    D) producers
38. Which organisms are at trophic level "c"?
    A) autotrophs
    B) primary consumers
    C) producers
    D) secondary consumers
39. If trophic level "c" contains approximately 100 kilograms of minnows, then what would trophic level "b" probably contain?
    A) 10 kg of algae
    B) 100 kg of algae
    C) 10 kg of bass
    D) 100 kg of bass
40. Which trophic level represents the secondary consumers?
    A) level "a"
    B) level "b"
    C) level "c"
    D) level "d"

Use the scenario described below to answer the questions.

Mrs. Roth has planted a small flower garden in her back yard with hopes of attracting butterflies. She has many different species of plants, all white or yellow flowers, but she has seen very few butterflies. Mrs. Roth suspects that butterflies are not attracted to the color of her flowers, and she is considering planting flowers with more vibrant colors (orange, red, pink). Because flowering plants are so expensive, Mrs. Roth is seeking advice from you first. You need to determine if this is a wise investment.

41. Briefly state the problem from the scenario.

42. Using proper format, write a hypothesis to the problem.

43. Design an experiment that will test your hypothesis. Write a step-by-step procedure.

44. What is the variable being studied?

45. What is your control group?

46. Use the scale below to rank your confidence in your knowledge of ecology. (In other words, how well do you think you understand ecology?)

1	2	3	4	5
no knowledge		average		very knowledgeable

47. Use the scale to rank your perception of your ability to solve ecological problems. (In other words, how skilled are you at identifying a problem and outlining steps to solve the problem?)

1	2	3	4	5
no skills		average		very skilled

48. Use the scale below to rank your perception of your ability to write a hypothesis and design experiments to test your hypotheses.

1	2	3	4	5
no skills		average		very skilled

APPENDIX C

STUDENT ACTIVITIES

APPENDIX C1-INVESTIGATION: AN ONION CONUNDRUM

PROBLEM
You and your lab partner have recently been hired by an environmental consulting firm, Hoikka's Environment Solutions (HES), as researchers for their agricultural division. Your first assignment is to assist an onion farmer, Mr. Vidalia, who claims that his onions have failed to take root.

OBSERVATION
Upon accepting this assignment, your first steps in solving his problem should be to interview the farmer and observe his onion crops.

Write at least five questions that you would ask Mr. Vidalia. Attach additional pieces of paper if needed.

1.
2.
3.
4.
5.

Write at least five things that you would look for in observing his crops or preliminary tests that you would run. Attach additional pieces of paper if needed.

1.

2.

3.

4.

5.

Once you have completed your initial questioning and observing, give your list of requested information to the supervisor of the HES lab. You will get a set of sample data and answers returned to you. This will give you all of the necessary information to begin your own investigation. If you have any remaining questions for the lab, write them in the space below and return your request to the lab.

HYPOTHESIS

Read the data and discuss all of the variables that might be affecting the onion crop. Choose one variable to investigate and write a hypothesis.

Hypothesis:

ANALYSIS

After gathering the data from your experiment, you are ready to draw some conclusions based on your experiment.

Was your hypothesis correct? How do you know?

If your hypothesis was not correct, what variable would you test next?

Were there any problems with your procedure that may have caused the results to be inaccurate?

PRESENTATION
It is now time to present the findings of your investigation to Mr. Vidalia. You should do this in the form of a formal report. Begin by explaining on what basis you formed your hypothesis and state your hypothesis. State the materials used and the experimental procedure you followed. Include a copy of your data table and your other form of visual representation of the data. Conclude with your final analysis of the situation and any recommendations you might have. Remember, this is your first big chance to impress your new employer–keep it neat and professional! Your boss is watching...

REFERENCE
Arms, Karen. Environmental Science. Holt, Rinehart & Winston. 1996.

HES INTERVIEW RESULTS

TO:

RE:

<u>QUESTION 1</u>

<u>QUESTION 2</u>

<u>QUESTION 3</u>

<u>QUESTION 4</u>

<u>QUESTION 5</u>

<u>QUESTION 6</u>

HES LAB RESULTS

TO:

RE:

NAME OF TEST	**RESULT**

INVESTIGATION: AN ONION CONUNDRUM–GRADING RUBRIC

OBSERVATION QUESTIONS • required number • relevant • additional questions if needed	0	1	2	3
HYPOTHESIS • relevant • proper form	0	1	2	3
EXPERIMENT • tests one variable • uses proper control • easy to follow • includes detail	0	1	2	3
DATA • neat table • units • includes all information	0	1	2	3
ADDITIONAL GRAPHIC • neat • visual • units	0	1	2	3
ANALYSIS • accurate • easy to understand • refers to hypothesis • includes next step or suggestions • states possible errors	0	1	2	3
PROFESSIONALISM • neat • spelling/grammar • proper format	0	1	2	3

INVESTIGATION: AN ONION CONUNDRUM–TEACHER'S NOTES

OBJECTIVES

Upon completing this activity, students should be able to do the following:

- organize observations
- form a hypothesis based on observations
- design an experiment to test a hypothesis
- organize data
- analyze data and draw relevant conclusions
- prepare a formal report illustrating their conclusions

PREREQUISITE SKILLS

In order to complete the activity, students must be able to do the following:

- know the components of a hypothesis
- be comfortable working with glassware and common lab equipment
- collect data
- draw conclusions

SUPPLYING INFORMATION TO THE STUDENTS

Once the students write their **"OBSERVATION"** questions and state the preliminary tests they would like to do, have the students submit those to you. Return to the students a fact sheet containing only the answers to those questions that have been asked. Also report to the students data from the field only for those preliminary tests they chose to have done.

Sample Questions	Sample Responses
Is the field irrigated?	Irrigated routinely when needed
What is the water source?	Pond near back of property
What type of fertilizer is used?	None
Are there any nearby industries?	No

After you report this information to the students, they may submit more questions to you, or they may proceed directly to forming a hypothesis.

EXPERIMENTAL PROCEDURES

Depending on the hypothesis, students may require a variety of materials to conduct their experiments. Some helpful suggestions:

low concentrations of bleach seem to have little effect on the growth of onion roots
high concentrations of bleach hinder the development of roots
commercial fertilizers in liquid form work very well and come in a variety of concentrations
"slicing" the end off the onion seems to result in formation of a taproot
"scraping" usually results in the formation of fibrous roots
allow the experiment to run 5-7 days

POSSIBLE EXTENSIONS

Try changing the focus to finding the best way to assist onions in taking root.

Continue the investigation by planting the onions after they have developed roots and determine any differences in shoot growth.

APPENDIX C2-INVESTIGATION: SOMETHING'S FISHY HERE

PROBLEM

Now that you have proven yourselves to be competent researchers, your supervisor at Hoikka's Environmental Solutions (HES) has decided you can handle a more challenging problem. A woman named A. M. Fibian called HES concerned about the condition of a pond that is located on her property. It is a natural pond located on the edge of a forest near her home. Ms. Fibian has kept the pond well stocked with a variety of fish, but in the past three weeks, many of the fish have been dying. The majority of the dead fish seems to be of the same species, but Ms. Fibian did not know the name of that species. You and your lab partner must assess the condition of Ms. Fibian's pond and determine the probable cause of the fish kill. Due to the nature of this investigation, your supervisor would like the two of you to specialize, one of you should act as the biologist and one of you should act as the chemist. Please decide your roles before you continue.

Biologist ______________________________

Chemist ______________________________

OBSERVATIONS

You will need to interview Ms. Fibian and make some observations at the site of the fish kill, but you must stay in close contact with each other and work together.

What questions might you ask Ms. Fibian regarding the biological aspects of the pond? List at least five.

1.

2.

3.

4.

5.

What questions might you ask Ms. Fibian regarding the chemical aspects of the pond? List at least five.

1.

2.

3.

4.

5.

EXPERIMENTATION/RESEARCH

What tests should the two of you perform in order to assess the quality of the pond and the probable cause of the fish kill? List as many as you thing you will need.

1.

2.

3.

4.

5.

Biologist:

Once you have gotten the answers to your interview questions, you must begin doing some research on the organisms in the pond. You may use any resources necessary (books, magazines, journals, computer, etc.), but you must carefully document any and all resources used. If further questions arise, you are encouraged to contact Ms. Fibian again.

Resources

1.

2.

3.

4.

Further Questions

1.

2.

3.

Chemist:

Obtain the water sample that you temporarily stored in the lab. Conduct all tests that you determined would be necessary. If you need any additional supplies, please see your supervisor. Do not forget to keep very accurate records of your tests in your data table.

DATA

Construct a data table below to show the results of all tests that were conducted.

ANALYSIS

Once all tests have been completed and the research is done, you and your partner must work as a team to determine the probable cause of the fish kill. Answering the following questions may help you draw your conclusions.

What possible problem areas, if any, were detected by the chemist?

What possible problem areas, if any, were detected by the biologist?

Are there any connections between these two?

Explain your conclusion as to the best cause of the fish kill.

Are there any other possibilities?

PRESENTATION

You and your partner must now present your findings to Ms. Fibian. You must include your initial observations, the test conducted and their results and an explanation of the research you conducted. Explain your final conclusion and the evidence that supports this conclusion. You should also list any other possibilities that may have contributed to the fish kill. Don't forget to include a complete bibliography in case Ms. Fibian wants to do some of her own research. This is a formal presentation, and it should look neat and professional. Your next raise may depend on this report!

INVESTIGATION: SOMETHING'S FISHY HERE–TEACHER'S NOTES

OBJECTIVES

Upon completing this activity, students should be able to do the following:

formulate questions based on observations
gather information to solve problems
organize data
integrate collected experimental data and literary information
analyze data and draw relevant conclusions
prepare a formal report illustrating their conclusions

PREREQUISITE SKILLS

In order to complete the activity, students must be able to do the following:

conduct a literature search
complete the specific water chemistry tests needed to obtain desired results
(Ex: DO, pH, nitrates, phosphates)
collect data
draw conclusions

SUPPLYING INFORMATION TO THE STUDENTS

Once the students write both their biological and chemical "OBSERVATION" questions, they should submit those to you. Return to the students a fact sheet containing only the answers to the specific questions asked. Do not supply any additional information unless formally asked by the students.

Check over the list of test the students feel should be completed. If you feel any of the tests should not or could not be done by the students, you may want to send them a memo similar to the one below:

NOTICE
To: Researcher ________________________
From: Lab Supervisor

The HES laboratory has insufficient facilities to conduct the test you requested.
Please suggest an alternative.

You must supply each group with a water sample. The water samples may be adjusted so that each group has different variables, or they may all be the same.

Suggested chemical variations:
- alter the pH of the water
- alter the amount of dissolved oxygen (increase by aeration, decrease by boiling)
- add various fertilizers to alter the levels of nitrogen and phosphorus
- make the water somewhat salty

Suggested biological variations:
- have the dead fish be brook trout (require more oxygen)
- show that grass carp are living in the pond in large numbers
  (illegal in Michigan due to destruction of habitat for native fish)

EXPERIMENTAL PROCEDURES

Depending on the extent of knowledge in the area of water quality, this will vary greatly. Water test kits are ideal for the chemical analysis. The amount of background the students have should dictate how you prepare their water samples.

POSSIBLE EXTENSIONS

Combine the pond study with an investigation of the forest nearby.
Have the students act as newspaper reporters doing a story on the fish kill in Ms. Fibian's pond. Have each student submit one article.

INVESTIGATION: SOMETHING'S FISHY HERE–GRADING RUBRIC

OBSERVATION QUESTIONS–BIOLOGIST • required number • relevant • additional questions if necessary	0	1	2	3
OBSERVATION QUESTIONS–CHEMIST • required number • relevant	0	1	2	3
EXPERIMENTATION • relevant • completed accurately	0	1	2	3
RESEARCH • complete • documented correctly • appropriate sources	0	1	2	3
DATA • neat table • units • includes all information	0	1	2	3
ANALYSIS • thorough • supported by fact • includes other possibilities	0	1	2	3
PROFESSIONALISM • neat • spelling/grammar • proper format	0	1	2	3

APPENDIX C3-INVESTIGATION: FINICKY FOWL

PROBLEM

In many ponds in the northeastern United States, two species of duckweed can be found growing together. The two species, *Spirodela polyrhiza* (Greater Duckweed) and *Lemna minor* (Lesser Duckweed) are so similar that they coexist in many pond habitats, and they compete for available resources. In nature, this is not usually a problem, but for Mr. Bill Fowl, it is an enormous problem. Mr. Fowl raises a special breed of ducks, and his ducks love to eat *L. minor*. For whatever reason, his ducks are not at all interested in *S. polyrhiza*. Mr. Fowl would like to find a way to reduce the amount of *S. polyrhiza* in his duck ponds so that more *L. minor* will be able to grow. At this point, we don't even know if this is possible. Obviously, adding herbicides of any type would destroy all of the duckweed, so Mr. Fowl brought his problem here to Hoikka's Environmental Solutions (HES). In order to better serve our client, I think it would be best if you and your partner worked as a team with two other lab partners.

OBSERVATIONS

Before you can begin to help Mr. Fowl, you may need to do some research on duckweed. You and your partner must answer the questions below.

What are some general characteristics of duckweed?

How can you distinguish between the two types?

What are the basic resources required by these plants?

HYPOTHESIS

Once you have completed your background study, you and your partner should form one hypothesis to test one of the resources shared by duckweed. Check in with the other two members of your team. Make sure that they are testing a different variable than you. Write your hypothesis below.

Hypothesis:

EXPERIMENT

Now that you have written your hypothesis. you must design an experiment to test you hypothesis. Remember, your experiment should focus only on the one variable mentioned in your hypothesis.

Materials:

Procedure:

DATA

Construct a data table below to record your information.

ANALYSIS

After gathering the data from your experiment, you are ready to draw some conclusions based on your tests.

Was your hypothesis correct? How do you know?

If your hypothesis was not correct, what variable would test next?

Were there any problems with your procedure that may have caused the results to be inaccurate?

What recommendations do you have for Mr. Fowl regarding his duckweed problem?

PRESENTATION

It is now time to present the findings of your investigation to Mr. Fowl. You should do this in the form of a formal report that is completed by your entire team. Begin by explaining on what basis both hypotheses were formed and state them both. List the materials used and the experimental procedure followed in both cases. Include reports of all of the data. Conclude with your final analysis of the situation and any recommendations the team might have. Four of you are putting this report together, so I'm expecting to be dazzled!

REFERENCE

Beiswenger, J.M.. Experiments to Teach Ecology. Ecological Society of America. 1993.

INVESTIGATION: FINICKY FOWL–TEACHER'S NOTES

OBJECTIVES

Upon completing this activity, students should be able to do the following:

- understand resource competition
- organize observations
- from a hypothesis based on observations
- design an experiment to test a hypothesis
- organize data
- analyze data and draw relevant conclusions
- prepare a formal report illustrating their conclusions

PREREQUISITE SKILLS

In order to complete the activity, the students must be able to do the following:

- know the components of a hypothesis
- have general knowledge of plant growth and required resources
- collect data
- draw conclusions

ABOUT DUCKWEED...

Duckweed, a free-floating plant, may be easily collected from the surface of ponds or areas of slow-moving or stagnate water. *Lemna minor* has small (2-5mm), round or oval leaves (commonly called thalli) that usually occur in clusters of 2-4. It has one root which tends to grow quite long. *Spirodela polyrhiza* has round leaves that are usually slightly larger (3-8mm) and are purple underneath. It usually has numerous roots that are quite short. Both species require the same basic resources: water, light nutrients and space.

EXPERIMENTAL PROCEDURES

The experiments could vary greatly depending on the amount of information and guidance you give the students.

Some helpful suggestions:

- use commercial liquid fertilizer
- alter photoperiods using grow lamps and dark closets
- change size of containers to determine effects of population density

INVESTIGATION: FINICKY FOWL–GRADING RUBRIC

OBSERVATIONS • characteristics • comparisons • required resources	0	1	2	3
HYPOTHESIS #1 • relevant • proper form	0	1	2	3
HYPOTHESIS #2	0	1	2	3
EXPERIMENT #1 • tests one variable • uses proper control • easy to follow • includes detail	0	1	2	3
EXPERIMENT #2	0	1	2	3
DATA • neat table • units • includes all information	0	1	2	3
ANALYSIS • accurate • easy to understand • refers to hypothesis • includes recommendation • states possible errors	0	1	2	3
PROFESSIONALISM • neat • spelling/grammar • proper format	0	1	2	3

APPENDIX D

STUDENT SURVEY

Directions: Read each pair of opposite statements referring to your opinions about the ecology unit just completed. Circle "1" if you definitely agree with the statement closest to the 1 or circle "5" if you definitely agree with the statement closest to the 5. All other numbers should be used as middle ranges.

Simple	1	2	3	4	5	Complex
Easy to learn	1	2	3	4	5	Difficult to learn
Boring	1	2	3	4	5	Interesting
Impractical	1	2	3	4	5	Practical
For scholars only	1	2	3	4	5	For everyone
Worthless to society	1	2	3	4	5	Valuable to society
Worthless to me	1	2	3	4	5	Valuable to me
Did not affect my critical thinking skills	1	2	3	4	5	Improved my critical thinking skills

Comments:____

____

____

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