DOCUMENT RESUME

ED 477 692 SE 067 932

AUTHOR	Kuech, Robert; Zogg, Gregory; Zeeman, Stephan; Johnson, Mark
TITLE	Technology Rich Biology Labs: Effects of Misconceptions.
PUB DATE	2003-03-00
NOTE	14p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (Philadelphia, PA, March, 2003).
PUB TYPE	Reports - Research (143)
EDRS PRICE	EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS	*Biology; Botany; *Concept Formation; Educational Technology; Higher Education; *Learning Problems; *Photosynthesis; Science Activities; Science Instruction; Science Laboratories; Secondary Education

ABSTRACT

This paper describes a study conducted on the lab sections of the general biology course for non-science majors at the University of New England, and reports findings of student misconceptions about photosynthesis and the mass/carbon uptake during plant growth. The current study placed high technology analytic tools in the hands of introductory biology students allowing them to collect and analyze real carbon data, with the intent of increasing their conceptual understanding of photosynthesis concepts and decreasing the frequency of misconceptions. Two lab sections of the course were used as a study for the teaching of photosynthesis. The control section (A) used the more traditional qualitative chemical approach to presenting the material, and the treatment section (B) used sophisticated technology to study the process quantitatively. Using the plant Brassica rapa, students worked in groups to explore three different factors contributing to plant growth and photosynthesis, the treatment group analytic technology. At the end of the laboratory activities about photosynthesis, the treatment students presented their work in the form of a symposium. Test scores, laboratory reports, and student semi-structured interview provided information about student understanding of photosynthesis. The paper reports detailed outlines of the class lab activities and technology use, and comments on the nature of student understanding of the mass/carbon uptake during photosynthesis. The study compared the understanding of students in both the treatment and control groups to assess the effectiveness of integrating technology into introductory biology lab activities on misconceptions about photosynthesis. (Author)

Reproductions supplied by EDRS are the best that can be made
from the original document.

ED 477 692

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY

R. Kuech

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

1

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

- This document has been reproduced as received from the person or organization originating it.
- Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Technology Rich Biology Labs: Effects on Misconceptions

Dr. Robert Kuech, Assistant Prof. Of Education
University of Southern Maine
Rkuech@usm.maine.edu

Dr. Gregory Zogg, Assistant Prof. Of Biology
University of New England
Gzogg@une.edu

Dr. Stephan Zeeman, Professor of Biological Sciences,
Dr. Mark Johnson, Asst. Professor of Biological Sciences
University of New England

BEST COPY AVAILABLE

SE067932

2

ABSTRACT

This paper describes a study conducted on the lab sections of the general biology course for non-science majors at the University of New England, and reports findings of student misconceptions about photosynthesis and the mass/carbon uptake during plant growth. The current study placed high technology analytical tools in the hands of introductory biology students allowing them to collect and analyze real carbon data, with the intent of increasing their conceptual understanding of photosynthesis concepts and decreasing the frequency of misconceptions. Two lab sections of the course were used as a study for the teaching of photosynthesis. The *control* section (A) used the more traditional qualitative chemical approach to presenting the material, and the *treatment* section (B) used sophisticated technology to study the process quantitatively. Using the plant *Brassica rapa*, students worked in groups to explore three different factors contributing to plant growth and photosynthesis, the treatment group using sophisticated analytic technology. At the end of the laboratory activities about photosynthesis and plant growth, the students presented their work in the form of a symposium. Test scores, laboratory reports, and student semi-structured interviews, provided information about student understandings of photosynthesis. The paper reports detailed outlines of the class lab activities and technology use, and comments on the nature of student understanding of the mass/carbon uptake during photosynthesis. The study compared the understanding of students in both the treatment (quantitative, technology rich) and control (qualitative, low tech) groups to assess the effectiveness of integrating technology into introductory biology lab activities on misconceptions about photosynthesis.

RATIONALE FOR THE STUDY

Pre-existing Ideas

Research has demonstrated that students enter a new science learning environment with pre-existing ideas and understandings of the concepts to be presented. These pre-existing ideas have been referred to in the literature as "preconceptions" and are described as beliefs about science concepts and their application before receiving formal science instruction (Mestre, 2001). Frequently, these initial conceptions do not reflect accepted scientific understanding and are called *misconceptions*. These *misconceptions* are found across the sciences, including in the study of basic biology concepts such as photosynthesis. (see for example: A *Private Universe,* Pyramid Film and Video; Wandersee, 1983; Mestre, 2001) Research has also indicated that these initial conceptions are quite stable and not easily changed by traditional methods of science instruction and are likely to remain or resurface even after students have demonstrated some degree of understanding (Mestre, 2001). Advocates have argued that computer technologies offer new tools that can assist teachers in promoting increased understanding in the science classroom. Digital technologies, when part of an appropriate learning environment, have an important role to play in providing experiences and information that can promote conceptual understanding for students in contemporary science classrooms (Kuech& Lunetta, 2002).. Digital technologies can allow the learner to collect and analyze real data that can provide a more meaningful scientific experience for the student. The current study placed high technology analytical tools in the hands of introductory biology students allowing them to collect and analyze real carbon data, with the intent of increasing their conceptual understanding of photosynthesis concepts and decreasing the frequency of misconceptions.

LEARNING IN TECHNOLOGY RICH CLASSROOMS

Salomon, Perkins, & Globerson, (1991) suggested that technology should be used to promote "mindful engagement" that will act as a starting point to help the learners build knowledge. Jonassen (1997) argued that technologies should be used as "*Mindtools*", that is as tools to enhance "cognitive learning ". When using technologies as *Mindtools*, students use " computer-based cognitive tools and learning environments that have been adapted or developed to facilitate critical thinking and higher order learning in learning." In the science classroom for example, technologies can provide students with instantaneous visual information about the data being gathered in their investigation giving them time to reflect on the investigation they have just performed (Kuech, 1999). This instantaneous feedback can allow the learners to modify their hypotheses, test alternative hypotheses, and evaluate the results (Friedler, Nachimus, & Linn, 1990). Technologies can provide multiple representations of information such as tables or graphs which may allow learners to achieve improved outcomes by giving the individual a variety of representations to use in evaluating their ideas and their understanding of the information they have generated in their recent

ERIC

investigation (Kuech & Lunetta, 2002). These choices may reinforce learning by enabling students to use their unique learning styles. Mokros and Tinker (1987) suggested that technologies can provide a real-time link between a concrete experience and its symbolic representation, thus providing a link between the student's formal and concrete operations, to use Piagetian terminology. Technologies can allow the learner to collect and analyze real data, which can provide a more meaningful scientific experience for the student. Digital technology tools can allow the learner to spend more time thinking about an investigation and its interpretation and less time performing repetitive measurements and calculations (Friedler, Nachimus, & Linn, 1990; Jonassen, 1995; Mokros and Tinker, 1987). Thus digital technologies tools provide mechanisms through which the learner can have more time for critical thinking and analysis of their investigations (Kuech, 1999).

Writers of the *National Science Education Standards,* (National Research Council 1996), envisioned technologies promoting more meaningful learning by extending and expanding explorations throughout the science curriculum. Their report emphasized the need for technology to promote students' understanding of scientific concepts and not simply reinforcing the ritualistic manipulation of algorithms and/or rote learning. The *National Science Education Standards* outlines a shift in emphasis from "Focusing on student acquisition of information" to "Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes" (NSES, p. 52).

New methods of improving student scientific understanding must be developed and utilized if we are to realize the shift of emphasis that is called for in the *National Science Education Standards.* Technology can be used as a tool to promote increased understanding in the science classroom. Digital technologies when part of an appropriate learning environment can provide experiences and information that can promote conceptual understanding for students in contemporary science classrooms (Kuech,2002). While much has been written about the potential impact and power of technology tools there has been insufficient research designed to examine how students can work with technology tools to promote more meaningful learning or to enhance conceptual understanding of biological concepts. The study reported in this paper has examined college student's learning of photosynthesis in an introductory biology lab in which they were engaged in activities that included use of high technology tools.

Overview of the Present Study

The present study was conducted in two classes, both of which were laboratory sections of the introductory biology course taught concurrently in the spring of 2002. In the so called low-tech Lab section (A) students used simple qualitative colorometric techniques to determine photosynthetic rate and measured changes in plant mass over time. In another Lab section (B) students used high technology tools to get a more quantitative analysis of the photosynthetic rate and plant carbon gain. Both of the classes attended the same lecture section, were about the same size (22-23 students), were taught by the same instructor (Zogg), and used the same general materials. Students in both sections were told that they were part of a research project aimed at improving the quality of biology instruction at the University. Students in both classes were asked to sign a consent form that: (1) informed them of the nature of the study; (2) explained that they were being asked, but not required, to complete anonymous surveys, and possibly be interviewed, (3) told that they were going to be video taped during lab time as they were working on activities, and; (4) assured that the results of the research would be used to improve the quality of biology instruction, but in no way affect their grade in the course.

Methods

<u>Data Sources</u>

There were two main data sources used for this study intended to answer the items of interest. These sources included the students' laboratory hand-out responses and semi-structured interviews. The student responses on their laboratory handouts were followed up with video taped semi-structured interviews.

On the laboratory handout, the first two questions (a and b) were especially informative to this study. Those questions were:

a. Can plant mass gain in this experiment be attributed to changes in soil mass?
b. Can plant mass gain in this experiment be attributed to changes in nutrient solution mass?

All of the students completed the answers to these questions as they worked in groups during their scheduled laboratory sessions. The open ended responses to these questions were separately analyzed by the instructor and the researcher to provide independent points of view as to how the answers should be categorized.

ERIC

Because the current study was involved with the understanding the students had developed around photosynthesis concepts, the laboratory questions were followed up with semi-structured interviews. These interviews were used to collect data about the students' understanding of the process of photosynthesis and how this process contributes to the overall mass of plants. The questions selected for use in these interviews were taken from the *Photosynthesis Concept Test* of Wandersee and his colleagues, who have spent considerable time and effort to develop and analyze questions that get at the nature of student understanding of photosynthesis (Wandersee, 1983). The three questions used to start the interviews were:

1. If a mouse were placed in a closed glass container, it would soon die. (Picture provided). If a plant were placed in the container along with the mouse – on a shelf the mouse couldn't reach – what do you predict would happen to the mouse and to the plant?

( ) The plant would die but the mouse would live.

( ) The mouse would die but the plant would live.

( ) Both the mouse and plant would live.

( ) Both the mouse and the plant would die.

2. Like animals, plants need food in order to stay alive. If you were asked where most of the food of plants comes from, which of the following choices would you consider to be the best answer?

( ) The food of plants comes from water.

( ) The food of plants comes from carbon dioxide.

( ) The food of plants comes from soil.

( ) The food of plants comes from water and air.

3. You may have heard the leaf called a "factory." All factories make a product. If you had to name the product a leaf makes, which of the following would you select?

( ) Proteins

( ) Fats

( ) Carbohydrates

The students were asked follow up questions to get them to elaborate on why they decided to choose their answers. The interviewer would be sure to ask enough questions to fully understand the meaning of the student response.

<u>Technology Used by the Students</u>

Below are excerpts from handouts provided to the students which describe the various technologies used in the lab exercises. In the low-tech lab section (A), students used the "Bromthymol blue carbon dioxide" assay as a qualitative index of photosynthetic activity and simply measured plant mass gain over time. Students in the high-tech lab section (B) used a "Carbon dioxide gas

ERIC

analyzer" to accurately measure plant carbon uptake, and a "Solid carbon analyzer" to quantify plant carbon gain, as well as changes in soil carbon over time.

Bromthymol blue carbon dioxide assay

In laboratory you will use a qualitative, low-tech indicator of CO_2, bromthymol blue, in order to determine the photosynthetic activity of your plants. Bromthymol blue is actually an indicator of acidity (amount of H^+ ions in solution), but because carbon dioxide alters the acidity of a solution as it dissolves, bromthymol blue can be used as an indirect indicator of the carbon dioxide concentration in a solution. The chemistry behind this reaction is as follows: carbon dioxide dissolves in (and reacts with) water, forming carbonic acid (H_2CO_3); carbonic acid then immediately dissociates into a hydrogen ion (H^+) and a bicarbonate ion ($HCO3^-$):

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO3^-$$

If the CO_2 concentration is high, there will be a lot of H^+ ions in solution, and the bromthymol blue yields a yellow color. If CO_2 concentrations are very low, few H^+ ions are in solution, and bromthymol blue yields a blue color. At intermediate CO_2 concentrations, bromthymol blue yields a blue-green color. Since photosynthesis consumes CO_2, and we started the bormomthymol blue assay with yellow solution in each tube (high CO_2 concentration), we can use the relative blueness of each tube after 3-4 days as an index of the amount of CO_2 utilized, and hence photosynthesis, during that period.

Carbon dioxide gas analyzer

This device provided a quantitative, high-tech method to measure the photosynthetic rate of plants. The LI-COR 6400 gas analyzer passes a known amount of carbon dioxide (a uniform concentration of carbon dioxide at a precisely controlled flow rate) into a chamber in which the plants are placed. As the plants photosynthesize they use up some of the carbon dioxide in the chamber. To detect the resulting differences in carbon dioxide levels between gas entering and leaving the plant chamber, the LI-COR 6400 utilizes an infra-red beam which is absorbed by carbon dioxide – the lower the concentration of carbon dioxide, the more infra-red radiation that is detected by the instrument. For example, if the infra-red detector indicates that the gas leaving the chamber absorbs considerably less infra-red radiation than the gas entering the chamber, we know that substantial amounts of carbon dioxide was removed in the chamber, and therefore the plants had high rates of photosynthesis. The true value of the LI-COR 6400 instrument is that the attached computer allows the student, to not only detect relative differences between photosynthetic rates, but to actually quantify them. (To simplify subsequent calculations of plant carbon gain, the data generated from the instrument was reported as mg of carbon uptake per day).

Solid carbon analyzer

This device was used to determine the carbon content of plants and soil, using a technique called flash-combustion. A small subsample of plant (or soil) was placed in a CE Instruments Model NC2500 analyzer, where it was combusted at approximately 800 °C and converted into a gas (e.g., the carbon in the subsample is converted into carbon dioxide). The resulting gases are then passed through a chromatography column which separates the carbon dioxide from other combustion products (e.g., nitrogen gas), and then onto a detector which determines the amount of carbon in the subsample. This value is then divided by the initial weight of the subsample, providing the percent carbon content of the plant (or soil) material. Multiplying percent carbon by the total weight of the plants (or soil) reliably estimates the total carbon content.

Liquid organic carbon analyzer

ERIC

The carbon in the nutrient solution was determined using the OI Analytical Model 1020A Total Organic Carbon Analyzer. This instrument combines some of the features of both the solid carbon analyzer and the carbon dioxide gas analyzer. Nutrient solution samples are initially combusted at high temperatures, resulting in the conversion of all the carbon in the sample into carbon dioxide (similar to the process used in the solid carbon analyzer). The amount of carbon dioxide produced is then quantified with an infra-red detector (as in the carbon dioxide gas analyzer). The resulting data are in units of mg carbon per ml of solution – by multiplying this value times the total amount of solution (ml), an estimate of the total carbon content of the solution is determined.

Description of the Two Laboratory Sections

Biology 104 is an introductory course intended for students not majoring in biology or other sciences and is designed to introduce the students to basic concepts in biology. The lab met once a week for 2 hours and 50. Most of the students in the class are freshmen, a few sophomores and the rest juniors and seniors. Most had taken high school biology courses, but for most this was their first college level biology course. In the first meeting of the class, the students were allowed to self-select (by virtue of where they chose to sit in the classroom) the other members of the collaborative group they were to be working with. The students were then instructed that these were their permanent teams for class work for the rest of the semester. In addition to the in class work the groups were required to also work together outside of the class to develop their symposium presentation that was the capstone activity of their Plant/Photosynthesis Experiment.

The actual lab activities began on the second meeting of the class, as the first day was taken up with pre -tests, surveys and general administrative duties. On the second meeting of the lab class, both sections were given the same materials describing the laboratory titled "Plant Experiment: The Fundamental Importance of Biotic and Abiotic Factors to the Growth of Organisms". Both groups were instructed how to set-up and label the plant growing systems, and assigned what factor their group would be testing. The students were then instructed on how to prepare the matrix in which the plants would grow, how to add the nutrient solution and how to plant the *brassica rapa* seeds. The plants were grown using a bottle biology technique. The top is cut off a plastic soda bottle, which is then inverted and placed back into the bottom. A wick is pushed through the top of the bottle down into the bottom, which contains nutrient solution. Vermiculite is then added to the inverted top of the bottle and the seeds are planted in this "soil". Each student had to generate an hypothesis before the next class as to how the plants would grow in relation to the four treatments in their experiment and were instructed to include a biologically-based rationale for their prediction.

On day eight of the experiment (the next lab meeting) both groups were still following the same lab procedure. The students took height measurements of the plants, made general observations about the health of the plants, added an additional measured amount of nutrient solution, and determined the treatment effects on average plant height by plotting the average plant height versus the relative treatment intensity for their plants.

It is on day 15 of the Plant Experiment that the two lab sections take a decidedly divergent path. On this day both sections were given the introduction and procedures for the lab "Photosynthesis: Making Food Literally Out of Thin Air." The first two pages of this lab including the introduction and objectives were identical. The third page titled "Photosynthesis: Technology Fact Sheet" was different for each of the sections. Section (A) had a description of "Bromthymol blue carbon dioxide assay." It was described as a "low-tech indicator of CO_2" used to determine the photosynthetic activity of the plants. The chemistry behind the reaction that causes the color change in the solution was provided for the students. This lab group harvested their plants and put them into a solution of bromothymol blue to perform a colorimetric, qualitative analysis of the plants' photosynthetic processes. The students then removed the rest of their plants from the soil so that they could be dried and massed in lab the following week.

The third page provided for section (B) also titled "Photosynthesis: Technology Fact Sheet", but included a description of three instruments to be used in the lab. The page described the activity as a "high-tech method to measure the photosynthetic rate of plants". The three instruments described were: carbon dioxide gas analyzer, solid carbon analyzer, and liquid organic carbon analyzer. The lab described the gas analyzer as an instrument that would allow the students to compare the differences in carbon dioxide levels of the gas entering and leaving the plant chamber. This device with its attached computer would allow the students to not only detect these differences, but to actually quantify them and report the mg of carbon uptake per day. The solid carbon analyzer was described as a device that would determine the carbon content of plants and soil. The liquid organic carbon analyzer

ERIC

is an instrument that combines some of the features of both the other two devices and allows the user to determine the carbon content of a liquid.

The students had to select one of their sets of plants to remove from the soil and place in the carbon gas analyzer, so that they could quantify the amount of carbon uptake per day. The students then removed the rest of their plants from the soil so that they could be dried and massed in lab the following week.

Table 1: Comparison of "Technology" used

Lab section (A)	Lab section (B)
Bromothymol blue	Carbon dioxide gas analyzer
	Solid carbon analyzer
	Liquid organic carbon analyzer

On plant Experiment day 22, the two sections are now performing procedures that are very different. During this meeting, Lab section (A): weighed dried plant and soil samples, compiled photosynthesis data, and determined treatment effects on average plant dry weight and photosynthesis. Part 2 of the lab for this day was titled "Where does Plant Mass Come From?" In this part of the exercise, lab section (A) quantified changes in the *weight* of plant, soil, and nutrient solutions for select bottle-growing systems in Light, Nutrient or density experiments using their group data. They examined the relationship between plant *mass* gain and photosynthesis across all three experiments using class data. The prepared for the "Plant Experiment/Photosynthesis Symposium" they would have to do the following week.

During their lab meeting, section (B): weighed dried plant and soil samples, Mixed select plant and soil samples for carbon analysis, weighed selected plant and soil samples for carbon analysis, compiled photosynthesis data, and determined treatment effects on average plant dry weight and photosynthesis. Part 2 of the lab for this day was titled "Where does Plant Mass Come From?" In this part of the exercise, lab section (B) quantified changes in the *carbon content* of plant, soil, and nutrient solutions for select bottle-growing systems in Light, Nutrient or density experiments using their group data. They examined the relationship between plant *carbon* gain and photosynthesis across all three experiments using class data. They prepared for the "Plant Experiment/Photosynthesis Symposium" they would have to do the following week.

Analysis and Findings

Laboratory section A followed a qualitative approach to learning about the process of photosynthesis. The central activity for estimating the photosynthetic activity of the plants was through a colorimetric test using bromothymol blue. In this part of the procedures, the students exhaled carbon dioxide into the bromothymol blue solution which causes it to turn pale yellow due to an increase in the pH level from the carbon dioxide. The students then placed the plants into the test tube containing the yellow bromothymol blue solution and let them sit for 72-96 hours under the grow lights in the lab. At this time the students observed the color change from pale yellow back to blue, going through various shades of green. (The plants would use up the carbon dioxide during photosynthesis and so the color change caused by the change in pH can be used as a crude indicator of photosynthetic activity) The higher the photosynthetic activity in the plants, the more carbon dioxide gets used up, and the closer the solution turns to blue. The students then ranked the color of the 4 test tubes that they had made during their experiment in order going from yellow (1) to blue (4) by comparing the tubes to each other and to yellow and blue control tubes.

In addition to the qualitative analysis of the photosynthetic activity, the students measured the mass of the soil and nutrient solution both before and after the experiment to determine if there were any changes in the relative mass. This comparison of mass data and the photosynthetic activity data were recorded on their lab handouts. After recording all the data on their lab handouts, the students needed to answer some questions to pull together the topics and concepts covered in the lab activity. The first two questions (a and b) on the lab handout were especially pertinent to this study. Those questions were:

c. Can plant mass gain in this experiment be attributed to changes in soil mass?
d. Can plant mass gain in this experiment be attributed to changes in nutrient solution mass?

ERIC

44% of the students in the class answered yes, to question "a" that the plant mass gain could be attributed to changes in soil mass. There were answers that said "in a very small amount, yes" and "the mass of the plant increased as the mass of the soil decreased". Another stated that there was a correlation between soil mass lost and plant mass gain.

On question "b", 76% of the students answered that yes, the plant mass gain in this experiment could be attributed to changes in nutrient solution mass. For this question there were answers such as "yes, the plants use the nutrient solution to grow", "the plants were able to grow by taking the nutrients from the solution", "The nutrients help the plant grow, so the plant grows and the plant mass gains, that's why the nutrient solution mass is negative in the end", "yes, because the plants used the water we supplied it as nutrients", and "yes, because the plant grew a lot and used up a lot of nutrients".

Laboratory section B followed a quantitative approach to learning about the process of photosynthesis. . The central activity for estimating the photosynthetic activity of the plants was through the use of the carbon dioxide gas analyzer. In this part of the activity, the students placed some of their plants in a small chamber connected to the analyzer for a short period of time during the lab period. As a measured amount of room air was drawn through the chamber, the carbon dioxide analyzer compared the amount of carbon dioxide entering and leaving, and then with the use of a computer calculated the uptake of carbon dioxide gas and reported it as mg of carbon uptake per day. By using this "high tech" device including the attached computer, the user is able to not only detect relative photosynthetic rates, but to actually quantify them. The students recorded this data on their lab handout.

In addition to the quantitative analysis of the photosynthetic activity, the students measured the carbon content of the plants, soil and nutrient solution both before and after the experiment to determine if there were any changes in the relative amounts. For this, the students used a solid carbon analyzer to determine the carbon content of the dried plants and soil. The carbon content of the nutrient solution was determined using the liquid organic carbon analyzer, which reported the results as mg of carbon per ml of solution. This comparison of carbon data and the photosynthetic activity data were recorded on the student lab handouts. After recording all the data on their lab handouts, the students needed to answer some questions to pull together the topics and concepts covered in the lab activity. The first two questions (a and b) on the lab handout were especially pertinent to this study. Those questions were:

a. Can plant C gain in this experiment be attributed to changes in soil C?
b. Can plant C gain in this experiment be attributed to changes in nutrient solution C?

35% of the students in the class answered yes, to question "a" that the plant C gain could be attributed to changes in soil C. There were answers such as: "yes, plant C gain can be attributed to changes in soil C, because the plant lives in the soil"; "yes, because as the soil becomes enriched the nutrient's carbon gets absorbed by the plants"; "of course it can"; "yes, due to the plant being in the soil".

On question (b) 50% of the students said that yes, plant C gain can be attributed to changes in nutrient solution C. It needs to be stated here that there is no carbon in any of the nutrients that have been added to the water solution. For this question there were answers such as: "Yes because the nutrient solution's purpose is to pass on its carbon to the plants"; Yes because as the plant gains more carbon the nutrient solution becomes depleted"; "yes, it is made clear when we see that as the plants' growth became larger, the nutrient solution numbers went considerably down"; "yes, because the nutrient solution started off high with C and the plant was low in C, but at the end the nutrient lost C where the plant gained"; "yes, the nutrient solution gives the plant & soil carbon". So if the nutrient solution ran out of carbon, the plant would only be getting C from the soil. When this was gone, the plant would have no source of carbon except from the atmosphere. The role of the nutrient solution was to give C to the plant".

Summarizing the Findings for Both Classes

In order to make a more direct comparison of the responses of the two different classes the answers to questions (a) and (b) are summarized in the following paragraph. For question (a) laboratory section (A) 44% felt that the plant growth gain came from the soil and for laboratory section (B) 35% felt that the plant growth gain came from the soil. For question (b) 76% of the students in laboratory section A thought that the plants' growth gain came from the nutrient solution and for laboratory section B 50% thought that the plant growth gain came from the nutrient solution.

ERIC

Mass/C from Soil

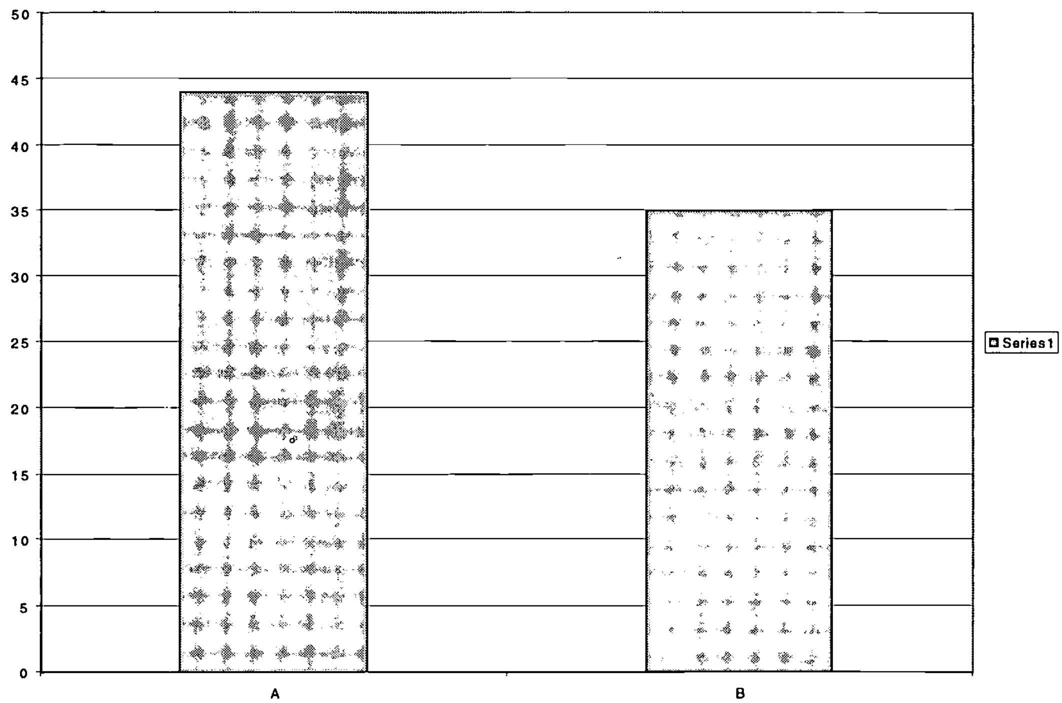

Figure 1. Percent of students from each lab section responding yes that the plant mass/C comes from the soil.

Mass/C from Nutrient Solution

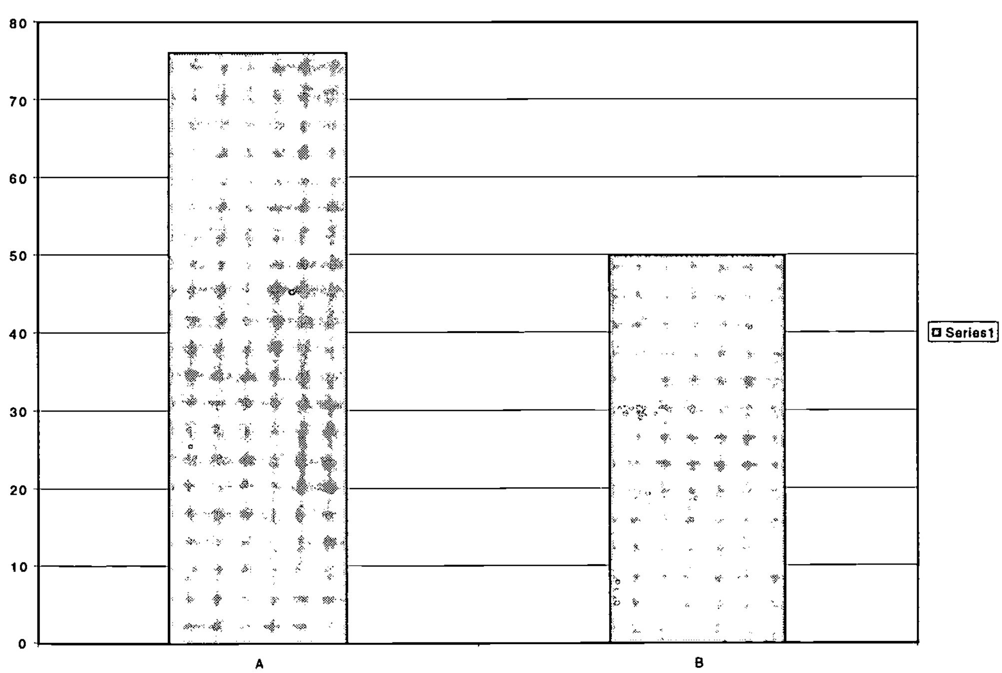

Figure 2. Percent of students from each lab section responding yes that the plant mass/C comes from the solution.

Insights from the Interviews

Question 1: If a mouse were placed in a closed glass container, it would soon die. (Picture provided). If a plant were placed in the container along with the mouse – on a shelf the mouse couldn't reach – what do you predict would happen to the mouse and to the plant?

In response to the first question about the closed container with a mouse and a plant, all of the groups correctly express that there is some relationship between the mouse and the plant that has to do with gaseous exchange. The general consensus of the groups on the first question seems to be a superficial understanding of the process of photosynthesis. "They would both live, because the plant carries on the process of photosynthesis that produces oxygen that the mouse needs to live." "It's like a relationship kind of thing. So the mouse breaths out carbon dioxide. The plant takes it in and puts out oxygen. Everyone's happy." They seem to have the general concept that the mouse produces carbon dioxide that the plant in turn takes in during photosynthesis. The groups appear to have an understanding that the process of photosynthesis involves the uptake of carbon dioxide and the giving off of oxygen. This would seem to be in line with the understanding of the chemical process of photosynthesis that students should have gained in their elementary classes somewhere between the fifth and eighth grades (NSES, 1996; State of Maine Learning Results, 1997).

Question 3: "You may have heard the leaf called a 'factory'. All factories make a product. If you had to name the product a leaf makes, which of the following would you select? [ ] proteins; [ ] fats; [ ] carbohydrates."

We get a more complete insight into the students' understanding of the process of photosynthesis by analyzing the responses to this interview question. Here there is a fifty-fifty split about the product that the leaves of the plant make. Half (50%) of the students correctly communicated that the process of photosynthesis produces glucose which is a carbohydrate, and thus the main product made by the "factory" in the leaf of a plant is carbohydrates.

A typical correct response to this question was "carbohydrates, glucose is produced by photosynthesis and glucose is a carbohydrate." "You think of what the plant produces as glucose. That is a carbohydrate, so, carbohydrates."

The other half of the students indicate that they think the product of photosynthesis is protein. The students appear to be connecting the process of photosynthesis with the growth of the plant and somehow feel that protein is needed for this growth. There were no answers that could be called typical, but the following would be a representative sample: "Proteins, because photosynthesis will produce proteins." Or "Proteins, I just remember photosynthesis, ATP and all that jazz." Responses such as this provided an indication that the students did not have a firm grasp of the overall process of photosynthesis, but knew that it had something to do with the formation of ATP. It was not clear however, if the students had any better understanding of the role that ATP played in the overall process of photosynthesis or of the carbon and energy cycles of the plant

Question 2: Like animals, plants need food in order to stay alive. If you were asked where most of the food of plants comes from, which of the following choices would you consider to be the best answer? ( ) The food of plants comes from water, ( ) The food of plants comes from carbon dioxide, ( ) The food of plants comes from soil, ( ) The food of plants comes from water and air.

The responses to this question point out just how tenacious the misconceptions about photosynthesis really are. Two thirds or 66% of the students responded that the food of plants comes from the nutrients in the soil. A typical explanation to this question was " soil, yeah, the nutrients in the soil. Think back on *brassica*, yeah, the nutrients, it has to be the soil." The students were reflecting back to their laboratory experiment with the *brassica* plants and remembering how they needed to add more nutrient solution to keep them growing. While adding nutrient solution to their plant growing bottles was an ongoing part of their laboratory, there was a lack of understanding of the significance of this activity. It is of further interest to note that the plants were grown in a small amount of vermiculite and not real soil, so the nutrients were provided by the water solution the students needed to add. Because this was a typical explanation provided by the students, it was interesting that a greater percentage of students did not give the answer as water.

Only one sixth or 16% of the students responded that the food of the plants came from the water. "Water because nutrients carry into the soil." "Water too, because water has nutrients in it." These students gave the same reasoning as the previous students did, that the plants needed the nutrients that were provided in the water. If they were relying on the fact that during their lab

ERIC

experiment with the *brassica* plants, they continually needed to add more nutrient solution to their plants, this answer seems somewhat logical in its reasoning.

The remaining 16% of students responded to question number 2 with answers that indicate a much better grasp of the overall concept of photosynthesis. The responses provided by this group of students are best represented by answers such as this. "It comes from water and air, because the carbon dioxide in photosynthesis comes from the air and the water from the soil. Essential parts of photosynthesis are water and carbon dioxide." It would have been beneficial if the students had continued on to provide a more complete representation of their understanding of the process of photosynthesis. This might include an explanation of the carbon and oxygen atoms needed to make glucose in the process coming from the carbon dioxide and the hydrogen coming from the water. Although the response they provided was not entirely complete, it was certainly more in line with the types of answers you would intend a student in a college level biology course to give.

Discussion

This study is part of a longitudinal comprehensive research project that seeks to examine whether exposure to "high-tech", quantitative data collection techniques and "structured inquiry" (Mestre, 2001) laboratory activities makes a difference in introductory biology students' achievement, resolution of misconceptions, and attitudes and beliefs toward and about the nature of science. This study reports on the first two semesters of work completed on teaching the laboratory sections using a high-tech quantitative approach versus a low-tech qualitative approach.

It can be seen that in general neither of the laboratory sections studied, dispelled their misconceptions about where the mass of plants comes from during the process of photosynthesis. 35 to 44 percent of the students in the laboratory sections still believed that the mass or carbon needed for growing plants came from the soil after the laboratory activities. During the follow-up interviews, 66 percent responded that the food of the plants came from the soil. 50 to 76 percent of the students in the laboratory sections still believed that the mass or carbon needed for plant growth came from the nutrient solution even after the laboratory activities. This was further articulated by the students in the semi-structured interviews. The responses in the interviews indicated that the food of the plants is connected to the nutrients provided by the soil. Studies have indicated that student misconceptions about science are very durable and difficult to dislodge even after explicit instruction. (See for example: Mestre, 2001; Anderson and Roth, 1989; Garnett and Treagust, 1992; Goldberg and McDermott, 1987; Wandersee, 1983) The intention of the quantitative activities was to specifically measure the carbon content of the soil, nutrient solution, and the amount of carbon uptake per day of the plants that the students were growing. It was intended that by explicitly measuring the carbon uptake by the plants and measuring the amount of carbon content in the dried plants after they had grown for more than three weeks, and measuring the carbon in the soil and nutrient solution, that the students would build new understandings related to the concept that plants get the carbon needed for growth directly from the air around them. This process did not seem to produce the desired results as 44% of the "low-tech" qualitative laboratory section stated that they believe the soil was a source of mass for the plants' growth after conducting the lab activities. Although a somewhat smaller (35%) of the "high-tech" quantitative laboratory section stated that they believed this was the case, this percentage is not acceptable. The findings were even more dramatic for the belief that the mass or carbon needed for plant growth comes from the nutrient solution. 76% of the section A qualitative laboratory section believed that the mass needed for plant growth comes from the nutrient solution, and 50% of the quantitative laboratory section believed that the carbon needed for plant growth comes from the nutrient solution. Although the quantitative high tech group demonstrated slightly lower percentage beliefs over the qualitative group, it is still unacceptable for 50 percent of the group to still have misconceptions about plant carbon uptake.

The findings for the qualitative group are not surprising given that prior research as noted above has demonstrated that the current state of instruction does not go far enough to remove the prior misconceptions that students have about science. It was surprising that the high-tech laboratory section demonstrated so little improvement after they had completed the laboratory activities. The student beliefs may have been complicated by the extreme accuracy of the carbon analyzing machines and the difficulty of removing all of the root material from the soil and nutrient solution. The root system of the plants was quite extensive on some of the plants after they had been growing for more than three weeks, and would extend down through the soil into the

ERIC

lower portion of the growing bottle where the nutrient solution was added. It is very difficult for even expert lab technicians to remove the plants from this growing apparatus and not leave behind any of the smaller roots or root hairs. Even a very small portion of this root material when left behind in either the soil or nutrient solution would show up in the carbon analyzer and lead novice learners to believe that there was carbon in the soil and nutrient solution. This complicating factor, when coupled with the students' prior misconceptions about plant growth and photosynthesis, may have been enough to reinforce their prior conceptions and prevented them from changing their conceptions to a more scientific view.

Implications

Based on the experience and data gathered from this study, student misconceptions about plant growth and photosynthesis are not dislodged, even through the use of new "high-tech" laboratory apparatus and activities that are intended to specifically target the mass of carbon in rapidly growing plants. Simply integrating high technology tools into current introductory biology lab activities does little to remove student misconceptions about photosynthesis. In fact, the accuracy of the carbon analyzing equipment may even add a complicating factor for student understanding. New lab activities integrating high technology and based on conceptual change strategies, need to be developed to promote improved understanding of biology concepts. The inquiry-based labs need to be supported by pedagogy that promotes high level cognitive interaction within the peer groups (Lumpe & Staver, 1995). One model for improving biological literacy within the context of inquiry-based labs, including initiating conceptual change toward replacing misconceptions of complex concepts like photosynthesis, is that of peer collaborative grouping. This model, when coupled with inquiry-based labs also has the potential of helping students better understand the "Nature of Science. Theories and current research into the social aspects of learning and cognition build a strong argument for the use of collaborative groups to improve conceptual understanding (Linn and Burbules 1993, Tao 1997, Marbach-Ad and Sokolove 2000, and Roth 1995). Specifically designed activities and appropriate pedagogy which creates cognitive conflict within the participants, has been shown to promote increased conceptual understanding, replacement of misconceptions, and increased understanding of the nature of science (Lumpe & Staver, 1995, Kuech, 1999, Lederman & Druger, 1985, Slavin, 1996). Further study needs to be done using appropriate activities and pedagogy to help understand how best to use "high-tech" laboratory equipment to improve student understanding and dislodge misconceptions about introductory biology concepts.

ERIC

References

Anderson, C.W. & Roth, K.J. (1989). Teaching for meaningful and self-regulated learning of science. In *Advances in Research on Teaching*, Vol I (pp. 265-309). JAI Press.

Heller, P., & Hollabough, M. (1992). Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups. *American Journal of Physics*, 60(7), 637-645.

Heller, P., Kcith, R., & Anderson, S. (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. *American Journal of Physics*, 60(70, 627-636.

Jonassen, D. (1995). Computers as Cognitive Tools: Learning with Technology, Not from Technology. *Journal of Computing in Higher Education*. Vol. 6(20), 40-73

Jonassen, D. (1997). Learning by Reflection WITH Technology: Mindtools for critical Thinking. 123-161.

Kuech, R. & Lunetta, V. (2002). Using digital technologies in the science classroom to promote conceptual understanding. *Journal of Computers in Mathematics and Science Teaching*. 21(2), 103-126.

Kuech, R. (1999). Student Collaboration, Investigation Problems, and Technology Use in an Innovative University Mechanics Class. Doctoral Dissertation. The Pennsylvania State University.

Lederman, N.G. and Druger, M. (1985). Classroom factors related to changes in students' conceptions on the nature of science. Journal of Research in Science Teaching. 22, (7), pp. 649-662

Linn, M. and Burbules, N. 1993. Construction of knowledge and group learning. Chapter 6 in The Practice of Constructivism in Science Education. New Jersey. Lawrence Erlbaum Associates. 91-119.

Lumpe, AT and JR Staver. 1995. Peer collaboration and concept development: learning about photosynthesis. Journal of Research in Science Teaching 32(1): 71-98.

Marbach-Ad, G and Sokolove, P. (2000) Can Undergraduate Biology Students Learn to Ask Higher Level Questions? *Journal of Research in Science Teaching*, 37, 8, 854-870.

Mestre, J. (2001). Cognitive Aspects of Learning and Teaching. In *Teacher Enhancement for Elementary and Secondary Science and Mathematics: Status, Issues, and Problems*. S.J. Fitzsimmons & L.C. Kerpelman (Eds.), Washington, D.C.: National Science Foundation (NSF 94-80).

Mokros,J. and Tinker, R. (1987). The Impact of Microcomputer-Based Labs on Children's Ability to Interpret Graphs. *Journal of Research in Science Teaching*. Vol.24,(4), 369-383.

Pyramid Film & Video. A *Private Universe*. Santa Monica, CA.

Roth, W-M. (1995). Authentic School Science: Knowing and learning in Open-Inquiry Science Laboratories. Dordrecht, The Netherlands. Kluwer Academic Publishers.

Salomon, G., Perkins, D.N., & Globerson, T. (1991). Partners in Cognition: Extending human intelligence with intelligent technologies. *Educational Researcher*. Vol. 29, (3), 2-9.

Tao, Ping-Kee. 1997. Conceptual change in science through collaborative learning at the computer. Paper presented at the 1997 Annual Meeting of the National Association of Research in Science Teaching. Oak Brook, Il.

Thornton,R. and Sokoloff,D.(1989). Learning Motion Concepts Using Real-Time Microcomputer-Based Laboratory Tools. *FIPSE Final Report,* U.S. Department of Education. pages 105-123.

Tinker,R.,Schoenberg,S. and Nyland,H.(1994). Educational Technology at TERC.Technical Education Research Centers. Cambridge,MA. pages 48-63.

Wandersee, J.H. (1983). Students' Misconceptions about photosynthesis: A cross-age study. In H. Helm & J. Novak (Eds.), *Proceedings of the International Seminar on Misconceptions in Science and Mathematics* (441-465). Ithaca, NY: Department of Education, Cornell University.

Webb, N.M., (1989). Peer Interaction in small groups. *International Journal of Educational Research*, 13, 21-39.

Wilson, J.(1994). The CUPLE Physics Studio. *The Physics Teacher*.Vol.32,pages518-523

ERIC

SE067932

U.S. Department of Education

Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: Technology Rich Biology Labs: Effects on Misconceptions	
Author(s): Dr. Robert Kuech and Dr. Gregory Zogg, et al.	
Corporate Source: University of Southern Maine	Publication Date:

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents	The sample sticker shown below will be affixed to all Level 2A documents	The sample sticker shown below will be affixed to all Level 2B documents
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 1	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE, AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2A	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2B
Level 1	Level 2A	Level 2B
✓ Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) *and* paper copy.	Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only	Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Signature: [signature]	Printed Name/Position/Title: Robert Kuech	
Organization/Address: 507 Bailey Hall, Univ. of So. Maine, Gorham, ME 04038	Telephone: 207 780-5089	FAX: 207 228 8252
	E-Mail Address: rkuech@usm.maine.edu	Date: 6-20-03

III. DOCUMENT AVAILABILITY INFORMATION (FROM NON-ERIC SOURCE):

If permission to reproduce is not granted to ERIC, or, if you wish ERIC to cite the availability of the document from another source, please provide the following information regarding the availability of the document. (ERIC will not announce a document unless it is publicly available, and a dependable source can be specified. Contributors should also be aware that ERIC selection criteria are significantly more stringent for documents that cannot be made available through EDRS.)

Publisher/Distributor:
Address:
Price:

IV. REFERRAL OF ERIC TO COPYRIGHT/REPRODUCTION RIGHTS HOLDER:

If the right to grant this reproduction release is held by someone other than the addressee, please provide the appropriate name and address:

Name:
Address:

V. WHERE TO SEND THIS FORM:

Send this form to the following ERIC Clearinghouse:

However, if solicited by the ERIC Facility, or if making an unsolicited contribution to ERIC, return this form (and the document being contributed) to:

ERIC Processing and Reference Facility
4483-A Forbes Boulevard
Lanham, Maryland 20706

Telephone: 301-552-4200
Toll Free: 800-799-3742
FAX: 301-552-4700
e-mail: ericfac@inet.ed.gov
WWW: http://ericfacility.org

EFF-088 (Rev. 2/2001)

ERIC
Full Text Provided by ERIC