THE EFFECTS OF PROBLEM-BASED LEARNING ON STUDENT UNDERSTANDING OF ADVANCED PLACEMENT® ENVIRONMENTAL SCIENCE TOPICS

by

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July 2012

DEDICATION

This project is dedicated to my family and friends who have endlessly supported me through acquiring this degree and in my hopes and dreams in life. Their support has been what has driven me this far and has greatly contributed to my success. I would also like to dedicate this project to my students, who without them this project would not have been possible and their willingness to participate in my crazy idea of trying something new.

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ABSTRACT

Often during second semester, I lose the attention of my students due to their preoccupation with being second semester seniors and with college acceptances. This project used student-centered, problem-based learning to regain their attention and make them more accountable for their learning in my AP® Environmental Science course. I also looked at the affect it had on their study strategies, motivation, and metacognition in class, along with my own attitude about teaching.

This project investigated the effect that problem-based learning had on understanding of AP® Environmental Science topics when compared to a traditional teacher-centered lecture based unit. Students understanding of material was assessed using pre and postunit assessments, along with formative assessments, and concept map interviews.

Other methods of data collection were used to understand changes in student's attitudes, study methods, and metacognition in all units. The attitude of students was determined through using attitude surveys and individual interviews. Student surveys along with interviews helped understand the changes in study habits and metacognition. Observations made throughout the units also supplied data to analyze these areas.

Results indicated a mixed effect on each of the areas addressed. In the first treatment unit there was a positive trend, with improvement in attitude, attainment of knowledge of concepts, and metacognition, but in the second treatment the trend was opposite. The same observation can be made with my attitude toward teaching that in the first unit it was more positive while in the second unit it was more negative.

INTRODUCTION AND BACKGROUND

This capstone project focused on the effects problem-based learning (PBL) in an Advanced Placement (AP®) Environmental Science classroom. Before I conducted my capstone project, my classroom had strayed from a student-centered climate to a more instructor-centered climate. Students relied on me to give them all of the knowledge they need to know and did not investigate on their own to enhance their knowledge or to further clarify information covered in class. This led to a classroom lacking in interest and excitement for both the students and me, even though the course tends to be one that is more engaging because of the real-world applications it affords.

I teach at a public high school where there is a mixture of students from different socioeconomic backgrounds with very different educational goals. While a public school, my school has a private school atmosphere. The majority of students are very high achieving with over 1700 AP® exams administered every year and 90% attending a two or four-year institution after high school graduation. Students are often expected to take higher-level advanced courses, like AP® Environmental Science, even if they have not been on the appropriate track for those courses. Furthermore, the students who are typically enrolled in AP® Environmental Science are generally 12th graders and not the typical AP® science student because they will not be science majors but business, political science, or English majors when they reach college. Being seniors, they often lack motivation or interest in the second semester when college admission letters start arriving, even if they are high-performing students. Upon reflection I have noticed that the one thing these students do have in common is that they are accustomed to being told what they need to know by instructors and often do not think independently nor how to learn independently. This leads to a lower level of metacognition, as the students do not reflect on how they think or learn.

The purpose of this project was to shift the focus from me back to the students using a problem-based learning framework through applying case studies. In problem-based learning, students are given poorly structured problems that have many possible solutions, causing them to investigate and analyze the problem to develop their own solution. Since I am teaching an AP® level class, students need to be held to a level of critical thinking and independent learning that is generally lacking in their educational experience. The goal is to have students take responsibility for their learning, become self-reliant learners, and in the end become better prepared for their college experience, through investigation and analysis of difficult, abstract questions and problems

My focus question for this project was, *what are the effects of case-based instruction through problem-based learning on students understanding of AP Environmental Science concepts?* The subquestions of my project were as follows: *what are the effects of using problem-based learning on students becoming independent learners; what are the effects of problem-based learning on students' motivation, and interest; what are the effects of problem-based learning on students' study strategies; what are the effects of problem-based learning on students' metacognition; and what are the effects of problem-based learning on my teaching and attitude toward my students?* I am unaware of any other science teachers using a problem-based learning approach in their classrooms at the school where I teach, so this project may illustrate a different approach that others can use.

To help me explore these questions in my project, I had a support team of people to aid in completing my project and refining the ideas of my project. Members of my support team include, Kathy Crain, an assistant principle at Memorial High School (MHS). She is a former English teacher who gave feedback on the actual writing content of my project. Dawn Cole, a former assistant principle at MHS, who was very familiar with my project due to many discussions we had the prior year and was always very supportive and willing to give feedback. My last team member was Michelle Marcil, a current science teacher at MHS and a graduate of the MSU MSSE program. I felt Michelle was able to give me valuable guidance on the science aspect of my project along with feedback on the MSSE side of the project. My MSSE Capstone Graduate Committee consisted of Dr. Jewel Reuter, my MSSE capstone advisor, and Dr. John Winnie Jr. of the Department of Ecology at Montana State University, my project reader. All members were able to supply me with valuable and insightful feedback on the progress and direction of my capstone project.

CONCEPTUAL FRAMEWORK

After having reviewed the literature on problem-based learning**,** I summarized a brief history of the use of this technique and its usefulness in secondary education. I concentrated on studies that showed evidence of improving independent learning in students and increasing critical thinking. These studies seem to support my project questions and give evidence that this teaching technique is effective.

Problem-based learning is a style of constructivist teaching that is often used in medical schools and in higher education. It is a very popular approach because it develops students that are flexible thinkers and are more apt in dealing with real-life problems (Gallagher, 1997). This is especially important when training students to become doctors, where their primary goal is to solve real-life unstructured problems, problems with missing pieces of information that have multiple outcomes or answers. Students need to have experience dealing with problems that mimic real life to help strengthen their reasoning and problem solving skills.

The above are among the reasons why problem-based learning is a popular method to use in advanced studies; however, it has only recently reached the realm of secondary education (Birch, 1986). Mostly tied to education of gifted students and a way to differentiate learning, problem-based learning has become a popular instructional trend in secondary education because of its constructivist ideas (Gallagher, 1997). In constructivist learning students gain new knowledge from personal experiences and link the experiences with prior knowledge resulting in knowledge gain. Since students are often used to getting all of the facts up front and rarely have to search for the information themselves, they are not accustomed to constructivist learning. Also, students who are often focused on just acquiring content due to emphasis on standardized tests and basic assessments do not have to expand their higher order thinking skills nor necessarily know how to use those skills (Dods, 1997). Loyens et al. (2006) discuss that first-year psychology students rely on their preexisting knowledge of learning through lectures and that it can have lasting effects. However, students with constructivist thinking experience were more inclined to practice cooperative learning and apply knowledge, and tended to have greater academic success. Loyens' study shows the influence prior education and concepts of learning can have on students' performance in higher education and even in chosen career fields.

Through problem-based learning, understanding in subject areas is enhanced in a high school setting. For example, students in a 10th grade biology class had a better understanding of scientific concepts when taught using problem-based learning through patient case studies compared to a traditional lecture-based course. While these students' acquisition of knowledge increased, so did their confidence in understanding concepts and their attitude towards the course also became more positive (Sungur, Tekkaya, & Geban, 2006). Dods (1997) discusses that problem-based learning resulted in more in-depth learning and emphasized a deeper understanding of concepts, with a group of 29 seniors and one junior taking a biochemistry course, instead of memorization**,** which is more common in traditional lecture-based classes. Another study showed that high school sophomore students in an American Studies course using a problem-based approach, while not necessarily scoring better than those in a traditional setting, did retain knowledge for much longer and have a deeper understanding of the concepts (Gallagher & Stepien, 1996). These studies support the concept that through problem-based learning in a high school setting one can help improve students' understanding of concepts and better prepare them for higher education regardless of their focus.

A major goal of problem-based learning is to develop students into independent learners, where they can take the appropriate steps in solving a problem and see the different routes they can take to reach a solution. Sungur et al. (2006) showed that problem-based learning can develop learning skills that students will utilize throughout their lives because the ill-structured questions often relate to life experiences and real world issues. It also develops problem solving and thinking skills that are more ordered, which eliminates solutions that are disconnected from the problem. Students are able to reason through a process to find an answer and take the necessary steps to learn the knowledge to get them there (Gallagher, Stepien, & Rosenthal, 1992).

Problem-based learning also helps develop students into self-regulated learners where they become the focus of a student-centered classroom, which results in higher achievement and success than students in traditional teacher-centered classrooms (Sungur & Tekkaya, 2006). By becoming independent learners, students are better able to tackle not only what happens in the classroom, but are better prepared for real life experiences and what awaits them when they enter college and beyond.

By using real-world problems and situations, problem-based learning may also affect the students' motivation and interest in the class at hand. Ideally, a well-developed problem-based learning unit will motivate students to go beyond what is generally expected of them in a traditional classroom (Gallagher, 1997). Also, students who develop and learn to become self-regulated learners tend to be more interested and motivated in their course work. These students study for reasons beyond just content acquisition, they study for understanding and general interest (Sungur & Tekkaya, 2006). However, there have been cases where motivation has not changed or has actually decreased with problem-based learning. Loyens et al. (2006) theorized that the chance of failure to actually come to a solution with a problem along with lack of confidence in being able to acquire knowledge can lead to demotivation of some students. The students though have to be willing to risk failing and the teacher needs to be a guide to ensure that failure does not happen, or that failure is viewed as an often necessary step in the learning process and is not to be feared. If developed and implemented correctly, problem-based learning should increase motivation, interest, and study habits that are more student-centered than would occur in a traditional classroom (Birch, 1986).

The potential to increase the metacognition of students is another benefit of the problem-based learning process by encouraging them to analyze their thought processes and how they go about solving problems. Problem-based learning focuses on metacognitive processes by tying in the material being studied with environmental cues and collaborating with peers (Sungur, Tekkaya, & Geban, 2006). It creates an environment where students must participate and work collectively in various roles to reach a goal. By using metacognitive strategies developed in problem-based learning, students are more likely to collaborate with peers and tend to apply more previous knowledge to handling solutions to novel problems (Sungur & Tekkaya, 2006). Through this process, students develop deeper and more critical thinking skills and are able to realize how connected problems are to real life experiences (Gallagher, 1997). This is especially important in a class like AP® Environmental Science, where content topics are often in every day news headlines and can directly impact the students, requiring them to think about what they think of these topics and what actions they can take individually.

In a classroom where problem-based learning is taking place, the teacher takes on an entirely new role; the teacher no longer plays the part of the instructor or the expert, the teacher is now a model, a guide of knowledge. The teacher should model how to learn and explore difficult questions. He/She should also be a coordinator of information and help guide the students in their task by asking metacognitive questions to ensure they explore all possible avenues (Sungur, et al., 2006; Sungur & Tekkaya, 2006; Gallagher, 1997). This allows the teacher to focus more on the goals of learning in the classroom and aids students in their own acquisition of knowledge since the student is now responsible for their own learning (Gallagher, 1997). The teacher is a critical part of success and through supporting the students the teacher helps to ensure their success and aid the students if they get off track (Sungur & Tekkaya, 2006). Classrooms vary though; the teacher can play either a very active or passive role in a problem-based learning unit. It is not practical to have an entire course revolve around problem-based learning, especially in high school, so the teacher must decide on how to use this technique best in his or her classroom (Gallagher, 1997). This shows that using this method of teaching can have an effect on the attitude towards teaching by changing up the classroom environment and altering the role of the educator within the classroom.

The key to successful implementation of problem-based learning into the classroom is careful selection of the problem being explored and proper facilitation of the problem. When selecting a problem to implement in a classroom, it is important to choose one that can be directly related to a real world situation or event (Lambros, 2004). This type of problem will further the students' interest and engagement in finding a solution and accomplishing the desired learning objectives. The facilitator must be able to guide students to a solution to the problem without giving them the direct pathway to reach it. One way to ensure this is to divide the class into small groups that contain students that are various types of learners using a learning style inventory to assign groups. Students then can use each other's learning styles and techniques to explore the problem being presented. When the facilitator is asked for guidance, it is important to use open-ended questions to help them toward their own solution (Lambros, 2004).

In summary, while problem-based learning is relatively new to the secondary education field, it has great potential to help students succeed within the classroom. Primarily, students gain a deeper understanding of the content while also excelling academically. Students become independent learners who are highly motivated and interested in the subject while also increasing their critical-thinking skills and metacognitive processes. In a problem-based classroom, the teacher takes on a new and unique role as a guide to aid the students through their quest for independent knowledge and ultimately transition a classroom from being teacher-centered to student-centered.

METHODOLOGY

Project Treatment

In this project I used a nontreatment unit and treatment units with the same students as a comparison. The nontreatment unit covered nonrenewable mineral and energy resources and the environmental impacts of use. There were two treatment units. The first treatment unit covered energy efficiency and renewable energy resources and their impacts on the environment. The second treatment unit covered the different forms of air pollution, both outdoor and indoor, and their effects on the environment and society.

The nontreatment unit consisted of the traditional instructional methods I normally implement in the classroom. I opened this unit with a lab activity on mineral extraction and resource consumption that can be found in Appendix A. For this unit I lectured using a PowerPoint for a total of five days spread throughout the unit. Students developed a presentation on a specific nonrenewable energy resource in groups of three and then presented it to the class. This assignment can be found in Appendix B. Other assignments during this unit included energy math practice worksheets the students, which were completed outside of class and a series of workbook review pages covering nonrenewable resources. During this unit, I administered one quiz and a summative assessment test at the end of the unit. I also used a pre and postunit assessments to serve as comparison with my treatment units.

In the treatment units, I introduced a problem-based learning style situation using case studies for the students to explore and solve in groups of four to five students. Problem-based learning consists of a poorly-structured problem that has many possible answers to the situation allowing students to expand their thinking and to approach a solution to the problem in an infinite number of ways. The groups consisted of students with various learning styles, assessed by using the Center for Innovative Teaching Experiences (C.I.T.E.) learning style inventory, seen in Appendix C**,** they took at the beginning of the nontreatment unit, and each student was assigned a specific role in the group (Babin, Burdine, Albright, & Randol, 1976). The four roles were manager, recorder, communicator, and researcher. For the two treatment units, students were assigned into different groups but still played the same role due to their learning style. After introducing the problem, I lectured only two days on basic concepts that the students needed to have background on in order to be successful with working on the problem. Students were given a series of articles and web resources to utilize and guide them toward solutions to the problem after the lecture. Laboratory activities were also carried out, but were more guided-inquiry activities when compared to the one in the nontreatment unit. In these lab activities, students asked their own questions and developed their own hypothesis, then carried out the experiments to find if their hypothesis was correct. Again, I used pre and postunit tests to assess prior knowledge and see how much their knowledge improved along with a summative exam at the end of the unit to assess complete learning of the material.

Treatment unit 1, on renewable energy and energy efficiency, I created a case study that is found in Appendix D. At the beginning of the unit, I did a brief lecture, during one class period, on the concept of renewable energy and energy efficiency in order to give the students an overall background on the concepts. I then introduced the problem they were to explore and passed out the supporting case study story for them to research that night. When they returned to class the next day, I assigned them to their project teams and explained the goals they needed to meet for this unit including the various laboratory activities they were expected to perform.

In this treatment, part of the problem the students needed to solve was finding new sustainable energy resources for a town that was destroyed in a natural disaster. One of the options to be explored was wind power. In this guided-inquiry activity, students went through different explorations to test the design of various shapes, numbers, weight, and angle of blades had on the energy output and efficiency of a wind turbine. Students used materials from home, a model wind turbine motor and base to create their designs. To aid them in their designs, students were given a booklet from the National Energy Education Development (NEED) Project covering wind turbine blade development to guide them in their design and development (NEED, 2011). This booklet helped to guide the students to look at the different variables involved in blade design, listed above, to create their own unique and best design of a wind turbine. Throughout the wind turbine development, students also analyzed the typography of Joplin, MO to determine if this is a valid option to use as a renewable energy resource in this area. This activity took three class periods for construction and trials to test for the best design of a wind blade. At the end of the activity, students created a summary of their findings to include in the sustainability report they are developing in this case study. Other activities exploring various renewable energy sources like hydrogen as a fuel source, solar energy, and insulation effectiveness were performed as well.

In the second treatment unit on air pollution, students solved two different problems instead of one in the previous treatment. I started the unit with a short lecture highlighting the important background concepts the students needed to proceed with solving the problems they were given. In one problem-based lesson, I placed students in the role of an advertising firm that has been hired by the Department of Health to create an ad campaign highlighting the dangers of air pollutants. Within their groups, students selected a pollutant to research and developed a multimedia advertising campaign for their pollutant. Through this activity students had to research the harmful effects of the pollutant along with its source. They were also required to design a campaign that brought complex scientific information down to a level a lay person would understand making them use higher-order reasoning skills to do so. Other activities in this unit included a study on indoor air pollutants and the effects of smog on health.

This treatment was helpful to answer my project questions because of the implementation of problem-based learning in each unit. This type of treatment, using problem-based learning, creates an ideal situation where students have to become independent learners making it an ideal treatment to use. Every unit will have a different problem associated with it so I think that by the time I implement my third treatment that the students will have a good grasp on how to use problem-based learning and will be on their way of becoming independent learners.

Data Collection Instruments

The class I used to collect data is my AP® Environmental Science (APES) course. The students enrolled in the course have a mixture of skill and knowledge levels. Some students have been enrolled in preAP/AP courses throughout high school while, for others this is their first AP® level course. Most students will not be entering a field of science when they enter college, which is atypical of students normally enrolled in an AP® level science courses. Due to this most students do not understand the level of outside work and critical thinking associated with an AP® level science course. Since it is expected that the students need to be independent learners and have a high level of critical thinking in an AP® science course, I chose my AP® Environmental Science students to be the sample in this project. I implemented the treatment in the two sections of the course, which consisted of 61 students in total, 60 in grade 12 and 1 in grade 11. Nineteen boys and 42 girls are enrolled in the course. All students get along well and appear to work well together in group activities. There are a few who do not typically pull their weight in group projects but other members of the group compensate for them or eventually they will step up and do their part. As a whole the students are interested in the APES course but are not the most willing to put in the work to fully understand the topics. They are very interactive and are willing to ask questions and participate in lecture, which is why I think problem-based learning was a good choice to work with this group. The school is public, located in Houston, TX and in a fairly prosperous suburban area. The student body is made up of primarily middle to upper middle class students with some lower income students.

To triangulate data, I collected various types of data to support answers to my focus question and subquestions. The data triangulation matrix for this project can be found in Table 1. By utilizing pre and postunit tests, I was able to assess students' prior knowledge before starting a unit and then assess advancement of knowledge after the unit by administering the same test as a postunit test. Through interviews I was able to assess students' attitudes towards the lesson and material and the effects it had on the way they study and interact with their peers. Surveys allowed me to assess attitudes from the overall class instead of just a select group of students. Attitude surveys were used to assess my attitude about how the lesson was going and the level of participation from the students. I also kept a journal about my experience to see if there were any changes in my feelings toward the project and my students through the implementation of the project.

My focus question was centered on how problem-based learning would affect my students' understanding of APES content. Prior to each unit, treatment and nontreatment, a preunit exam was administered covering important concepts within the unit. After the unit was complete, a postunit exam was then administered for each of the nontreatment and treatment units. The same questions were asked of the students for both the pre and postunit exams. The questions used for the nontreatment unit can be found in Appendix E and the questions used for both treatment units can be found in Appendix F.

Table 1
Data triangulation matrix

Project Questions	Data Source 1	Data Source 2	Data Source 3
What are the effects of problem-based learning on students understanding of AP® Environmental Science concepts?	Pre and postunit assessment	The Minute Paper	Pre and Postunit Student Concept Interview
What are the effects of using problem-based learning on students becoming independent learners?	Pre and Postreatment Student Surveys	Pre and Postreatment Individual Student Interviews	Pre and Postreatment Observational notes
What are the effects of problem-based learning on students' motivation, interest and study strategies?	Pre and Postreatment Attitude Scale/Survey	Pre and Postreatment Student Interviews	Pre and Postreatment Observational notes
What are the effects of problem-based learning on student metacognition?	Pre and Postreatment Observational notes	Pre and Postreatment Student Surveys	Pre and Postreatment Student Interviews
What are the effects of problem-based learning on my teaching and attitude towards my students?	Personal Journal	Personal Survey	Attitude scale

The second source of data to address my focus question was a type of formative assessment, the minute paper, to assess the students understanding and conception of certain material in both the nontreatment and treatment units. The prompts used for the minute papers can be found in Appendix G. These formative assessments were administered to the entire class midway through the unit to check for levels of understanding of certain main ideas.

For the third source, I gathered data through interviews to address my project questions concerning understanding of APES concepts, motivation, metacognition, and independence of learning. I selected students to participate in an interview based on their class performance. I selected three students who were high-performing, three who were midlevel performing and three who were low-performing students. I asked students if they would be interested in participating in an interview about the project and if they declined, asked another until I filled the spots I needed. I used two types of interviews, concept interviews and attitude interviews about learning and going to class. In concept interviews, which can be found in Appendix H and I, students were asked pre and postunit to develop a concept map using a list of key terms supplied to them. They were then asked to explain their concept map. Concept questions were asked of the students only postunit since these questions are very specific and would be difficult to answer without any prior knowledge.

All students were asked the same set of interview questions before and after the treatment units, which can be found in Appendix J. Students signed up for a time either before or after school to conduct the interview. I used a tape recorder to record the interview as well as took notes during the interview process. Through interviews I was able to collect direct feedback from the students about their attitudes toward each unit and how it impacted their study habits and feelings about the course.

The fourth data collection source was surveys to support my questions on students becoming independent learners, metacognition, and their attitude. These surveys were used to receive feedback from all students in the course during each unit, nontreatment and treatment. The pretreatment survey was administered on the first day of the nontreatment unit and the postreatment survey was administered on the last day of the unit. Each survey consisted of Likert scale questions along with some open-ended questions. A copy of the pre and postreatment surveys can be found in Appendix K. The survey allowed me to see how study habits and independent learning changed or did not change from unit to unit. A second survey concentrating on attitude toward school, class, and learning was also administered (Appendix L) to all students. This survey consisted of 20 questions, based on a Likert scale in order to collect quantitative data on the students' attitudes and trends of their attitude through both the nontreatment and treatment units.

The last data collection instrument I used was to support my question on students' development of becoming independent learners and their motivation and interest in APES. Using observational prompts (Appendix M), observations were made by me while students were doing active group discussion work and lab activities during the nontreatment and treatment units. I did at least two planned observations during each of the units. Through these observations I was able to see the different levels of participation and the utilization of the assigned roles in each group. I was also able to monitor the focus of each group and gauge the level of thinking students were at by the questions they asked each other.

The final subquestion in my project was about the effects problem-based learning on my attitude and teaching in the classroom. Using constructed open-ended prompts (Appendix N), I made a journal entry after school three times a week, Monday, Wednesday, and Friday to monitor my general thoughts and feelings about how the nontreatment and treatment units were going. The attitude survey, found in Appendix O, was taken weekly on Friday, which is normally is my lowest point of energy and morale during the school week. The survey consisted of 10 questions answered using a Likert scale. I did this through both the nontreatment and treatment units to serve as a comparison between the two.

All data collection instruments have been designed to collect a mixture of qualitative and quantitative data. Likert scale questions served as a means to compare pre and postreatment in a quantitative means to see if there was a numerical difference between the units in attitude and academic performance using the pre and postunit exams. Open-ended survey and interview questions along with observational notes served as mechanisms to collect qualitative data and acquire students' comments and thoughts on the techniques being used in the class.

A timeline for the implementation of the project can be found in Appendix P. This project will cover units that are equal in difficulty and are units that are normally lower scoring in the AP® Environmental Science course because of the topics they cover and that they are discussed at the beginning of the second semester, which normally shows lower performance over all.

DATA AND ANALYSIS

Data from the nontreatment and treatment units were collected and triangulated to determine the effect of problem-based learning on learning AP® Environmental Science concepts. Using pre and postunit assessments allowed for a comparison of the improvement on learning AP® Environmental Science concepts in each unit. These data are displayed in Table 2 below. For each individual unit the same set of questions was used for the pre and postunit assessments. The assessments can be found in Appendices H and I.

Table 2
Average Scores of Preunit Assessments and Postunit Assessments for Nontreatment Unit and Treatment Units (N=61)

Description of Data	Nontreatment Unit (%)	Treatment Unit #1 (%)	Treatment Unit #2 (%)
Preunit assessment Average Score	16	17	7
Postunit assessment Average Score	65	65	54
Percent Change	306	282	671

In all units there was a gain when comparing the pre and post unit assessment average scores. The preunit assessments for the nontreatment unit and the first treatment unit were more than double the average score for the second treatment unit. One reason for this is that the nontreatment unit, nonrenewable resources, and the first treatment unit, energy efficiency and renewable energy, were units that the students already had previous knowledge of from previous courses. The first treatment unit also had a higher preunit assessment score than the nontreatment unit likely because many concepts in the nontreatment unit were ones that laid a foundation for material covered in the first treatment unit. The second treatment unit, air pollution, was material that most students had no prior knowledge of and had many misconceptions about it. In treatment unit two the average preunit score was very low further emphasizing the lack of prior knowledge in that content. Both the nontreatment and treatment unit postassesements had scores of only 65% and still had room for additional improvement.

The largest change between pre and postunit assessment was seen in second treatment unit at 671%. While the postunit average score was lower than the other two units, the largest amount of growth took place between the pre and postunit assessments of treatment group 2. With an average score of 54 on the postunit assessment, this suggests that the students still did not fully grasp the content they were supposed to cover, especially when comparing it to the postunit assessment average scores of the other two units. While two students scored high on the postunit assessment, 90 and 100, 13 students scored below a 40 on the assessment further suggesting the lack of understanding of the material.

The first treatment unit showed the lowest change between the pre and postunit assessments with a percent change of 282%. There were only 5 scores though below 40 and five scores at or above 90 suggesting a better level of understanding of the material than compared to the second treatment unit.

With a percent change of 306% between the preunit and postunit assessments, the nontreatment unit showed the second highest level of change. The postunit average score though was identical to the first treatment unit postunit average score. There was not a large difference between these two units in the amount of learning that had taken place. In the nontreatment unit the postunit scores were similar to the distribution found in the first treatment postunit assessment.

The second source of data collected determine the effect of problem-based learning on understanding AP® Environmental Science concepts was using pre and postunit student concept interviews with two low-performing students, two midperforming students, and two high-performing students. The results from the scored concept maps can be found below in Table 3. The questions used in the concept interviews can be found in Appendix H and I. Concept maps were scored using the rubric found in Appendix R.

Table 3
Concept Map Scores Preunit and Postunit for Nontreatment Unit and Treatment Units (N=6)

Student	Nontreatment Unit			Treatment unit #1			Treatment Unit #2		
	Pre score	Post score	% change	Pre score	Post score	% change	Pre score	Post score	% change
Low 1	18	39	117	12	37	208	20	24	20
Low 2	24	40	67	16	20	25	18	20	11
Mid 1	34	77	126	20	30	50	23	33	43
Mid 2	31	46	48	18	26	44	18	27	50
High 1	45	87	93	29	45	55	32	70	119
High 2	96	148	54	45	96	113	42	76	81

Note. Low 1 = Low-performing student #1, Low 2 = Low-performing student #2, Mid 1 = Midperforming student #1, Mid 2 = Midperforming student #2, High1 = High-performing student #1, High 2 = High-performing student #2.

Some interesting trends were noted when looking at the concept map interviews between each of the performance levels and units. All the postunit scores were in line with the expected performance level of each of the students with the low-performing students having the lowest scores and the highest students have the highest scores for almost all units. The only exception to that was in treatment unit #1 where low student 1 out scored both mid students. This trend could be due to the fact that both high students and one mid, mid 1, had previous experience using concept maps while the other students had no prior experience to using concept maps and were not aware of what a concept map was and how it is useful. One observation was when both mid and low students made their concept maps, in all pre and postunits, they were very unsure and self-conscious about getting them “wrong” even when I explained to them there was no wrong way to make them. All of them were very unsure of the process and how their maps turned out.

They were not able to soundly explain neither their process nor why they put connections and certain words in certain spaces. Both high performing students constructed their maps quickly and were able to elaborate on them with more vocabulary and pictures. Often they would draw pictures and include many defining points to further explain the connections. It was more common for them to do this in the postunit concept map showing a solidification of knowledge on the unit.

Figure 1 illustrates distribution of the percent change between the pre and postunit scores for each student. It appears that the highest values were mostly seen in the nontreatment unit. Two students, low 1 and high 2, had the highest percent change seen in the first treatment unit while high 1 had the highest change in the second treatment unit. This data suggests that problem-based learning appears to help some students understanding of environmental topics but not all. It also seems to depend on the topic at hand as well. For some students, standard lecture based instruction worked the best at helping them understand environmental topics and see the connections between them.

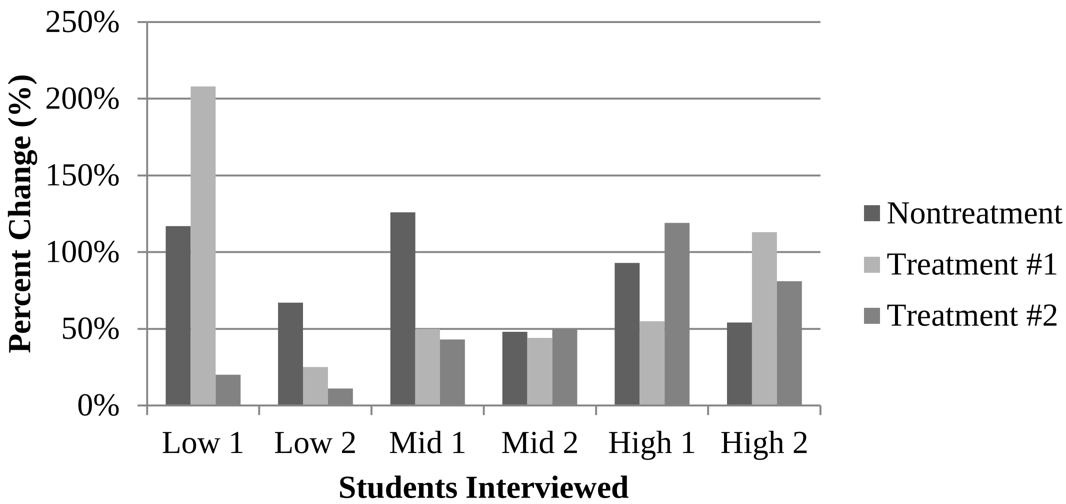

Figure 1. Percent change of concept map construction for students between nontreatment and treatment units, (*N*=6). *Note.* Low 1 = Low-performing student #1, Low 2 = Low-performing student #2, Mid 1 = Midperforming student #1, Mid 2 = Midperforming student #2, High1 = High-performing student #1, High 2 = High-performing student #2

A third source of data collected determine the effect of problem-based learning on understanding AP® Environmental Science concepts was using a formative assessment, the 5 minute paper, to check for students' understanding of unit concepts based on what they felt was important in the unit. The questions used in the formative assessment can be found in Appendix G. Figure 2 shows the distribution of responses in to the first nontreatment unit question, *What is the importance of nonrenewable resources and why?*

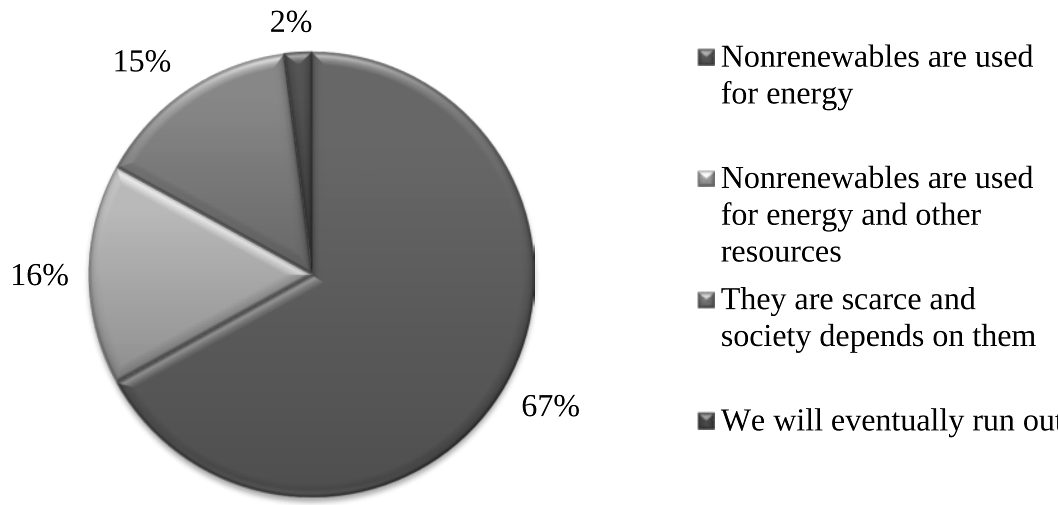

Figure 2. Percent of student responses to the first nontreatment formative assessment question: What is the importance of nonrenewable resources? (*N*=61).

In the nontreatment unit the majority of students said that the reason for the importance of nonrenewable resources was energy. One student stated “Nonrenewable resources are important because they can be used to generate energy with ease” while another commented “Nonrenewable resources are important because many of them are key providers of electricity and transportation.” While not incorrect these answers are not very in-depth and miss the aspect that nonrenewable resources are used for more than just energy. Some students commented on the importance of these resources for more than just energy showing a deeper understanding of the use of nonrenewable resources. A student commented that nonrenewables were important because “Nonrenewable resources are the source of almost every product in use today. Wiring, my pencil, store tables, the metal frame of a building, all come from nonrenewable resources.” Societies dependence and the scarcity of nonrenewable resources were the reason other students said they were important. A vague but understandable statement one student said “the importance of nonrenewable resources is that they help in our everyday lives… we use them every day in a plethora of ways." While another student clearly indicated their importance because of scarcity and cost, "Nonrenewable resources are important because of their finite quantities. The greater the need for a resource and the hard the resource becomes the values of the resource also increases." There was only one student who incorrectly stated that they were important because we will eventually run out of these resources. Overall the students appeared to get the general idea that these resources are scarce and important for many goods in our society, especially energy. Most though did miss the point that nonrenewable resources are more than just energy sources.

In the first treatment unit, the first question students were asked was, *why were renewable resources important?* Two responses were most common, as can be seen in Figure 4 below. The first, *we won't run out of them and they are more sustainable* while the second was, *because they pollute less/are cleaner/better for the environment than nonrenewables*. Some example responses include: "Renewable energy resource are important for their rate of renewal, which allows there to be more of them through the smaller amount of time needed to renew them compared to the time needed for nonrenewable resources to be created." "Renewable energy sources are important because they are better for the environment (often less air pollution) we do not degrade the earth as much to obtain them." Some students responded that renewables were important because nonrenewables would run out. "Renewable energy is important because it is the only option to have if we deplete our nonrenewable reserves which we eventually will. It can essentially support us forever b/c the resources are renewable."

There were a couple students who said that renewables were economically cheaper but did not explain themselves showing a lack of full comprehension of the topic.

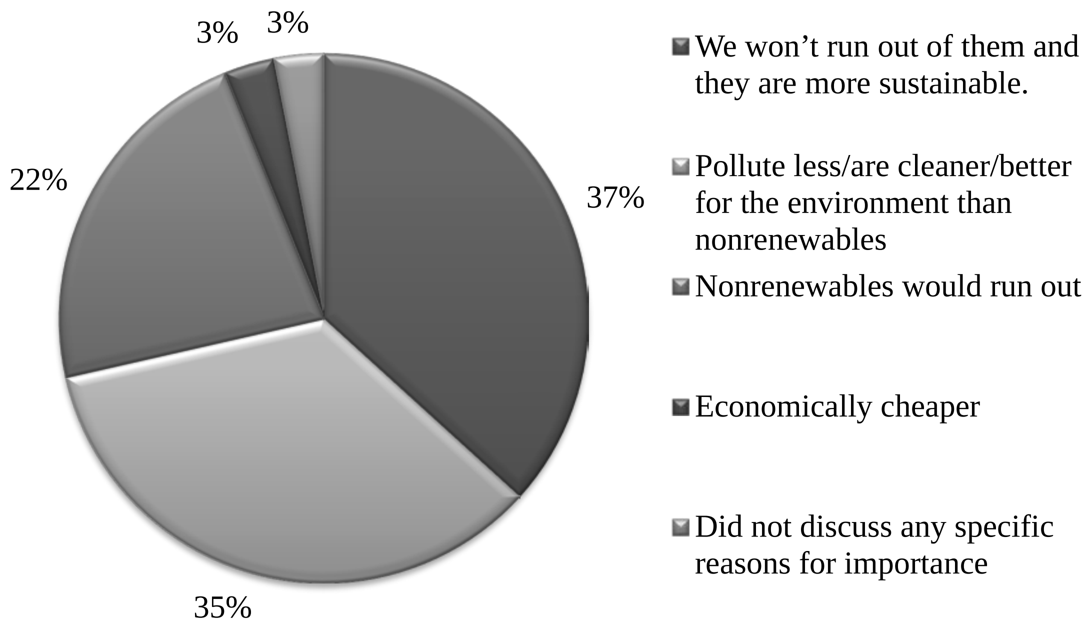

Figure 3. Percent of student responses to the first treatment formative assessment question: What is the importance of renewable energy resources? (*N*=58).

In the second treatment unit students were asked two basic questions about air pollution, *why is it a problem* and *which pollutant is the worst?* For the first question most students answered vaguely with only 18 students giving specific health and environmental affects while 14 students answered with some detail. For example one student answered with great detail, “It causes a wide range of health conditions including lung cancer and chronic bronchitis. It also affects vegetation and fisheries. Leaching of toxic metal into soil hinders plants ability to uptake nutrients. This can result in lower food production rates.” Compared to another student who had the general idea but did not go into great detail, that “it causes negative effects on peoples and animals health, can cause cancer, destroys ecosystems and diminishes the quality of the earth for future generations." There were 10 students who commented on that it affects environment and health but that was all they said, there was no detail while, some students concentrated on only human health issues, five students, while others, four students, concentrated on only environmental issues. Four students incorrectly said that it is depleting the ozone layer, which for the type of pollutants that were discussed was very inaccurate and shows a common area of misunderstanding in environmental science.

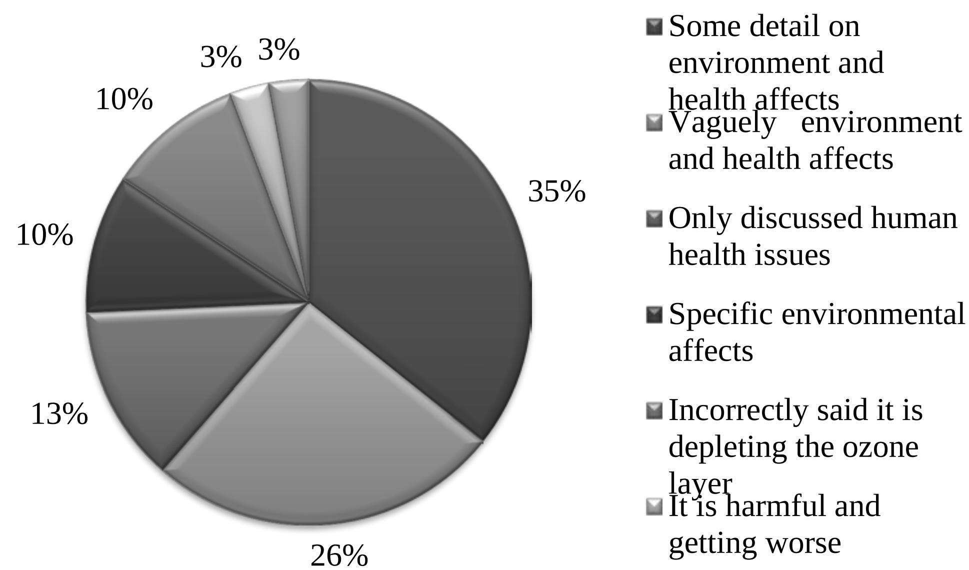

Figure 4. Percent of student responses to the second treatment unit, first formative assessment question: Why is air pollution a problem? (*N*=57).

When comparing the nontreatment to the treatment data for the formative assessment, some patterns can be seen. The most notable difference when looking at the responses to the questions is the number of different and type of responses given. In the nontreatment unit, responses tended to be very specific and not very in-depth. Not too surprising, they centered a lot on what was lectured on in class. The treatment units though, had more variation in the number and types of responses given. These data show a difference between memorizing and repeating what is thought to be the correct answer versus thinking about what they had learned independently. The students had no “right” answer to go by in the treatment units so they were more open to answer based on how they interpreted information from the research they did on their project. This is a fine line though, because, students can start going down the wrong path with information so you have to be aware of where they are going and help guide them back to the right path. Further data showing this trend for the other question asked in the formative assessments can be found in Appendix Q.

To answer the subquestion what are the effects of using problem-based learning on students becoming independent learners, data from the nontreatment and treatment units was collected and triangulated. Observational notes were made during all units on student’s engagement and participation in class. Prompts for the observational notes can be found in Appendix M. Table 4 below shows the data for the average number of students who were actively engaged and those that were not participating during observed class time. Looking at the data there was no difference between the nontreatment unit and the second treatment unit in the number of students engaged and those that were not participating. In the first treatment unit though, most of the students were engaged and actively participating in the activities.

Table 4
Average Student Engagement and Participation in Treatment and Nontreatment Units (N=61)

	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
How many students were engaged	20	28	20
How many students were not participating	10	2	10

Other observations gathered during both the nontreatment and treatment units included how the students were working together and evidence of higher order thinking skills. In the nontreatment unit most students worked exclusively by themselves with very little interaction and communication between their laboratory partners. In the first treatment group, the exact opposite was observed. Students were actively discussing how they were going to approach the problem they were given and dividing up the work amongst each other. There was a sense of collaboration between them that was missing in the nontreatment unit. Another observation was that students were more willing to ask questions about the content and ways to approach the problem and the laboratory activities. In a typical day during the first treatment, I would field at least five questions or more from each lab group while during the nontreatment I was only getting one to two questions from each group. This questioning showed me students were going more in-depth with their research and it resulted in questions that showed higher order skills and processing. In the second treatment unit though, this all was lost. Students were not as focused, did not stay working with their assigned groups, they were not working on the problem and had essentially stopped asking questions. It is possible the students were not as interested in the second treatment topic, which led to a decline in their work quality from what I had witnessed in the first treatment unit.

To answer the subquestion what are the effects of problem-based learning on students' motivation, interest, and study strategies, data from the nontreatment and treatment units was collected and triangulated. Prior to the nontreatment unit and after both treatment units, students were administered an attitude survey where they ranked their attitudes for 20 different statements. The attitude survey can be found in Appendix L. A summary of the data can be found below in Table 5. Overall, the data indicate that the treatment or the student's anticipation of graduation caused a decrease in student attitude.

Table 5
Average Attitude Survey Responses for Nontreatment and First Treatment Units (N=60)

Attitude survey question	Nontreatment Unit	Treatment Unit 1	Percent Change (%)
I like to go to APES	3.43	3.14	-8.67
School is very boring for me	3.15	3.14	-0.46
Getting good grades in APES is important to me	3.92	3.80	-3.07
APES doesn't matter since I've applied to college	2.48	2.54	2.38
I enjoy learning new APES information	3.42	3.39	-0.79
I know how I learn best in APES	3.32	3.63	9.36
I like environmental science	3.37	3.32	-1.33
I enjoy APES more than I thought I would	3.52	3.10	-11.80

Note. 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree
APES stands for AP® Environmental Science

Based on the percent change in these responses, it can see that overall there was a trend towards more negative attitudes from the start of the nontreatment unit to the end of the second treatment unit. The appeal of the course itself and the enjoyment of it both dropped 1.33% and 11.80% respectively. Also dropping was their perception of the importance of getting a good grade in APES by 3.07%. There was a more positive trend, 2.38% increase, on the student's thoughts of the class mattering or not since they had now applied and in most cases gotten into college suggesting they were leaning more towards agreeing that it did not matter anymore. Another interesting positive trend was that the students increased by 9.36% in their thinking they know how to learn best.

The level of motivation seemed to continue to drop as can be seen in the data from Table 6 below. Motivation decreased but most students moved to either a medium level of motivation or a very low level of motivation. There were no increases in motivation noted.

Table 6
Level of Motivation for Nontreatment (n=59) and Treatment Units (n =56)

Unit	Current Level of Motivation %				
	Very High	High	Medium	Low	Very Low
Pretreatment Unit	8	24	46	17	5
Posttreatment Unit	5	23	50	13	9

Correlating with the level of motivation, the amount of studying also dropped between the nontreatment and treatment units as can be seen in Table 7 below. Further compounding the lower level of motivation and studying, 25% of students said they were studying less than normal while 40% said they were studying more than normal at the end of the second treatment unit. This is contradictory to the information in Table 6 where students appeared to be studying fewer hours a week. There appears to be a disconnection between how much a student studies and how much they think they are studying each week.

Table 7
Percent of Students Studying for Different Hour Intervals in Nontreatment (n=59) and Treatment Units (n=56)

Unit	Number of Hours Studied (%) 1 - 2 hours	3 - 4 hours	5 - 6 hours	7 or more
Pretreatment Unit	29	51	17	3
Posttreatment Unit	45	38	18	0

Data from the nontreatment and treatment units were collected and triangulated to look at the effects of problem-based learning on student metacognition. As can be seen from Table 5 above, student's perception of knowing how to learn increased by 9.36%. Also in all interviews with students and in all surveys, students always answered that they thought about how they learned. When asked to clarify though, they were confused as to what I meant. Only a few students were able to clearly say things such as "I know that for me to learn the material I need to hear you lecture about it and then go home and read the book." Another student said "I do best when I have a copy of the notes in front of me while you lecture and can annotate it while you are talking. Then I can ask you about what I don't understand in tutorials." So while not all, some students were aware of how they learned best.

When asking students the same questions after the treatment units, responses changed quite a bit. They still responded saying they did think about how they learned but the responses changed to being more aware of the importance lecture was to them. Students seemed to actually be less confident in their own ability to independently learn at the end of the last treatment unit. Most students (30 students) commented that lecture was how they learned best while in the nontreatment it seemed to be more projects, activities and laboratories that they preferred learning through. One comment a student made, “going over topics on the test instead of sifting through useless data in the book” as to why they preferred learning through lecture really showed that students have become reliant on a lecture way of learning. There were a few students though (4 students) who preferred to learn through a lecture laboratory combination. One reason for this was made was, “... because during lecture the teacher explains about the stuff we will learn and during the lab, we get to actually test and see what will happen.”

Lastly, to answer the subquestion what are the effects of problem-based learning on my teaching and attitude towards my students, data from the nontreatment and treatment units was collected and triangulated. A personal journal was kept throughout both the nontreatment and treatment units. The prompt for the personal journal can be found in Appendix N. During the nontreatment unit, there were a few days where I felt excited but the majority of the unit I felt very bored about the class. I was most excited about the very beginning of the unit because I was trying a new lab that I had not done before and felt the students would really enjoy it. The students enjoyed the lab activity and I felt that they understood the concepts that were to be accomplished by doing the lab. As the unit progressed though, this excitement changed very quickly to boredom. I started to get very tired after the class and was losing my voice because of how much lecture I was doing. I had very little interactions with the students; it was mostly me just talking at them. In the first treatment unit I found that I was very excited every day to be in class. The students were working diligently and I felt that they were really doing science with the lab activities for the problem they were working to solve. I was constantly interacting with my students and discussing where their project was going and what they were accomplishing. That excitement was still there at the beginning of the second treatment unit but quickly diminished. I became very stressed and frustrated with the students because they were not working at the level they had in the previous unit. I was doing more reprimanding than discussing where their project was going. I felt very little science was being done and at the end felt like the whole unit was a failure.

These feelings were also reflected in the attitude survey I took at the end of every week. Table 8 below displays the average scores for some of the questions asked in my attitude survey. Between the nontreatment and first treatment unit my attitude about going to work, excitement about teaching, and interacting with my students increased and became more positive. The exact opposite was seen though when comparing the nontreatment and the second treatment unit. My attitude either got worse or did not change. When evaluating my frustration level with how my students were progressing through the unit, my average scores dropped from a 3 to a 2 between the nontreatment and second treatment units. This is a negative percent change of 33.3%. My motivation also saw a decrease from an average score of 3 to 2.67 in being motivated to work.

Table 8
Average Teacher Attitude Scores for Treatment and Nontreatment Units (N=1)

My Attitude	Nontreatment	Treatment 1	Treatment 2
I like to go to work	3	1.33	3.33
I find teaching exciting	2	1.67	2.33
I enjoy interacting with my students	2.67	1.33	2.67
I had trouble motivating myself to come to work today	3	4.33	2.67
I am feeling frustrated by the progress of my students	3	3.67	2

Note. 1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree

INTERPRETATION AND CONCLUSION

Results indicated mixed results for each of the treatment units when compared to the nontreatment unit. In the first treatment unit a positive trend was seen for attainment of knowledge of concepts and metacognition but in the second treatment unit an opposite trend was observed. The same observation can be made with my attitude toward teaching that in the first unit it was more positive while in the second unit it was more negative.

The effects of using problem-based learning on students understanding of AP® Environmental Science concepts was an opposite trend seen when comparing the two treatment units. In all units students obviously gained knowledge as can be seen by the pre and post-unit assessment scores in Table 2. The largest gain in knowledge was in the second treatment unit however in other data sets it was also the area that students had the least understanding of the material as is seen in Figure 1 and Figure 4. On the contrary, the first treatment unit had the lowest gain in pre and post-unit assessment scores and the highest level of understanding as can be seen in Figure 1 and Figure 3. There are a few reasons as to why I believe this is trend is actually not too surprising when looking at the data. The first treatment unit covered energy efficiency and renewable resources, which followed the nontreatment unit of nonrenewable resources. These two units have common concepts and basic knowledge that tie them together. It is very likely that the students were better prepared for the first treatment solely because they had gained enough knowledge from the nontreatment unit to help give them a background on general energy concepts. Also students tend to be more familiar with both of these topics because of media coverage and most of their parents work in an energy resource field. This is evident by the higher pre-assessment scores for both the nontreatment unit and first treatment unit. The second treatment unit though, air pollution, is a topic that most students do not have background on and have many misconceptions about, shown by the low pre-assessment scores. This unfamiliarity of a topic could have caused underlying frustration and lack of interest in a topic leading to a basic regression of interest and motivation for this unit.

The effects of using problem-based learning on students becoming independent learners was again mixed with students being very efficient with their time and owning their learning in the first treatment unit but less so in the second treatment unit. One major difference between the two treatment units that could contribute to this effect was the number of laboratory activities students were expected to do to supplement their learning in class. In treatment unit one, students had to perform three different laboratory activities, two of which that were complete inquiry based and designed by the students themselves. Due to the amount of labs they were expected to complete, students were hard at work almost every day in class working on either designing their lab or working on their project for the problem they were given. Evidence of this is seen in Table 4 where most students were observed as being engaged during the first treatment unit. The second treatment unit though, there was only one extensive investigative laboratory activity the students were required to do. This left much more time in class to work on the problem they were given but many did not work on the project and instead worked on other work or socialized. This shows me that keeping the students busy, with lab work and other things in class, is essential to maintain their interest and motivation in the subject. I also feel it gives them more of a sense of responsibility for their own learning because of the time management that must take place to accomplish all the tasks ahead of them.

The effects of problem-based learning on student metacognition were that students become more aware of how much they depended on lecture to learn information. Their perception of how they learn did increase after the treatment units but it was not in the way of independent learning and more of the direction of dependent learning, which I found disappointing. Students do seem aware of ways they learn best and how to study but to me it seems they do not exactly know how to put this into solid practice to succeed. When given the learning styles inventory at the beginning of the nontreatment unit, all students when asked if they were surprised by their results were not. They knew if they were a visual, auditory, or kinesthetic learner and if they worked better in groups or individually. What seemed to be missing though was how to take this information and make it useful for themselves in studying and progressing in class. Some students who performed poorly were unable to explain exactly what they were having difficulty with in the material. Often I would try to lead them towards one learning problem or another and they would just agree with all of them. What it appeared to come down to though was the level of motivation and interest in what we were covering. During the time of my treatment, students were getting their college acceptance letters and trying to decide where to go the following year. This excitement leads to distraction and lack of focus on the task at hand, resulting in a drop in grades. When investigating their grades in other classes, this phenomenon was not isolated to just my class, there was an obvious trend seen in all of their advanced courses.

The effects of problem-based learning on students' motivation, interest and study strategies was a gain in motivation and interest in the first treatment unit but a reverse in trend back to nontreatment levels, or below, in the second treatment unit. Students study strategies seemed to overall decrease in the amount of studying when comparing nontreatment to treatment units. Again these trends are likely due to reasons discussed in analyzing the pervious questions. An unfamiliar topic can either be very engaging for students or very frustrating and uninteresting. I think with the second treatment unit, this topic just was not interesting to the students and they found its complexity frustrating. This led to a direct decline in levels of motivation and interest during that treatment. The lack of motivation and interest would obviously have a direct influence on study strategies because students are not willing to invest time in learning something they are not interested about, even if their grade depends on it. This also leads to the difficulty of implementing new ideas and strategies in a class with second semester seniors because of their lack of concern about their grades since they are already admitted into college.

The effects of problem-based learning on my teaching and attitude towards my students mirrored that of the student's attitude in the various units. The drop of performance towards the end of the second treatment unit I found greatly affected my attitude about this project and my classes. I became very frustrated with the lack of work and effort taking place in my classes. No matter what pushing I gave them, or reminders, the students were not motivated to work. They also had difficulty in carrying out tasks and solving problems that were open ended and kept looking to me to keep guiding them more than I was willing to. Again, I was frustrated that the students were so unwilling to think on their own and just wanted me to tell them exactly what to do. I rarely do this in class, even in a nontreatment situation, and find it very exhausting and stressful when the students ask me to. I want them to learn how to discover and explain new ideas and information on their own and find it difficult to explain to them why it is important for their future. Overall, I think this could be remedied by slowly introducing the students to the concepts and goals of problem-based learning throughout the year. By slowly guiding them towards independence hopefully when the time comes to a large project, like I did in both treatment units, the students will be more willing to take on the challenge and be more confident and motivated in what they are learning.

In conclusion, I think some very valuable things can be taken away from this study. When students are engaged and interested in a topic problem-based learning can be successful. One way to harness this is to implement case studies at the beginning of the year to introduce students to the style of learning expected out of problem-based learning. I find my students tend to be creatures of habit, so by spontaneously introducing something completely new to them, they had difficulty adapting to it. Through gradual introduction, they would hopefully take to it in a more positive manner and it would be a more successful technique to use in my AP® Environmental Science course. Another change I would consider making is not to have one large problem be the basis of the project for the entire unit. All the learning of the unit depended on the students working on a solution to one or two large problems, making them feel very overwhelmed with the amount they were responsible for. A small problem-based project for only a small portion of the unit would be more manageable for them and lessen the amount of anxiety associated with finding a correct solution, even though there is never one correct solution.

VALUE

This capstone project proved valuable in my growth as an educator and in exposing my students to a different type of learning. I was able to explore a new teaching strategy and share with my colleagues the development of my project and its results. It showed both my students and me the importance of student centered learning and independent thinking. It allowed me to attend a conference on using case studies, a type of problem-based learning, in my classroom and how to write them so they are engaging for students. This conference proved very valuable professionally as I learned different problem-based learning teaching strategies and enabled me to further develop my project and design my own case studies.

Through problem-based learning, I was able to incorporate more real-world situations and expose the students to solving problems and developing projects that have no true correct way of doing things. While it proved frustrating to the students, I believe over time they learned more about how to function as members of a team and gained some real-life experience that will help them in the future. One of my goals as an educator is to make my students better citizens. I feel that through problem-based learning I am exposing my students to situations that mimic what they will experience in their future lives and jobs. Also it makes them responsible for decisions about situations that they are unfamiliar with and requires them to go out of their way to research. While they were not the most open and welcome to the idea, as taken from something a student said in class “I don’t care about the real world, I care about the AP exam,” I think this was more beneficial to them than they realize for their future.

I am looking forward to the new school year and figuring out ways I can implement problem-based learning throughout the year and in my freshman preAP biology class as well. The use of case studies seemed to really pique the interest of my students and made the material more applicable to their lives. Based on the data I have collected though, quickly throwing something new at them was not the best method, especially half way through the year. By starting the year using problem-based learning, slowly integrating case studies and teaching the students how best to use them I think will make their use more beneficial.

I have enjoyed learning this new strategy and implementing it into my teaching. It has showed me how important it is to constantly try new methods of teaching in your classroom and to share this with others in your school. I feel I have grown a lot professionally through learning a new technique of teaching and implementing it in my classroom. My sense of professionalism has also been expanded by having more conversations with colleagues on how to implement new techniques and strategies in the classroom. I now plan on submitting professional development courses about problem-based learning that I can share with other teachers in the district. Trying new methods can be intimidating and not always well received by students and the administration but we, as educators, have to realize the importance of taking that risk. By trying new things, we better ourselves as educators and model lifelong learning to our students. We also demonstrate to our students how trying new things is good even though it can be difficult.

In the end, I learned much about myself as an educator and a lot about how my students approach their ways of learning. I found the MSSE program to be extremely valuable in expanding my scientific knowledge and how to assess new strategies in helping students learn. I am very passionate about helping my students discover and understand how they learn best. What works for one student is not necessarily what works for another. They are all very unique individuals and using things like learning style surveys and giving them choices in how they implement their own learning and do projects helps them grow. I hope that in the future I can continue fostering this exploration of learning and knowledge and continue finding new and interesting ways to get students excited and interested in learning, especially about science.

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APPENDICES

APPENDIX A

NONTREATMENT UNIT LAB ACTIVITY

Nontreatment Lab Activity on Mineral Extraction

Cookie Mining

INTRODUCTION:

A Primer on Strip/Surface Mining (The Pros and Cons)

Mineral extraction has long been key to management and use of resources by industrialized nations. Minerals are essential to the manufacture of the technology and tools utilized by most countries (i.e. iron ore for machinery, trace metals for computer technology, titanium for lacrosse sticks, etc.) and have also been linked to the production of power (i.e. coal). Mining operations such as strip mines or surface mines do have economic benefits. While the initial construction of a strip mine is expensive, maintenance of the operation is reasonably inexpensive when the resource being mined is abundant. As well, mines provide employment in the form of machine operators, transportation workers, geologists, engineers, and surveyors. As well, after a strip mine has been closed, the area has been reclaimed for a variety of sources including agriculture (i.e. farming and animal grazing) and even aquatic habitats (i.e. lakes, ponds, wetlands, etc.). The ponds and wetlands created by reclaimed mining lands can also be used to clean wastewater from other area mining operations.

Yet, there are significant environmental impacts due to strip mines including but not limited to:

- erosion issues from removal of plant life and root system that holds onto soil
- loss of topsoil due to removal of overburden
- flooding due to open area runoff of rain water
- contamination of water supplies due to runoff of arsenic, cadmium, uranium, and mercury from mine tailings
- destruction of habitat from mine construction (results in loss of biodiversity)
- noise and light (night) pollution disrupts communities and may affect wildlife hibernation or migration patterns
- habitat fragmentation and modification due to construction of roads, vibrations, and dust
- landslides and mudslides due to compromised geological integrity

Most of the coal in the United States is harvested through strip or surface mines. Another significant effect of surface coal mines on the environment is directly related to the sulfur content of the soil. Sulfur, in sulfate form contained in the coal, can be dissolved in water used in the mining process and cause any of the following:

- acidification of the soil when it combines with water ($SO_4^- + H_2O \Rightarrow H_2SO_4$)

- acidification of groundwater or other surface water sources
- reduced plant growth due to altered pH
- corrosion of roads and drainage culverts
- increased solubility of water to toxic heavy metals (i.e. mercury, lead, etc.) due to acidic affinity for metals (remember chemistry?)

Cost-Benefit Analysis and Investing the Feasibility of a Process through ***Modeling***

Many energy resources are unevenly distributed and have limits to their usefulness. In fact, in most processes, energy is not uniformly distributed. Thus, processes that require greater quantities of energy are often less economical and therefore abandoned for "cheaper" and "easier" techniques. Consider this idea as you complete the exercise.

In this lab, you will demonstrate mining of the earth's surface and underground, and will observe the limits of several energy sources to determine the point where the costs of a process outweigh the apparent benefits.

Purpose:
To simulate the actual processes involved in mining for resources and to maximize economic gains while maintaining ecosystem integrity.

Procedure:

1. Buy a mine:
   a. HEB Store Brand $250,000
   b. Chips Ahoy $400,000
   c. Chips Deluxe $500,000
2. Name your mine.
3. Weigh your mine & record its mass.
4. Weigh two pieces of paper separately and record the mass.
   a. One will be for your chips
   b. One will be for your cookie crumbs
5. Place your mine on the graph paper and trace its outline. Record the number of squares covered by the mine. This gives you the original area of the mine.
   a. **NOTE:** Partial squares count as a whole square.
6. **As of now, you are not allowed to touch the cookie with anything other than the mining equipment**.
7. Buy your mining equipment:
   a. Flat toothpick $100,000
   b. Round toothpick $275,000
   c. Paper clip $350,000

   ***You may purchase more than one piece of equipment.**

   *** If you break your equipment, you must buy a replacement.**

8. Record the cost of your mining equipment.
9. Mine the chips out of your cookie – **you may NOT touch the cookie with your fingers.** The paper & the tool are the only things that can touch the cookie.
   a. The maximum mining time is 5 minutes with a cost of $50,000 per minute.
10. As you mine, separate the chocolate from the crumbled cookie, by carefully placing your chocolate on one sheet of pre-massed paper and the crumbled cookie on the other sheet of pre-massed paper.
    a. **Your goal is to mine as MUCH chocolate as possible BUT also damage as LITTLE of the "cookie land" as possible.**
11. When mining is completed, mass the number of chips you obtained.
12. Now mass your cookie crumbles. This represents the reclamation you must pay for due to the removal of overburden and ore.
13. Lastly mass your remaining undisturbed cookie.
14. Clean up & go to another lab group that bought a different cookie than you did and record the type of cookie they bought, the mass of the cookie and the mass of the chips.
    a. Do this until you have information for each of the three types of cookies.

Data:

1. Complete data sheet (6pts) and answer questions.
   a. **Show ALL calculations and answer in complete sentences**! (6pts)

Questions (4pts each)

1. Were the minerals evenly distributed throughout the cookie?
   a. Do you think this is a realistic simulation of ore distribution?
   b. Why or why not?
2. Did you leave any chips behind in the cookie? Why or why not? How does this compare to a real mine?
3. What does the chocolate represent?
4. What does the cookie represent?
5. Which type of cookie mine had the best chips to cookie mass ratio?
6. Where was the most time and energy invested in the mining process?
7. What are other sources of time and energy not measured by the activity?
8. What changes in your mining technique would have resulted in more profit?
9. What % of the original mass were tailings?
10. What % of the original mass was ore?
11. What % of the original mass was left undisturbed?
12. Was your mining venture profitable? Why or why not?
13. Why must a mining company reclaim a mine and what is the law that makes this so?
14. Do you think the mining process is faster when you know in advance that the land must be restored? Explain
15. Do you think that legislation requiring the restoration of the land makes mining more expensive?

16. The average copper ore mined in 1900 was 5% copper by weight. Today the average copper ore is 0.5% copper by weight. What factors could account for this difference?
17. How can recycling save energy as well as materials?
18. Strip mining is often employed by mining groups but cited as most destructive by environmental groups. Using your lab introduction, textbook, and current cookie mining experience, offer an explanation for why by citing three PROS and three CONS of surface (or strip) mining.
19. Research 2 minerals mined in the U.S. (**4pts each**) For each mineral,
    b. briefly describe the mining process
    c. identify where and in what industry the mineral is used

Good conservation practices and the RCRA (Resource Conservation and Recovery Act) require that the overburden be replaced and the surface of a strip mine area be restored to its original condition. Restoration requires the following four steps:

1. recontouring/regrading the lab to its original topography
2. replacing and/or adding topsoil and/or nutrients as needed to improve soil quality or structure
3. replanting with native vegetation/fast growing species/early successional species
4. monitoring for either 5 or 10 years depending upon location

20. Arid climates, such as desert areas, have been targeted as having new prospective mineral resources. Consider this and the information given above to describe WHY restoration might be particularly challenging in an arid ecosystem (one with less than 10 inches of rain per year). (**8pts)**

Mining Data Sheet

1. Name of Cookie ______________________
2. Price of Cookie $______________
3. Size of Cookie ______________squares
4. Mass of cookie_____________ g
5. Mass of chips ________ g
6. Mining Equipment
   a. Flat toothpick ____ x $100,000 = $_____________
   b. Round toothpick ____ x $275,000 = $_____________
   c. Paperclip ____ x $350,000 = $_____________
   d. Total Equipment Costs = $_____________

7. Mining & Reclamation time costs
   _____ minutes x $50,000/minute = $___________

8. Total costs of mining = $_____________

9. Income from chip sales
   mass of chips ______ x $100,000/g = _________

10. Profit = value of chips – cost of mining

    $_________- $_________= $____________

11. Reclamation costs
    ______ mass of crumbles x $50,000/g = $_______

12. Profit after reclamation = $_______________.

13. Calculate the % ore that was extracted in your mine. Show all work

14. Other cookie brands, cookie mass, and chip mass:
    a.
    b.

APPENDIX B

NONTREATMENT UNIT GROUP PRESENTATION ASSIGNMENT

Energy Source Presentations

You and two partners will be presenting a section on Energy. This must be a PowerPoint or Prezi with a minimum of 15 slides of **content material** (title slide, bibliography slide, slide with your names on it, etc. **DO NOT count** as part of the 15) that have a minimum of FIVE pictures, which need to contain the following information:

1. Type of energy, and what it is (its form).
    a. Where the energy comes from and how it is formed.
2. What countries are the leaders in using this form of energy?
3. What countries contain the most resources for this energy?
4. How the energy works.
    a. How is the primary source converted to a secondary source to be used by industry/public? Can use diagrams.
    b. Is it renewable or nonrenewable and why.
    c. **Schematic** that is labeled and explained for your type of energy (for example, if you had solar energy, a schematic of a solar cell would be appropriate) for how it is collected/created/used etc.
        i. **You need to be able to explain the schematic, we need to know how this works**
5. Pros and Cons
    a. What are the advantages to using this type of energy?
    b. What are the disadvantages of using this energy?
6. What are the environmental effects/impacts of using this energy?
7. **Could** this energy be a sustainable type of energy?
    a. Why or why not?
    b. If not how could it be?
8. Does this energy resource affect biodiversity? How?
9. Is this energy resource found or only useful in particular biomes or areas?
    a. Which ones?
    b. Why?
10. Where this energy is used in the United States (map)?
11. Are there any laws that govern the creation/use/waste from this type of energy?
    a. Which ones and how/why?
12. Any other information you can find about this type of energy to fill up the 15 slides.
13. Bibliography slide with all sources cited (minimum of 5 sources NOT including Wikipedia or Google searches must be used)

    Energy resources to choose from:
    1. Oil
    2. Coal
    3. Natural Gas
    4. Nuclear Energy
    5. Synfuels
    6. Oil shale/Tar sand

APPENDIX C

C.I.T.E LEARNING STYLE INVENTORY

C.I.T.E Learning styles Inventory

Questions	Most Like Me			Least Like Me
1. Making things for my studies helps me to remember what I have learned.	4	3	2	1
2. I can write about most of the things I know better than I can tell about them.	4	3	2	1
3. When I really want to understand what I have read, I read it softly to myself.	4	3	2	1
4. I get more done when I work alone	4	3	2	1
5. I remember what I have read better than what I have heard.	4	3	2	1
6. When I answer questions, I can say the answer better than I can write it.	4	3	2	1
7. When I do math problems in my head, I say the numbers to myself.	4	3	2	1
8. I enjoy joining in on class discussions.	4	3	2	1
9. I understand a math problem that is written down better than one that I hear.	4	3	2	1
10. I do better when I can write the answer instead of having to say it.	4	3	2	1
11. I understand spoken directions better than written ones.	4	3	2	1
12. I like to work by myself.	4	3	2	1
13. I would rather read a story than listen to it read.	4	3	2	1
14. I would rather show and explain how a thing works than write about how it works.	4	3	2	1
15. If someone tells me three numbers to add, I can usually get the right answer without writing them down.	4	3	2	1
16. I prefer to work with a group when there is work to be done.	4	3	2	1
17. A graph or chart of numbers is easier for me to understand	4	3	2	1

than hearing the numbers said.				
18. Writing a spelling word several times helps me to remember it better.	4	3	2	1
19. I learn better if someone reads a book to me than if I read it silently to myself.	4	3	2	1
20. I learn best when I study alone.	4	3	2	1
21. When I have a choice between reading and listening, I usually read.	4	3	2	1
22. I would rather tell a story than write it.	4	3	2	1
23. Saying the multiplication tables over and over helps me remember them better than writing them over and over.	4	3	2	1
24. I do my best work in a group.	4	3	2	1
25. I understand a math problem that is written down better than one I hear.	4	3	2	1
26. In a group project, I would rather make a chart or poster than gather the information to put on it.	4	3	2	1
27. Written assignments are easy for me to follow.	4	3	2	1
28. I remember more of what I learn if I learn it alone.	4	3	2	1
29. I do well in classes where most of the information has to be read.	4	3	2	1
30. I would enjoy giving an oral report to the class.	4	3	2	1
31. I learn math better from spoken explanations than written ones.	4	3	2	1
32. If I have to decide something, I ask other people for their opinions.	4	3	2	1
33.Written math problems are easier for me to do than oral ones.	4	3	2	1
34. I like to make things with my hands.	4	3	2	1

35. I don't mind doing written assignments.	4	3	2	1
36. I remember things I hear better than things I read.	4	3	2	1
37. I learn better by reading than by listening.	4	3	2	1
38. It is easy for me to tell about the things that I know.	4	3	2	1
39. I make it easier when I say the numbers of a problem to myself as I work it out.	4	3	2	1
40. If I understand a problem, I like to help someone else understand it too.	4	3	2	1
41. Seeing a number makes more sense to me than hearing a number.	4	3	2	1
42. I understand what I have learned better when I am involved in making something for the subject.	4	3	2	1
43. The things I write on paper sound better than when I say them.	4	3	2	1
44. I find it easier to remember what I have heard than what I have read.	4	3	2	1
45. It is fun to learn with classmates, but it is hard to study with them.	4	3	2	1

Scoring directions:

0. The numbers listed under each of the nine (9) learning styles areas designate the statements on the Inventory which measure that particular style
1. To determine the score for each style, do the following:
    a. Look up the response given for each statement and write it in the right hand column.
    b. total the numbers.
    c. Multiply the sum of the numbers by two (2) and record the total in the score blank.

Score:

- 33 - 40 = Major Leaning Style
- 20 - 32 = Minor Learning Style
- 5 - 19 = Seldom used

C.I.T.E. Learning Styles Instrument – Score Sheet

Visual Language	Social - Individual	Auditory Numerical
05 -- ______	04 -- ______	07 -- ______
13 -- ______	12 -- ______	15 -- ______
21 -- ______	20 -- ______	23 -- ______
29 -- ______	28 -- ______	31 -- ______
37 -- ______	45 -- ______	39 -- ______
Total ______ x 2 = ______	Total ______ x 2 = ______	Total ______ x 2 = ______
(Score)	(Score)	(Score)
Visual Numerical	**Social - Group**	**Kinesthetic - Tactile**
09 -- ______	08 -- ______	01 -- ______
17 -- ______	16 -- ______	18 -- ______
25 -- ______	24 -- ______	26 -- ______
33 -- ______	32 -- ______	34 -- ______
41 -- ______	40 -- ______	42 -- ______
Total ______ x 2 = ______	Total ______ x 2 = ______	Total ______ x 2 = ______
(Score)	(Score)	(Score)
Auditory Language	**Expressiveness - Oral**	**Expressiveness - Written**
03 -- ______	06 -- ______	02 -- ______
11 -- ______	14 -- ______	10 -- ______
19 -- ______	22 -- ______	27 -- ______
36 -- ______	30 -- ______	35 -- ______
44 -- ______	38 -- ______	43 -- ______
Total ______ x 2 = ______	Total ______ x 2 = ______	Total ______ x 2 = ______
(Score)	(Score)	(Score)

C.I.T.E. LEARNING STYLES DESCRIPTIVE INFORMATION:

Visual Language:
These students learn language skills by sight, mainly by reading and watching. They tend to be fast thinkers, to gesture freely while talking, and to communicate very clearly and concisely. They learn well from the demonstration process--must see to understand.

Visual Numeric:
These students do better with numbers when they see them written. They must see to understand. Learn best by reading and watching. They tend to be fast thinkers.

Auditory Language:
These students learn better by listening. (Individuals with low auditory skills may have trouble taking notes.)

Auditory Numeric:
These students are better with numbers when they can hear them spoken. (Individuals with low auditory skills may have trouble taking notes.)

Tactile/Kinesthetic:
These people are feeling and touch oriented, good at hands-on tasks, good linguists, and very sensitive to others' feelings. They learn best by doing and moving. Good ways to learn are hands-on projects or experiments, writing down the information, and applying it to real-life situations. They may have difficulty sitting for long periods of time.

Social Individual:
These students usually prefer to study on their own.

Social Group:
These students usually learn best by interacting with a group.

Oral Expressiveness:
Means how well students express themselves verbally. These students usually do well in speech classes. They need to talk about the information to be learned, and to express their ideas and opinions.

Written Expressiveness:
This means how well students express themselves in writing.

From: Center for Innovative Teaching Experiences (CITE) A.M. Babich, P. Burdine, L. Albright, P. Randol, Wichita Public Schools, Murdock Teaching Center

APPENDIX D

TREATMENT UNIT CASE STUDY

Renewable Energy/Energy Efficiency – treatment unit

Case study Prompt

In the southern part of Kansas lies Greensburg. On May 4th, 2007 it was ground zero for an EF-5 tornado, which destroyed 95% of the city of 1,389 residents. The remaining 5% of the city was severely damaged. Surprisingly only 11 people died in this natural disaster even with the majority of their city being destroyed.

A farm town, Greensburg had started to see a down turn in population and economy since before the tornado hit. Committed to rebuilding, the city council developed a Sustainable Comprehensive Plan to map out the direction to rebuild the city. Part of this resolution was to build all city buildings to LEED Platinum standards and reduce the cities footprint. So far they have been successful in their endeavor with support of many non-profit organizations and the US department of energy (DOE).

The following is a video produced by the US DOE highlighting the successes seen in Greensburg in a very short period of time.
http://www.youtube.com/watch?v=o4SIVdVCs-I

Almost exactly 4 years later another EF-5 tornado hit another town straight on. This time it was in Joplin, MO. A much larger city than Greensburg, Joplin at a population of 50,150, suffered about 25% complete destruction and 75% of the city was damaged. The death toll was also much higher in Joplin with 162 known deaths directly associated with the tornado.

The following video is raw footage from tornado chasers of the formation of the Joplin tornado along with its direct aftermath immediately following it.
http://www.youtube.com/watch?v=XT7CtF5ljxY&feature=related
http://www.youtube.com/watch?v=XT7CtF5ljxY&feature=related

The following video is various security camera feeds from the Joplin East Middle School, which was directly hit by the tornado
http://www.youtube.com/watch?v=64covicCcIY&feature=related

While Joplin does not have to do the complete rebuild that Greensburg had to they still have an opportunity to rework an infrastructure in a green manner to improve energy efficiency and move towards sustainable green energy.

Your Task

Your team has been hired by the Joplin City Council to present a proposal on the ways they can improve the energy efficiency of their city along with potential green energy solutions that will be available to them in their area.

Your team will gather information about the following areas of interest, through research and laboratory investigations, to form your sustainability proposal for the Joplin City Council. The plan will be presented to the Joplin City Council in two and a half weeks. Time to get to work!

Areas of interest that need to be included in your sustainability proposal:

1. Energy efficiency
    a. Building energy efficient buildings
    b. Retrofitting current buildings to be energy efficient
    c. Municipal efficiency – water, lights, etc
2. Sustainable Energy
    a. Potential forms of sustainable energy resources
    b. Municipal and private
    c. Renewable forms of energy resources

Laboratory Investigations to be completed

The following laboratory investigations must be completed as part of your project development:

1. Exploring Wind Power
2. Exploring Hydrogen Power
3. Exploring Solar Power
4. Insulation Investigation

APPENDIX E

NONTREATMENT PRE/POSTUNIT TEST

Pre/Postunit Test on Nonrenewable resources

1. Name one technique of surface mining and explain the **specific** environmental impact(s) associated with it.

2. Describe the process of producing electricity from coal.

3. Identify and distinguish the measures that can be made to extend the depletion time of a resource.

4. What benefit does using natural gas have over other nonrenewable resources?

5. Using the concept of Net Energy, justify the use of one nonrenewable energy resource.

APPENDIX F

TREATMENT PRE/POSTUNIT TEST

Pre/Postunit Test on
Energy Efficiency and Renewable Energy Resources

1. Interpret what is meant by the phrase “lifetime cost?”

2. Explain how the laws of thermodynamics relate to energy efficiency.

3. Describe how can being energy efficient save our resources and environment.

4. Analyze 2 advantages and 2 disadvantages for each type of renewable energy source

5. A 16 W compact florescent light bulb is 20% efficient. This blub is equivalent to a 65 W incandescent bulb, which is 5% efficient. (1W = 1J/s) **SHOW YOUR WORK!**
    a. How much energy (in Joules) does the compact florescent bulb use to produce light for 10 hours?
    b. How much energy are you saving by using a compact florescent vs. incandescent bulb?

Pre/Postunit Test on Air Pollution

1. Describe how photochemical smog forms?

2. Analyze the difference between photochemical and industrial smog.

3. Identify the causes of acid deposition and the environmental effects of it.

4. What is sick building syndrome?

5. Describe steps that can be made to reduce indoor air pollution.

APPENDIX G

MINUTE PAPER PROMPTS

Prompts used for Minute Paper Responses

Nontreatment – Nonrenewable Resources:

1. What is the importance of nonrenewable resources?
2. Briefly describe ways we can extend the life of our nonrenewable resources and if you think this is possible. Support your response.

Treatment – Energy Efficiency and Renewable Energy Resources:

1. What is the importance of renewable energy resources?
2. What are the difficulties that we face in transitioning to renewable energy resources?
3. What is the quickest way for us to be "energy friendly" in a world of limited resources?

Treatment – Air Pollution:

1. Why is air pollution a problem?
2. Which air pollutant do you think is the worst one and why?

APPENDIX H

PRE/POST STUDENT CONCEPT INTERVIEW QUESTIONS: NONTREATMENT

Pre/Post Student Concept Interview Questions: Nontreatment

Concept Map

Recall that a concept map is an organized way to link concepts and ideas together into a cohesive unit. You are going to develop a concept map using the following concepts below.

1. Nonrenewable resources (starting concept)
2. Minerals
3. Energy
4. Mining
5. Oil
6. Coal
7. Natural Gas
8. Uranium
9. Fossil fuel
10. Economic depletion

You are not limited to using these concepts in your concept map, so feel free to add terms you feel are needed. Make sure to add linking terms and/or phrases to show how the concepts are related to each other.

When you are completed with constructing your concept map, you will explain your map to me.

Interview Questions

1. Can you describe to me the different types of mining methods? Which one do you consider the worst? Why?
2. Describe to me what economic depletion refers to. What are ways we can extend this depletion rate? Which method do you feel is the more reliable way and why?
3. What techniques can we do to lessen our dependence of foreign sources of energy and resources?
4. What do you think the United States should do about its energy future? Why?
5. Is there any concept that you would like to further explore or feel that we did not cover well enough? Why?

APPENDIX I

PRE/POST STUDENT CONCEPT INTERVIEW QUESTIONS: TREATMENT

Pre/Post Student Concept Interview Questions: Treatment

Renewable Energy Unit

Concept Map (pre/post treatment)

Recall that a concept map is an organized way to link concepts and ideas together into a cohesive unit. You are going to develop a concept map using the following concepts below.

1. Renewable resources (starting concept)
2. Energy efficiency
3. Hydrogen
4. Wind
5. Solar
6. Geothermal
7. Hydropower
8. Life cycle cost
9. Net energy
10. Decentralized energy

You are not limited to using these concepts in your concept map, so feel free to add terms you feel are needed. Make sure to add linking terms and/or phrases to show how the concepts are related to each other.

When you are completed with constructing your concept map, you will explain your map to me.

Interview Questions

1. What are at least two benefits and two detriments of renewable forms of energy? Explain why you chose these.
2. Why is energy efficiency important to look at?
3. What does the term life cycle cost refer to?
4. How can decentralized energy be useful in communities?
5. How practical do you think it is for the United States to make the transition to renewable energy resources? Why?
6. What do you think the United States should do about its energy future? Why?
7. Is there any concept that you would like to further explore or feel that we did not cover well enough? Why?

Pre/Post Student Concept Interview Questions: Treatment

Air Pollution Unit

Concept Map (pre/post treatment)

Recall that a concept map is an organized way to link concepts and ideas together into a cohesive unit. You are going to develop a concept map using the following concepts below.

1. Air pollution (Starting Concept)
2. Outdoor pollution
3. Indoor pollution
4. Smog
5. Acid deposition
6. Sick building syndrome
7. Clean air act
8. Inversion

You are not limited to using these concepts in your concept map, so feel free to add terms you feel are needed. Make sure to add linking terms and/or phrases to show how the concepts are related to each other.

When you are completed with constructing your concept map, you will explain your map to me.

Interview Questions

1. Describe to me the difference between photochemical and industrial smog. What are some effects of them? What techniques can we do to lessen their impact?
2. What causes acid deposition? What are some effects of it? What techniques can be used to lessen its impact?
3. Which is a worse problem: indoor or outdoor air pollution? Why?
4. Do you think the clean air act should be strengthened? Why or why not?
5. How concerned are you about the ramifications of air pollution? Why or why not?
6. Is there any concept that you would like to further explore or feel that we did not cover well enough? Why?

APPENDIX J

PRE/POST TREATMENT STUDENT INTERVIEW QUESTIONS

Pretreatment Student Interview Questions

1. What activities in APES help you learn most?
2. Do you normally prefer to work independently or with a group?
3. How do you feel about working in a team? Why?
4. What are your feelings and thoughts about doing more hands on projects than lectures in class to learn material?
5. Do you think you can learn material without lectures? Why or why not?
6. How would you say you learn material best? Why?
7. What kind of study techniques do you use? Explain.
8. Would solving a problem be a way you would be interested in learning? Why or why not?
9. How do you think you can improve as a student?
10. What is your level of interest in renewable energy resources? Air pollution?
11. What would your ideal way to learn be?
12. Do you think about ways to improve your ability to learn? Do you think about how you learn?

Postreatment Student Interview Questions

1. Do you normally prefer to work independently or with a group?
2. How do you feel about working in a team? Why?
3. What are your feelings and thoughts about doing more hands on projects than lectures in class to learn material?
4. Do you think you can learn material without lectures? Why or why not?
5. How would you say you learn material best? Why?
6. What kind of study techniques do you use? Explain.
7. Would solving a problem be a way you would be interested in learning? Why or why not?
8. How do you think you can improve as a student?
9. What is your level of interest in renewable energy resources? Air pollution?
10. What would your ideal way to learn be?
11. Do you think about ways to improve your ability to learn? Do you think about how you learn?
12. How did this type of unit affect your opinion on working with groups or independently?
13. Did you enjoy working with a team? Why or why not?
14. How did this type of project affect your studying habits?
15. Did this type of learning/project affect how you think you learn best? Why or why not?
16. Did you find you had to be more independent in looking up information? How do you feel about this?

17. How interested were you in this topic? Did trying to solve a real world problem make it more interesting?
18. Do you feel you gained about the same, less or more knowledge on the material by solving this problem compared to a normal lecture? Why or why not?
19. Do you prefer this type of instruction? Why or why not?
20. Are there any changes you would suggest to make things go smoother or better in this unit?

APPENDIX K

PRETREATMENT AND POSTTREATMENT STUDENT SURVEY QUESTIONS

Pretreatment Student Survey

1. What classroom activities do you find help you learn the most and understand the most material? Please explain.
2. How does participating in a group project affect how you study?
3. How does participating in group projects affect how you think about the world around you?
4. How do you feel about group problem solving?
5. Do you prefer to solve problems in groups or independently?
6. Have you ever thought about how you learn or how you learn best? Explain.
7. Do you prefer learning through (Please elaborate on your response)
    a. Lectures: very little little some much very much
    b. Activities: very little little some much very much
    c. Projects: very little little some much very much
    d. Laboratories: very little little some much very much
8. How would you rate your level of motivation currently in school?

    (Circle one) very low low medium high very high
9. How many hours did you spend outside of class preparing or studying normally for AP Environmental Science a week?

    (Circle one) 1-2 hours 3-4 hours 5-6 hours 7 or more hours

Postreatment Student Survey

1. What classroom activities do you find help you learn the most and understand the most material? Please explain.
2. How does participating in a group project affect how you study?
3. How does participating in group projects affect how you think about the world around you?
4. How do you feel about group problem solving?
5. Do you prefer to solve problems in groups or independently?
6. Have you ever thought about how you learn or how you learn best? Explain.
7. Do you prefer this type of activity compared to a lecture based unit? Why or why not?
8. On a scale of 1-5, 1 being not motivated, 5 being highly motivated, how would you rate your level of motivation in this unit?

   (Circle one) 1 2 3 4 5
9. How many hours did you spend outside of class preparing or studying for this unit?

   (Circle one) 1-2 hours 3-4 hours 5-6 hours 7 or more hours
10. How does this time studying compare to the amount you study normally?

    (Circle one) Much More More Same Less Much less

APPENDIX L

STUDENT ATTITUDE SURVEY

Student APES Attitude Survey

My Attitudes	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I like to go to APES	5	4	3	2	1
2. School is very boring for me	5	4	3	2	1
3. Getting good grades in APES is important to me	5	4	3	2	1
4. APES doesn't matter since I've applied to college	5	4	3	2	1
5. I enjoy learning new APES information	5	4	3	2	1
6. I know how I learn best in APES	5	4	3	2	1
7. I like environmental science	5	4	3	2	1
8. I enjoy APES more than I thought I would	5	4	3	2	1
9. Studying APES is difficult for me	5	4	3	2	1
10. I am focused when I am in class	5	4	3	2	1
11. Its important for me to do well in APES	5	4	3	2	1
12. I participate in class	5	4	3	2	1
13. I pay attention in class	5	4	3	2	1
14. I can do well in school if I want to	5	4	3	2	1
15. My parents expect me to do well in school	5	4	3	2	1
16. I don't know how to get good grades in school	5	4	3	2	1
17. I have effective study habits	5	4	3	2	1
18. I do not like science	5	4	3	2	1

19. I am able to motivate myself to learn	5	4	3	2	1
20. I enjoy laboratory activities	5	4	3	2	1

APPENDIX M

OBSERVATIONAL PROMPTS

Observation Prompts

1. Are all students engaged in the activity?
   0-10 students 11-15 students 16-20 students 21-25 students 26-31 students
   a. What phase of class: Beginning Middle End
   b. Comments:

2. Who is not participating?
   0-10 students 11-15 students 16-20 students 21-25 students 26-31 students
   a. What phase of class: Beginning Middle End
   b. Comments:

3. Are students working together to solve the problem?
   a. What phase of class: Beginning Middle End
   b. Comments:

4. Does it appear students are being left out?
   a. What phase of class: Beginning Middle End
   b. Comments:

5. Is there evidence of higher order thinking?
   a. What phase of class: Beginning Middle End
   b. Comments:

6. Are students willing to ask questions?
   a. What phase of class: Beginning Middle End
   b. Comments:

7. Other comments and observations:

APPENDIX N

PERSONAL JOURNAL PROMPTS

Personal Journal Prompts

1. Today I feel __________________ about class.

2. What could I have done to better prepare for today?

3. Did students accomplish what I wanted them to?

4. After the class, was I tired?

5. What were some interactions I had with students?

6. I was excited about class: very little little some much very much
   a. Comments:

7. I looked forward to class: very little little some much very much
   a. Comments:

8. I felt that I helped the students learn today: very little little some much very much
   a. Comments:

9. I feel the class was really learning science: very little little some much very much
   a. Comments:

10. Other comments about today:

APPENDIX O

PERSONAL ATITUDE SURVEY

Teacher Attitude Survey

My Attitudes	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I like to go to work	1	2	3	4	5
2. I find teaching exciting	1	2	3	4	5
3. I enjoy interacting with my students	1	2	3	4	5
4. I had trouble motivating myself to come to work today	1	2	3	4	5
5. I know the best techniques to educate my students	1	2	3	4	5
6. I am not confident in what is to occur in class today	1	2	3	4	5
7. I feel prepared to answer student questions	1	2	3	4	5
8. I am feeling frustrated by the progress of my students	1	2	3	4	5
9. Student failure is a reflection of my ability as a teacher	1	2	3	4	5
10. If students are actively engaged in an activity, I've done my job.	1	2	3	4	5

APPENDIX P

PROJECT TIMELINE

Project Timeline

- January 4th, 2012: Administer C.I.T.E.S, Pretreatment Survey, and Attitude Survey
- January 5th, 2012: Nontreatment Unit, 2.5 weeks – Nonrenewable mineral and energy resources
    - Preunit assessment and preunit concept interviews given on Jan. 5th
    - Cookie Mining Laboratory activity Jan. 6th
    - Observation of groups on Jan. 6th and 12th
    - Personal attitude survey on Jan. 6th , 13th, and 20th
    - Lecture Jan. 6th- 13th
    - One Minute Paper Formative Assessment Jan. 13th
    - Energy Presentations Jan. 14th
    - Postunit assessment on Jan. 17th
    - Summative assessment Jan. 18th
    - Postunit survey, attitude survey and student concept interviews Jan. 19th
- January 20th, 2012: Treatment Unit 1, 2.5 weeks – Energy efficiency and renewable resources
    - Preunit assessment and preunit concept interviews given on Jan. 20th
    - Assign problem on Jan. 20th
    - Lecture Jan. 23-24th
    - Lab activities and research problem Jan. 25-Feb. 10th
    - Observation of groups on Jan. 25th, 27th, Feb. 1st, 3rd, and 7th
    - Personal attitude survey on Jan. 27th, Feb. 3rd, and 10th

- Share solutions Feb. 8th-10th
- Formative Assessment Feb. 6th
- Postunit Assessment on Feb. 13th
- Summative assessment Feb. 14th
- Postunit survey, attitude survey and student concept interviews Feb. 15th

* February 16th, 2011: Treatment Unit 2, 2 weeks – Air pollution and Effects
    - Preunit assessment and preunit concept interviews given on Feb. 16th
    - Assign problem on Feb. 16th
    - Lecture Feb. 17th and 21st
    - Lab activities and research problem Feb. 16th – March 1st
    - Observation of groups on Feb. 22nd , 24th , 28th and March 1st
    - Personal attitude survey on Feb 17th , 24th, and March 3rd
    - Formative Assessment Feb. 27th
    - Postunit Assessment on Feb. 29th
    - Summative assessment March 2nd
    - Postunit survey, attitude survey and student concept interviews March 6th

APPENDIX Q

FORMATIVE ASSESSMENT DATA

Formative Assessment Data From Both Nontreatment and Treatment Units

The second assessment question in the nontreatment unit, had students ponder ways to extend the life of nonrenewable resources. The answers were varied but fell into a few general categories as can be seen in Figure 3 below. Some students suggested using less using less and putting limits or making laws to reduce the use of renewable resources. One response was, "there are ways to discourage constant resource use by promoting less driving and purchasing cars with smaller gas requirements. But unless strict laws are put in place to carefully monitor and ration each individual's resource use…little can be done to extend the resources available." This response shows the thought that this student put into their explanation. Many students discussed various ways that were listed in class such as recycling, mining low-grade ore, technology to find more, alternative resources and using less, exhibiting the ability to recall basic information covered in class. The majority of students discussed the transition to renewable resources would be the best option. One student thought using biomass as a way, "By finding alternative forms of energy (preferably renewable) and learning how to maximize their potential. For instance, waste from all humans could be recycled for biomass, a growing form of energy." Some students concentrated on improving efficiency of extraction and use of resources through technology. For example one student said, "…we must use them more efficiently. This can be achieved by developing more efficient technologies that waste or use less of the energy, or by developing technology that uses both renewable and nonrenewable resources." There were four students though who did not discuss any specific ways or discussed incorrect ways and did not show understanding of the question.

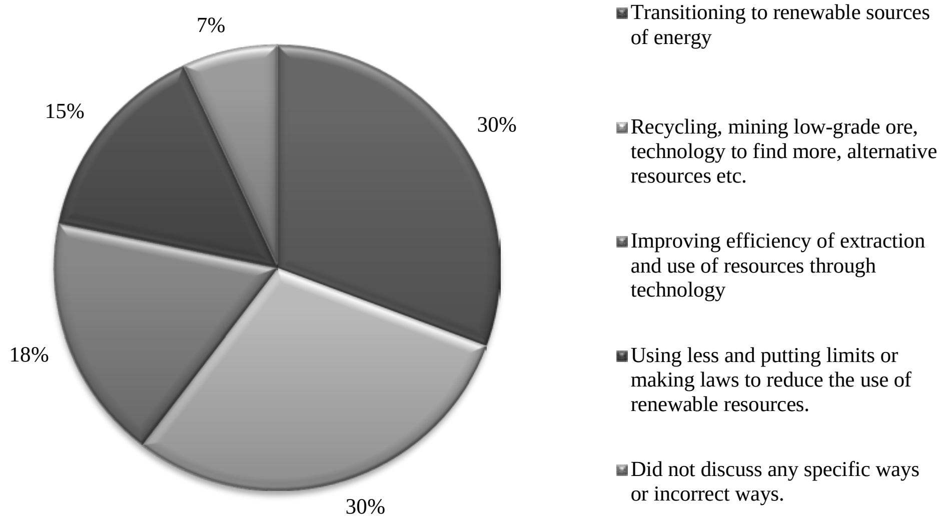

Figure 5. Percent of student responses to the second nontreatment formative assessment question: Briefly describe ways we can extend the life of our nonrenewable resources and if you think this is possible, (*N*=61).

For the second formative assessment question in the first treatment unit, students were asked why moving to nonrenewable is going to be difficult. As seen in Figure 5 below, the majority of students discussed that the cost and infrastructure to switch to renewables is the biggest problem we have to overcome. One student said, “We’d have to change the current motors, stoves, and all appliances that run on nonrenewable energy as well as find a place and way to install renewable apparatuses.” Many students said the reason was that the cost of nonrenewable energy sources is cheaper/more efficient than renewables. One response that also brought in the advanced concept of net energy discussed in a previous unit was, “Renewable resources are difficult to completely rely on because of the high cost of harvesting energy from them. Also renewable resources don’t always produce a high net energy like fossil fuels do.” This point is very valid and a high order linking together concepts from a couple different units. Two other viewpoints expressed were that society was too reliant on nonrenewable resources, six students, and that it is because of society not caring, eight students. One student's insight on society was "It is difficult to change humans' lifestyle and to make them and our world change/transform into a renewable way.

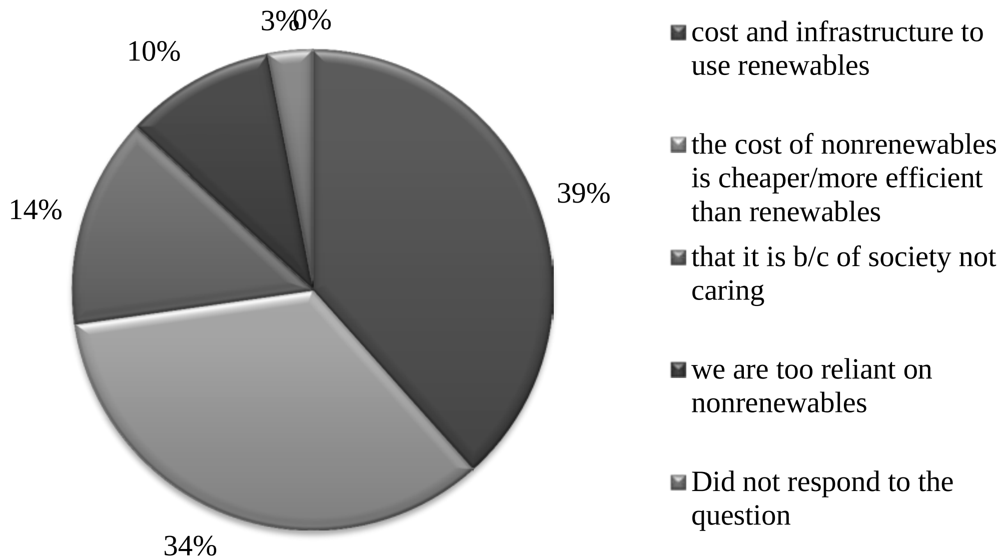

Figure 6. Percent of student responses to the first treatment unit, second formative assessment question: What are the difficulties that we face in transitioning to renewable energy resources? (*N*=58).

The last assessment question the students were asked was, what is the quickest way to be energy friendly? There were many different answers for this question, as seen in Figure 6 below, but many were vague and not exactly what I was hoping for. Only a few students responded correctly that being more energy efficient was the best and quickest way. There were many students who replied saying to conserve, use less, turn off, carpool, turn down thermostat etc. which was close to energy efficiency but they did not actually say efficiency. Therefore they had the general concept but did not use the correct terminology to go with it. Statements included, “Conserve by simply making small adjustments like turning off a light or switching to a smaller car, carpooling, etc.” and “Is to conserve energy, by not overusing resources and eliminating opportunities for wasted energy use.” The most common answer was to reduce, reuse and/or recycle which is also related to efficiency but there were some incorrect statements associated with this answer. One student responded, “…by conserving energy and reusing/recycling mater and energy,” which is inaccurate because while matter can be recycled, energy is not recyclable. Other responses included switching to renewable energy resources or using a variety of different resources. Some students suggested putting restrictions and using government legislation on what amount is used while one student said “by using only what is required and to be careful.”

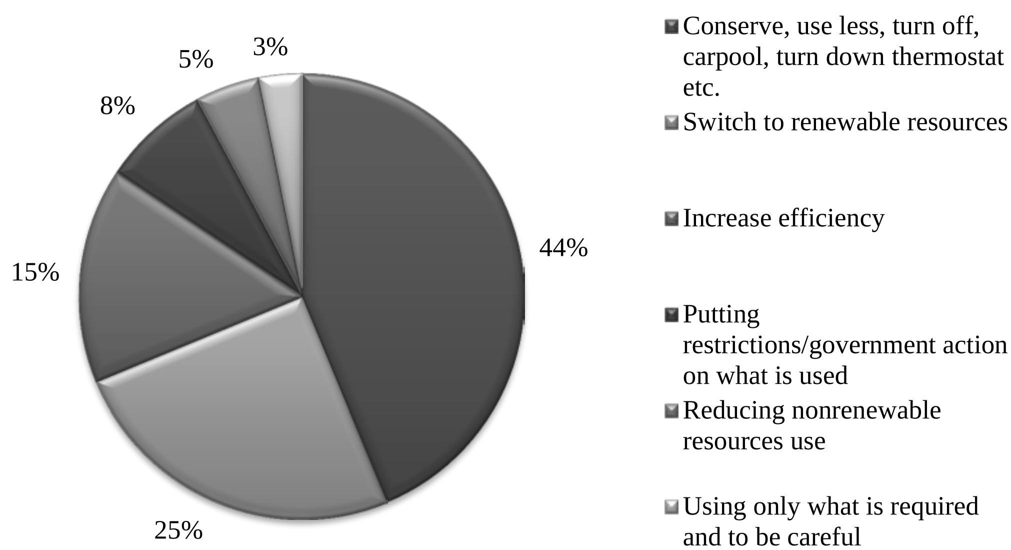

Figure 7. Percent of student responses to the first treatment unit, third formative assessment question: What is the quickest way to be energy friendly in a world of limited resources? (*N*=58).

When asked what was the worst air pollutant and why, there were a wide variety of answers as can be seen in Figure 8 below. Many students though did not expand on the why part of this question though, showing a possibly lack of complete understanding of the pollutants and the problems they cause. Some students also used general types of air pollutants instead of specific ones. One student for example, stated smog as the worst air pollutant, but there are two types of smog and many pollutants make up what we refer to as smog. One student also said car exhaust as the worst air pollutant, which again is very general, and not taking into consideration the components that make it up. Carbon monoxide was the most common response, but there was very little background into exactly why and where it came from. For example, one student stated that “carbon monoxide because it is the most commonly talked about and it creates a lot of damage.” The second most common response was cigarette smoke, which was not too surprising considering they have been told their entire lives that smoking is bad and harmful to your health. Again though, there was a variety of reasons why, most of them being vague like, “it lingers and contains high levels of carcinogens” while some were more specific, “it includes most of the extremely harmful pollutants combined in one. Additionally, cigarette smoke is taken directly into the lungs, increasing the chance of experiencing chronic health problems such as lung and gum cancer.” The two other most common responses, formaldehyde and indoor air pollution, to me showed expanded knowledge on areas that were likely not exposed to previously. Some explanations by a few students lead me to this conclusion. One student said about formaldehyde “because of its abundance in our buildings and confined spaces and because it is found in so many everyday materials and furniture. It is a major contributor to indoor air pollution which is a huge concern because it can cause severe health problems without people being aware." Another student said about indoor air pollution "it directly affects us. The time we spend indoors is greatly high than the amount we spend outside, and sometimes the air isn't circulated so we end up breathing the same pollutants without ever realizing it."

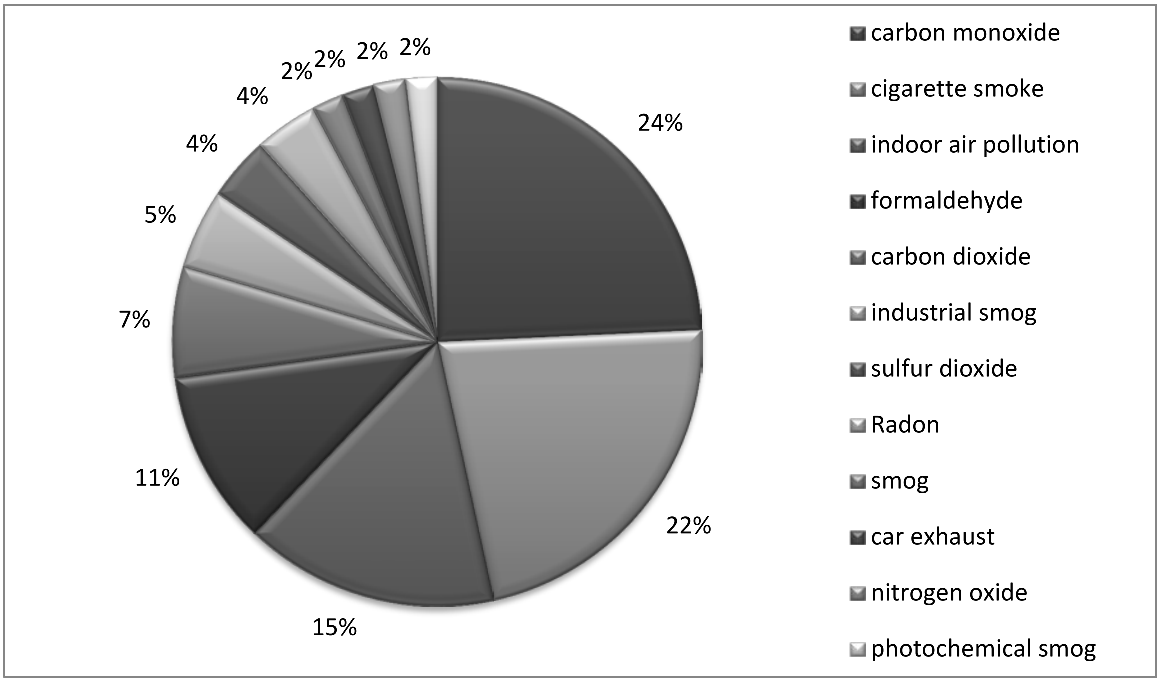

Figure 8. Percent of student responses to the second treatment unit, first formative assessment question: What is the worst air pollutant and why? (*N*=57).

APPENDIX R

CONCEPT MAPPING SCORING RUBRIC

Concept Map Scoring Rubric

Category	Number of Points	Points Awarded
Relationships (if valid)	2 each	
Terms used beyond given terms	3 each	
Levels of Hierarchy	5 each	
Crosslinks	10 each	
Examples given	1 each	
Total Score		

Criteria:

1. Relationships: Is there a valid relationship between two concepts with a line connecting the words?

2. Terms beyond those given: Did the student use appropriate terms to demonstrate valid relationships between concepts that were not given?

3. Levels of Hierarchy: Is hierarchy present? Does the concept map go from general to specific in the concepts being linked? How many different levels of hierarchy are present?

4. Cross Links: Are there meaningful and valid connections between different segments of the levels of hierarchy?

5. Examples: Are specific events, dates, cities, etc. given to further support linkage of the concepts?

Novak, J. D. & Gowin, D. B. (1984). *Learning how to learn*. New York, NY: Cambridge University Press.