Appendix 1: Identifying Common Science Misconceptions in 5th Grade Science Classes at Lewis and Clark Elementary School

A1.1 The ECOS Program

This appendix topic is presented in fulfillment of the funding requirements for the ECOS fellowship for the 2005-2006 school year. The ECOS program at the University of Montana is funded by the National Science Foundation. ECOS promotes hands-on science education in schoolyards and adjacent open areas in western Montana, and brings graduate researchers into K-12 county schools in Missoula, Montana. The purposes of this fellowship are two-fold. First, the fellowship gives graduate students the opportunity to develop teaching skills and curriculum writing expertise. Opportunities for true teaching and curriculum development are a rare occurrence in the science fields in graduate institutions, making this fellowship a golden opportunity for students who may want to pursue post-graduate teaching careers. The second purpose of the ECOS fellowship is to bring research from the University of Montana to the local school system. It is a hope that this program will inspire school age children to pursue degrees in science, and will also expose teachers to new ideas and techniques for classroom teaching. In this sense, both graduate students and K-12 teachers learn from each other. Graduate students may learn tried and true teaching techniques, and the teachers can learn ways to integrate cutting-edge research into their existing curriculum.

One of the requirements of the ECOS fellowship is to write a paper focusing on some aspect of these new skills learned as a "resident ecologist" in K-12 classrooms. As per the fellowship guidelines, this paper will be added to the thesis of the fellow. To fulfill this requirement, I chose to focus on science misconceptions in the three 5th grade classes at Lewis and Clark Elementary School, because as a potential educator it is important to understand the learning process and try to identify areas where students may be struggling to understand specific concepts or ideas. Once misconceptions are identified they can be addressed and hopefully changed to fit true scientific concepts. If misconceptions are not identified and addressed, they can easily persist until college or even well into adulthood when there would be little chance of ever changing the misconception into something more valid.

A1.2 Identifying Science Misconceptions

A misconception is defined as a mistaken thought, idea or notion; a misunderstanding.[1] This idea of misconceptions is also known as an alternative concept or a naïve concept.[2] Students form misconceptions based on their experiences and what they see and hear. Misconceptions can come from a variety of factors and unfortunately, these interpretations have been shown to impede learning of fundamental scientific concepts. Students develop misconceptions as mechanisms for understanding phenomena in the world around them, and the sources for acquiring this information are often not science-based. In addition to this, misconceptions can even arise from incorrect teaching in school, especially when the concepts are never challenged again and persist into adulthood. A students' prior knowledge can be used as a building block for acquiring new knowledge, when this information is correct. When the information is incorrect however, prior knowledge interferes with a student's ability to process new science concepts.[2]

In order to correct science misconceptions, these concepts need to first be identified so that the students can replace them with new information. Several studies have shown that it can be difficult to convince a student to give up a long held misconception[3] unless the new concepts "are more valid, more powerful, more useful, or in some other way preferable to their existing concepts."[4] One way to identify and correct misconceptions is to assess the students' prior knowledge, keeping in mind that giving the student the "correct" information will not necessarily cause them to abandon their misconceptions and adopt this new information.

The most predominant and accepted model for instruction in the U.S. school system is lecture based, which is founded on the assumption that knowledge can be transferred intact from the mind of the teacher to the mind of the learner. This lecture method of teaching is another way that misconceptions can form. As educators, teachers must be aware that teaching and learning are not synonymous; we can "teach" without having the students "learn". This realization is based on the Constructivist Learning Theory [5] which states that knowledge is constructed in the mind of the learner and misconceptions play a role in this process of acquiring knowledge. Many misconceptions encountered in science are no more than a reflection of poorly differentiated concepts that have developed naturally. Students often hold the correct concept but have not applied it properly to problems in the classroom and the real world. This is where identification and hands on application can be used to change the misconception into a valid and working concept.

A1.3 ECOS Experiences from a 5th Grade Classroom

The ECOS program is designed to bring a hands-on approach to understanding science. One of the goals of the ECOS program was to develop curricula pertaining to ecological science topics in a very hands-on, inquiry-based format. These curricula were developed to provide background information to the students on a particular topic; students then determined the “answers” to questions presented in the activity. In this sense, students were allowed to make initial hypotheses or guesses and then work their way through the activity to come to some sort of a conclusion. Generally, there was a concluding session to help students solidify their observations into answers. The goal of the ECOS program was never to identify and alleviate science misconceptions, but working with these students during the year did provide the opportunity to identify some misconceptions that were prevalent in the 5th grade science classrooms.

To identify some misconceptions that exist amongst the 5th graders at Lewis and Clark Elementary, students were given a worksheet (Figure A.1) with several questions on topics that have been identified previously as areas where misconceptions are known to exist.[6,7] The questions were set up as either true/false or multiple choice. The students were told that they would not be graded on the worksheet in hopes that this would alleviate any stress they might feel about getting the “correct” answer. This worksheet was given to not only the two ECOS classes that we had worked with all year, but it was also given to a non-ECOS class of 5th graders with whom we had not interacted with at all during the year.

Science Trivia Questions

Check yes or no, or circle the correct answer

1. If you drop a 1 pound weight and a 10 pound at the same time from the same height, the 10 pound weight will hit the ground first.

□ Yes □ No

2. It is warmer during the summer in North America because the Earth is closer to the Sun.

□ Yes □ No

3. The moon increases and decreases in size throughout the month.

□ Yes □ No

4. Plants get food from:

a.) fertilizer
b.) the ground water
c.) making their own food internally
d.) absorbing it from the soil via the roots

5. Plants, fungi, eggs and seeds are not living.

□ Yes □ No

6. What are the bubbles in boiling water composed of?

a.) air
b.) water vapor
c.) oxygen
d.) nothing

7. We can see objects because:

a.) light reflects off the object and our eyes focus the reflecting light.
b.) they are bathed in light.
c.) light travels from our eyes to the object.
d.) light travels faster at night.

8. Whales, jellyfish, and starfish are all fish.

□ Yes □ No

9. A species high on the food web is a predator to everything below it.

□ Yes □ No

10. Air and oxygen are the same gas.

□ Yes □ No

Figure A.1: Worksheet given to 5th grade students at Lewis and Clark to determine common misconceptions.

The goal of this worksheet was two-fold. First, the worksheet was given out to hopefully determine any misconceptions that are commonly held among the 5th grade classrooms at Lewis and Clark Elementary School. Identifying misconceptions is the first step in changing a misconception into a valid concept. The hope would be to give this information to the teachers so they could potentially work to identify and alleviate some of these misconceptions in upcoming 5th grade science classes. The second goal was a very qualitative goal. We had intentionally added misconception questions based on topics that we had specifically worked on with the two ECOS classes (questions 4, 6,and 7; Fig. A.1) while others concerned areas that we had not discussed. Again, when these topics were presented early in the year, the goal was not to change an existing misconception, and misconceptions had not previously been identified in these classrooms. Although the science trivia quiz is structured such that a positive response indicates that the student had the misconception and a negative response indicates the correct answer, we felt that the high prevalence of misconceptions would negate any effect of consistency in the answers.

A1.4 Results of the Misconception Worksheet

The first question on our misconception worksheet concerned gravity, and the false idea that a heavier object will fall faster than a lighter object of the same size. This misconception was just as common among both study groups (approximately 35% of all students). Little difference existed among ECOS and non-ECOS student responses to the misconception regarding the idea that the seasons occur because of earth's changing distance from the sun, rather than its tilt. This idea again was relatively common, as 27% of the students identified this as a true statement. The third misconception, that the moon changes size over the course of the month, also did not produce a different proportion of student responses between the two study groups. Nearly 50% of both ECOS and non-ECOS students believed this to be true. However, upon further examination, we realized that the wording of the question is poor and most likely caused confusion amongst the students, as they may have thought that we were referring to the appearance of the moon rather than its actual shape.

The fourth common misconception, a multiple choice question about plant food sources, did show different responses between our study groups. The non-ECOS students responded equally to the three incorrect statements, which identified fertilizer, ground water, and soil as the primary food source of a plant. However, only one non-ECOS student correctly identified the true source (internal), while the vast majority of ECOS students selected the correct answer (Figure A.2). The next misconception included on our worksheet was the idea that plants, eggs, and seeds are non-living. Very few of the students surveyed in either group believed this to be true. ECOS students again had a greater proportion of correct responses to the next multiple choice question, which asked for the composition of the bubbles in boiling water. Most of the non-ECOS students incorrectly believed that the bubbles are made of air, while the majority of ECOS students knew that they are made of water vapor (Figure A.3).

Both study groups performed equally well on the question testing for the misconception that we see objects because they are bathed in light or because light travels from our eyes to the object. A substantial proportion of students, approximately 30% of both groups, did not understand that light reflects off an object and our eyes focus the reflecting light. In addition, 19% of ECOS and non-ECOS students believed that whales, jellyfish, and starfish are all fish. Again, there was little to no difference in responses between the two groups. One question for which the non-ECOS students had a greater proportion of correct answers than ECOS students regarded the idea that a species high on the food web is a predator to everything below it. 45% of non-ECOS students correctly identified this idea as false, while only 33% of the ECOS students answered false. Lastly, the students were asked whether air and oxygen were the same gas. As with several of the other questions, ECOS students and non-ECOS students responded similarly: approximately 50% of the students in both groups believed this to be true.

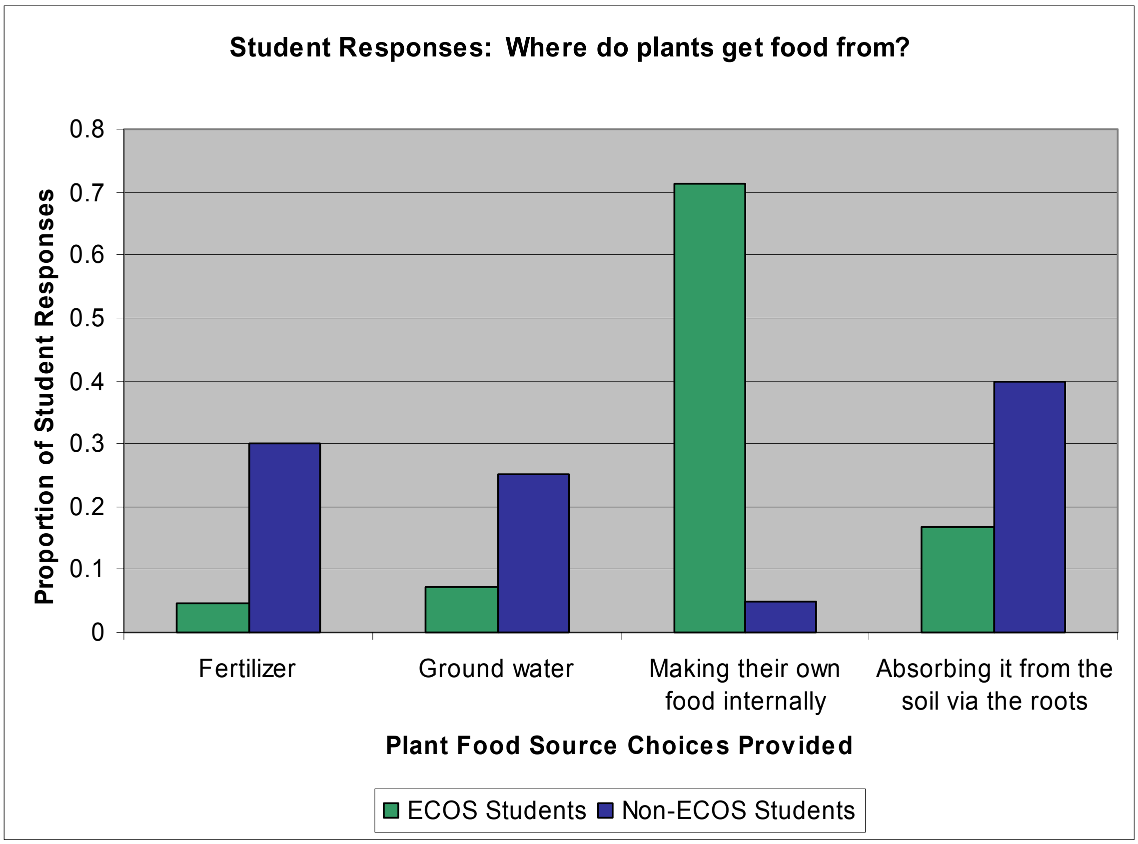

Figure A1.2: Graphical representation of the responses to multiple choice question number 4 of the misconception worksheet. This question asked students to identify where plants produce their food from and the available answers are shown below each bar set. Responses were normalized and ECOS student responses are shown in green and non-ECOS student responses are shown in blue.

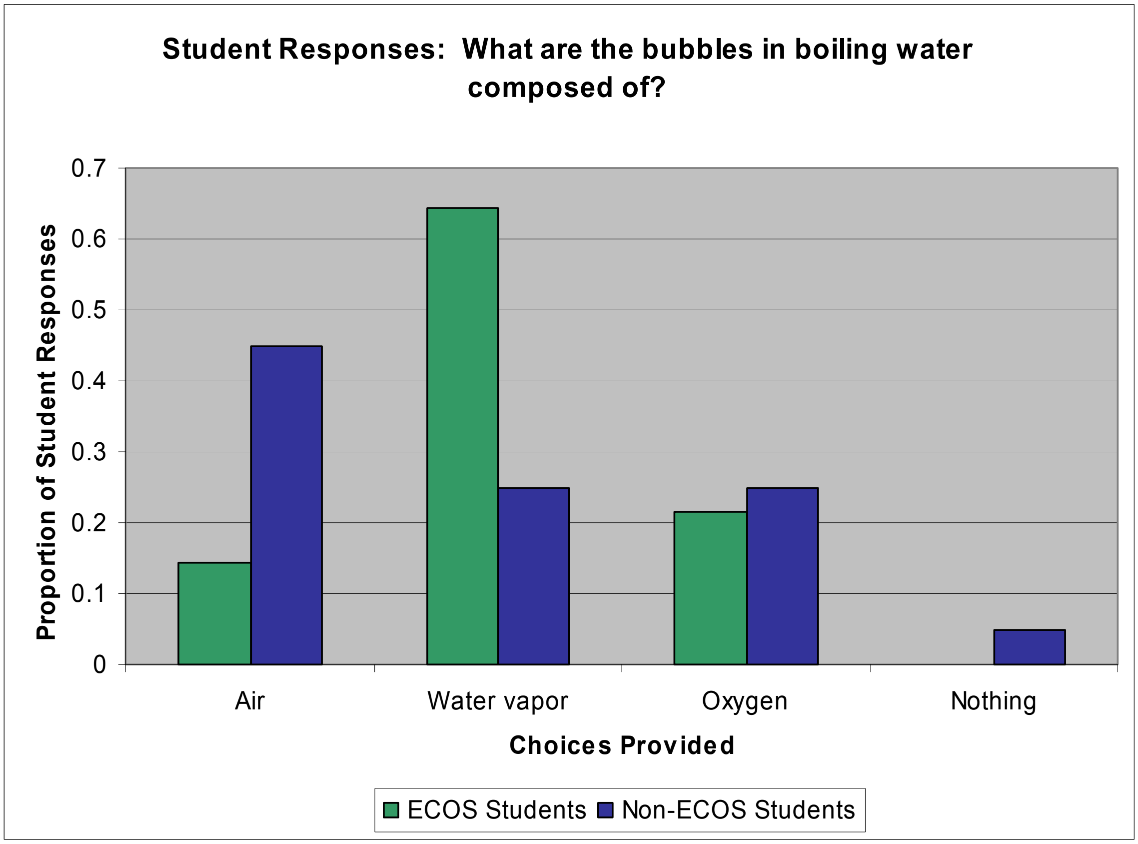

Figure A1.3: Graphical representation of the responses to multiple choice question number 6 of the misconception worksheet. This question asked students to identify what the bubbles in boiling water are composed of and the available answers are shown below each bar set. Responses were normalized and ECOS student responses are shown in green and non-ECOS student responses are shown in blue.

A1.5 Discussion

The results from our misconception worksheet indicate that the majority of students at Lewis and Clark Elementary School hold a variety of scientific misconceptions. These misconceptions could exist for a variety of reasons. For instance, some of the topics on the worksheet may be areas of study that they have never been exposed to, or may be topics they have learned about from non-traditional teaching sources (e.g. museum, TV program, parent or friend, etc.). The worksheet did not identify how the students came to the answer that they indicated. However, while this misconception worksheet does not identify reasons behind the misconception, it does prove that misconceptions exist among the 5th graders tested. This worksheet also indicates areas of study that could be further evaluated to help change the misconceptions that these students hold.

The misconceptions identified are similar in all three classes signifying that all the students are roughly at the same educational level and have been exposed to similar topics. However, from our worksheet, we are able to see that in two of the three areas for which we specifically developed lessons, there are significant differences between ECOS and non-ECOS classes. During the school year, we introduced a variety of curriculum pieces oriented towards understanding plants. The awareness that plants need a variety of factors from the environment to live but actually make their food internally was identified to a much higher extent by ECOS students than by the non-ECOS students (Figure A.2). In addition, curriculum pieces were also designed to specifically illustrate the phases of matter, and water was used as a specific example several times. When asked what the bubbles are composed of in boiling water, the majority of ECOS students answered correctly. This was not the case in the responses from the non-ECOS students (Figure A.3).

In contrast to the first two questions, the third curriculum piece that was developed did not yield similar results. This curriculum piece pertained to light. The students in the ECOS classes were able to work through an experiment on light and were given some information on how our eyes perceive light and color, yet these students did not answer the light question correctly (question #7) any more so than the non-ECOS students. This could be interpreted as an instance in which introducing students to a particular concept caused more misconceptions than actually creating knowledge and valid concepts in the minds of students. This is something that both the ECOS fellows and teachers should be aware. Students can regularly be assessed to determine whether knowledge is being organized into valid concepts or misconceptions, and if confusion still exists with a particular topic more time can be spent to alleviate this confusion.

If students are taught a concept correctly, why are misconceptions so resistant to change through instruction? One explanation is that each of us constructs knowledge that "fits" our experiences. Once we have constructed this knowledge, simply being told that we are wrong is not enough to make us change our (mis)concepts.[8] The only way to get rid of an old theory is to construct a new theory that does a better job of explaining the experimental evidence or finds a more appropriate set of experimental facts to explain.[8] We as educators must design lessons that clarify and direct students into different and more valid thought patterns.

Following some of the ideas put forth in the constructivist model of knowledge there are important implications for the way students are taught. Social knowledge such as the days of the week can be taught by direct instruction. It can even be argued that this is the only way that children can learn social conventions.[9] However, physical and logical knowledge cannot be transferred from the mind of the teacher to the mind of the learner. Following this idea would cause a shift in the classroom from someone who "teaches" to someone who tries to facilitate learning; a shift from teaching by imposition to teaching by negotiation.[10]

The goal of the ECOS program has been to loosely follow this way of teaching by negotiation. The curriculum that was developed for Lewis and Clark Elementary was designed to allow students to discover ideas and concepts and come to original conclusions. We worked to develop these concepts with the students so that their conclusions would be based upon valid observations. However, we did not specifically work to change any preconceived notions or misconceptions. Our goal was to design the lessons in such a way that the correct or valid conclusion would be the most obvious and make the most real world sense. Again, we have no true assessments that might indicate that our goals were reached other than conversations with our students at the end of each lesson and discussions on conclusions presented to us from the class.

A1.6 Future Directions

While the idea of identifying science misconceptions is incredibly important, it is equally important to test for those misconceptions in the proper way. In order to correctly determine the naïve concepts held by the students, they should be first pre-tested with a very sound worksheet or test. Our worksheet falls short of this goal, but with some revision would work well. For instance, question number 3 is very poorly written and most likely caused a great amount of confusion amongst the students. In addition to this, the worksheet should have been thoroughly reviewed by the 5th grade teachers at Lewis and Clark. With their advice, only questions with which students have had significant experience would have been included on the misconceptions worksheet.

Once a number of misconceptions have been identified, new lessons will need to be developed to convince the students that there is a more valid way of understanding and using a particular concept. This is where the next group of ECOS fellows could make a significant impact. Once the misconceptions are identified, the fellows could work to change the misconceptions into more valid concepts through different hands-on experimental activities. Providing a hands-on activity allows the student to experiment with different "real-world" variables that would hopefully allow the student to re-evaluate his or her current (mis)concept. In addition to providing hands-on lessons, fellows should have the students describe their thought process and how they have determined a new way of thinking about a concept (or why they believe their current concept is still valid). At the end of the year, students could again be tested to see if their misconceptions have changed into working concepts.

Misconceptions are prevalent in all age groups of students, and if unidentified, these misconceptions can persist well into adulthood. The ECOS program provides the prefect platform to identify and work to change naïve concepts into valid working concepts. This study should certainly be continued during the 2006/2007 school year. Not only could valuable thinking skills be taught today's youth, but new ways of accurately teaching concepts could be developed and implemented in the school curricula.

A1.7 References

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