ABSTRACT

THURMOND, BRANDI NICHOLE. Promoting Students' Problem Solving Skills and Knowledge of STEM Concepts in a Data-Rich Learning Environment: Using Online Data as a Tool for Teaching about Renewable Energy Technologies. (Under the direction of committee co-chairs Dr. Shawn Holmes and Dr. John C. Park.)

This study sought to compare a data-rich learning (DRL) environment that utilized online data as a tool for teaching about renewable energy technologies (RET) to a lecture-based learning environment to determine the impact of the learning environment on students' knowledge of Science, Technology, Engineering, and Math (STEM) concepts related to renewable energy technologies and students' problem solving skills. Two purposefully selected Advanced Placement (AP) Environmental Science teachers were included in the study. Each teacher taught one class about RET in a lecture-based environment (control) and another class in a DRL environment (treatment), for a total of four classes of students (n=128). This study utilized a quasi-experimental, pretest/posttest, control-group design. The initial hypothesis that the treatment group would have a significant gain in knowledge of STEM concepts related to RET and be better able to solve problems when compared to the control group was not supported by the data. Although students in the DRL environment had a significant gain in knowledge after instruction, posttest score comparisons of the control and treatment groups revealed no significant differences between the groups. Further, no significant differences were noted in students' problem solving abilities as measured by scores on a problem-based activity and self-reported abilities on a reflective questionnaire. This suggests that the DRL environment is at least as effective as the lecture-based learning environment in teaching AP Environmental Science students about RET and fostering the development of problem solving skills. As this was a small scale study, further research is needed to provide information about effectiveness of DRL environments in promoting students' knowledge of STEM concepts and problem-solving skills.

Promoting Students' Problem Solving Skills and Knowledge of STEM Concepts in a Data-Rich Learning Environment: Using Online Data as a Tool for Teaching about Renewable Energy Technologies

by
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DEDICATION

I want to dedicate this to my family who has been there to support and encourage me throughout the years in all of my endeavors. I dedicate this to my best friend and understanding husband, Greg, who has endured this process right alongside me. Finally, I dedicate this to my little boy, Brayden, who is truly a gift from God. No matter how distracted or tired I was, you always had a smile. You are the sunshine of my life.

BIOGRAPHY

Brandi Thurmond grew up in Indiana. It was during her high school years taking biology that she found her passion for science and for teaching. It was during these years that she also met her future husband. Brandi and her high school sweetheart moved to Florida after graduating high school where they attended college together.

Since a little girl, Brandi was interested in dolphins. In college, she majored in marine biology, where she studied dolphins and other marine life. After graduating with a B.S. in marine biology, she pursued a Master's of Science and Teaching degree from Florida Atlantic University and began teaching high school and community college science courses. Two years later, Brandi and her high school sweetheart got married on the beach and moved to North Carolina.

After a couple of years teaching high school and community college science courses in North Carolina, Brandi decided to go back to school to pursue a PhD in Science Education. During the last semester of her graduate coursework, Brandi was blessed with her baby boy, Brayden.

Currently, Brandi is teaching online science courses for North Carolina Virtual Public School and enjoying being able to stay at home with Brayden, while still doing what she loves – teaching science.

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cannot," to "I think I can," to "I can." Thank you to Dr. Jason Osborne for one of the most beneficial courses that I took during my graduate career. Just one summer in your course prepared me to conduct the quantitative data analysis for my dissertation. The book for your course was a great investment as well. Rest assured, the assumptions of the statistical tests I utilized were checked prior to running each test, to ensure I did not violate any of the test assumptions.

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CHAPTER 1: INTRODUCTION

Observational studies have suggested that data-rich learning environments can improve student learning about science and promote higher order thinking skills (Manduca & Mogk, 2002). Although a variety of instructional methods can be utilized to incorporate data into science classrooms, Manduca and Mogk (2002) have suggested that inquiry and discovery based learning models support the effective use of data in classrooms.

Throughout the history of science education there have been movements towards implementing new teaching strategies into science classrooms to improve teaching and student learning, several of which have been short lived, as one teaching strategy is replaced by another. Further, there is often a gap between teaching strategies that promote learning as indicated in research, and what is actually being practiced in today's schools. Recently, science education has moved away from direct instruction and rote memorization to constructivism and focusing on learning concepts through inquiry (DeBoer, 2000). Data-rich learning environments support inquiry based learning.

> Data-rich activities can be used to engage students with issues […] in deep, interdisciplinary, inquiry-driven thinking that fosters the development of higher order critical thinking skills and enables integration of scientific reasoning into a student's decision making and life reasoning (Maduca & Mogk, 2002, p. 12).

This study explores the potential implementation of data-rich learning (DRL) environments, in which online data is used as a tool for teaching about renewable energy technology (RET), in secondary school science classrooms to promote students' knowledge of Science, Technology, Engineering, and Math (STEM) concepts and students' problem solving skills.

Renewable Energy Education

One of the competency goals of the North Carolina environmental and earth science curriculum is for students to be able to "analyze the sources and impacts of society's use of energy," including renewable and nonrenewable sources (p. 122). The world's energy supplies, still primarily dependent on nonrenewable fossil fuels, have been linked to air pollution, water pollution, land degradation, and global climate change (Dincer, 1999). As a result of environmental degradation and the concerns over the use of foreign energy supplies, many nations are investing in alternative renewable energy resources, including solar, wind, hydroelectric, and biomass energy. Being one of the fastest growing energy technologies, it is important for educators to provide opportunities for students to learn about RET (Daughtery & Carter, 2010). According to Daughtery and Carter (2010), "it is imperative that current students become aware of and familiar with emerging renewable energy technologies and how these technologies will continue to influence their lives in the 21st century" (p.24).

Several studies have examined student understanding of energy concepts (Goldring & Osborne, 1994; Saglam-Arslan, 2010; Singh & Rosengrant, 2003) and the status of energy education (Broman, 1994; Kandpal & Garg, 1999). Goldring and Osborne (1994), using a questionnaire administered to 75 students, found that more than half of the students in the study struggled not only with quantitative reasoning, but also with qualitative reasoning about energy concepts. The questionnaire data highlighted student difficulties understanding the basic concepts and ideas related to energy. The implication of such studies is that much of what is being learned by students in schools today is ‘shallow learning’ in that students are merely recalling information they were taught. Students engaged in shallow learning are unable to apply the knowledge they have learned to have a deeper understanding of the concepts. DRL environments afford the opportunity to engage students in deep learning about RET.

Despite the importance of teaching about RET across the sciences to promote students’ understanding of STEM concepts, studies have indicated little integration of renewable energy technologies into the science curriculum. Liarakou, Gavvilakis, and Flouri (2009) used an online survey administered to secondary school teachers to assess teachers’ knowledge and attitudes towards renewable energy. The researchers found that there was an overall lack of integration of renewable energy technologies in the science curriculum due to the strict nature of the curriculum, lack of teacher in-service training, and lack of educational materials for teachers to utilize in their classrooms. It was due to these constraints, that Advanced Placement (AP) Environmental Science teachers were chosen for this study. Although the AP Environmental science curriculum includes a breadth of topics that are covered to varying depths, teachers have flexibility in the methods and resources they use to teach these topics in their classrooms (The College Board, 2010). For this study, teachers received curricula materials and training for both the DRL and lecture-based learning environments to teach students about RET.

Advanced Placement Environmental Science Curriculum

Advanced Placement Environmental Science (APES) is meant to be equivalent to an introductory college level environmental science course that includes a lab component and is intended to be a rigorous, interdisciplinary course that teaches students about scientific principles related to environmental science. One of the goals of the APES curriculum is for students to identify and analyze solutions to environmental problems.

Unifying themes of APES include a) science as a process b) energy conversions c) the interconnectedness of Earth's systems d) human alteration of the environment e) the role of social, cultural, and economic factors in environmental decision making and f) sustainability. Each of these unifying themes can be addressed by using online data to teach about renewable energy technologies (RET). In using data to answer questions about RET, students are learning the process of science. By accessing, manipulating, and analyzing online data collected from RET, students are able to answer real-world problems surrounding RET. Students are able to learn about energy conversions as they investigate the amount of energy produced and energy efficiency of RET. Students can analyze meteorological data alongside data obtained from the RET, to investigate the effects of weather on RET, thus gaining an appreciation that Earth is an interconnected system. Students are able to determine the amount of pollution that is avoided by using RET by using data collected from the RET. By examining energy consumption, production, and efficiency of RET, students learn about the cost and benefits of using RET. By using data to understand the aforementioned unifying themes of APES, students are able to better understand the role of RET as a sustainable way to harness energy for household energy consumption.

The APES curriculum covers a breadth and depth of topics. RET addresses several topics within the course. The RET curriculum covers topics in each of the goals.

I. Earth Systems and Resources

  A. Earth Science Concepts (solar intensity and latitude)

  B. The Atmosphere (seasons; weather and climate)

II. The Living World

  E. Natural Biogeochemical Cycles (carbon)

III. Population

  B. Human Population

    2. Population size (strategies for sustainability)

    3. Impacts of population growth (resource use)

IV. Land and Water Use

  D. Other Land Use

    1. Urban land development

V. Energy Resources and Consumption

  A. Energy Concepts (energy forms; power; units; conversions; Laws of Thermodynamics)

  B. Energy Consumption

    1. History (energy crisis)

    2. Present global energy use

    3. Future energy needs

      F. Energy Conservation (energy efficiency)

G. Renewable Energy (solar energy; solar electricity; wind energy; environmental advantages/disadvantages)

VI. Pollution

A. Air pollution (major air pollutants; measurement units)

VII. Global Change

B. Global Warming (Greenhouse gases)

Although the learning environments for the control and treatment groups differed in the method designed to aid in teaching students about RET, the curriculum for both groups included activities and assignments designed by the researcher, a former APES teacher, and evaluated by a non-participating APES teacher, to ensure the same breadth and depth of coverage of topics and potential for developing knowledge related to RET. It was important that both groups of students had the same opportunities to learn the content in order to investigate the potential of DRL to be used as a tool for teaching students about RET. Since the students were higher level AP students, the curriculum was designed to be demanding, but within the students' capabilities. Activities and assignments for both the treatment and control groups were designed to enhance students' understandings of RET and allow students to learn in a collaborative environment when completing the in-class activities.

Data Rich Learning Environments

According to the Science Standard Course of Study and Grade Level Competencies outlined by the North Carolina State Board of Education and Department of Public Instruction (2004), "it is impossible to learn science without developing some appreciation for technology" (p. 101). These standards address the need for students to be able to identify problems, analyze data, and present potential solutions to problems using science and technology. The National Science Education Standards also address the need to teach students about science and technology. "Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology-related challenges. However, understanding science alone will not resolve local, national, or global challenges." (NSES, 1996, p. 199)

Although there is an abundance of online data sources for teachers to utilize in their curricula to teach science concepts, the effectiveness of these data sources as a tool for teaching and learning has not been thoroughly researched. Smith, Campbell, and Hoopingarner (2004) conducted a study to examine high school students' engagement in an activity using data on the internet to solve scientific problems. Students were immersed in an inquiry activity, requiring students to interpret, evaluate, and apply online data to answer research questions and solve real problems in science. According to the authors of the study, "the internet has emerged in the last decade as a promising instructional tool that schools and teachers have been urged to employ in ways that encourage inquiry-based teaching" (p.9).

> The use of the Internet immerses students in the interpretation of data that is not accessible in a firsthand manner. From this data, students construct their own knowledge about the topic being investigated. They learn how to use a powerful tool to amass information they can modify and apply rather than copy. In other words, students are cast in the role of a scientist. Some scientists collect their own data; others interpret data they did not

> collect themselves. Thus, even though data mining does not require students to collect data firsthand, they are emulating the work of many scientists. (Smith, Campbell, & Hoopingamer, 2009, p. 11)

Used in the manner in which Smith, Campbell, and Hoopingamer (2009) describe, students can engage in data mining in order to investigate issues relevant to their lives. As an educational initiative, the College of Engineering at North Carolina State University created the NC Solar Center, which utilizes wind, biomass, and passive and active solar energy technologies. For over ten years, the Solar Center has provided educational materials to K-12 teachers. A project called Green Research for Incorporating Data in the Classroom (GRIDc), funded by an NSF grant, installed sensors at the Solar Center to monitor and collect data from the renewable energy technologies. For this study, curricular materials for the treatment group (DRL) were designed to allow for students to analyze, synthesize, and evaluate the data provided by the GRIDc project in order to investigate the potential of this data resource to be used in science classrooms to teach STEM concepts and promote problem solving skills among students. Initial results from a GRIDc pilot study (DeLuca, Carpenter, & Lari, 2010) indicated significant gains in students' general knowledge about RET and students' metacognitive performance. Although in its pilot stages, results from this study indicate that instruction that includes the use of the GRIDc online data has the potential to increase student knowledge of RET and problem solving skills. The current study further informs the aforementioned pilot study and provides greater insight into the types and depth of learning that occur in data-rich learning environments and the ability of these environments to promote higher order thinking skills, including problem solving skills.

Significance of Study

Richard A. Duschl, committee chair of The National Academies 2006 report: *Major changes needed to boost K-8 science achievement*, states that our

> 'current teaching approaches are insufficient to launch students on a path to participation in a society infused with job opportunities in scientific and technical fields, as well as scientific issues such as alternative fuels, avian influenza, global warming, and nanotechnology. To improve science education, a curriculum coordinated across grade levels and broad changes in assessment and instruction are urgently needed' (p. 1).

Results from a 2007 national education technology survey echoed concerns about the way science is currently taught in schools and concerns about students' preparation for the workforce and decreasing interest in pursuing STEM careers. The national Speak Up survey collected responses from K-12 students, teachers, and parents to explore views of STEM education, 21st century skills, and the future of schools. The survey was a national survey on educational technology. Results from the survey suggest that the way science is currently taught in schools leaves much to be desired by students, including students' desires to learn science through real-world problem solving and technology integration (Appel, 2007).

Research into the ability of using online data as a tool for teaching about renewable energy technologies (RET) in a DRL environment, addresses these concerns. DRL is an instructional approach that can increase students' understanding of science concepts, as well as promote 21st century skills needed for the workforce, including communication skills, problem solving and critical thinking skills (Manduca & Mogk, 2002). The use of online data in this type of environment to teach about RET, supports the integration of math, science, and technology concepts, addressing the need for an integrated curriculum to increase students' knowledge of STEM concepts and students' interest in pursuing STEM careers. Transforming science classrooms into DRL environments is a potential model for STEM instruction, preparing students with not only science content knowledge, but also with 21st century skills needed to be successful in science and technology related fields.

Purpose of Study

The purpose of this study was to compare a data-rich learning (DRL) environment that utilized online data as a tool for teaching about renewable energy technologies (RET) to a lecture-based learning environment to determine the impact of the learning environment on students' knowledge of STEM concepts related to RET and students' problem solving skills. To test this purpose, students in both groups were pre- and post-tested to investigate differences in students' knowledge of STEM concepts related to RET. Student responses on a problem-based activity were compared to test the effect of the learning environment on students' problem solving skills. A student questionnaire was also employed to investigate students' self-reported understanding of RET and ability to solve problems following instruction.

Research Questions

1. Is there a significant difference in students' knowledge of STEM concepts related to renewable energy between students in the lecture-based and students in the data-rich learning environments?
2. Is there a significant difference in students' problem solving abilities between students in the lecture-based and students in the data-rich learning environments?

Hypotheses

Hypotheses for this study were that students taught in the DRL environment a) would have a significant gain in knowledge of STEM concepts related to RET and b) be better able to solve problems when compared to students taught in the lecture-based environment.

Null Hypothesis 1: There will be no significant difference in students' knowledge of STEM concepts related to renewable energy between students in the lecture-based and students in the data-rich learning environments.

Null Hypothesis 2: There will be no significant difference in students' problem solving abilities between students in the lecture-based and students in the data-rich learning environments.

Assumptions

The limitations of this study include methodological and theoretical assumptions. One methodological assumption of this study was that student scores on the administered posttests were dependent on the teaching method utilized, when there may have been confounding variables responsible for the differences examined between the groups in terms of the pre-and posttest gains. It was assumed that because the curricula materials for both groups were designed and evaluated to ensure students in the DRL and lecture-based learning environment had the opportunity to learn the same concepts related to RET in their respective learning environments, that the posttest scores would be a valid measurement of the effect of the treatment on students' knowledge and problem-solving skills. One of the factors that threatened the validity of the posttest was students being made aware that they were participating in a research study and that student performance on the pre- and posttest would not count as a grade for the class, possibly affecting the time and effort students exerted in answering the questions to the best of their abilities. Thus, student scores on the pre- and posttest may not accurately reflect students' knowledge of STEM concepts related to RET. By having a control group (lecture-based without the use of online data) to compare against the outcome of the treatment (using online data in a DRL environment) it is more likely that the differences in scores between the groups can be attributed to the teaching method utilized and not some other variable, although it is difficult to achieve a true control group in educational research.

Another study assumption was that students in the DRL and lecture-based learning groups were equivalent in terms of their initial knowledge of RET and problem solving skills, and that both groups were representative. The assumption that students in control and treatment groups were equivalent at the onset of the study in their knowledge of RET and problem solving skills was based on several factors. First, the study was conducted at the beginning of the school year, prior to students having had the opportunity to build a knowledge base in environmental science from direct involvement in the class. Therefore, prior knowledge of RET was assumed to be equivalent from the onset of the study. It is likely; however, that previous coursework, interest in the topic, and media influences resulted in differences in individual students' prior knowledge of RET. Pretest scores and demographic variables were compared between the groups to test for equivalence.

The student population included in this study may not be representative, which would reduce the generalizability of the study. Since true randomization was not possible, two AP Environmental Science teachers from the same school were chosen to reduce selection bias and reduce variations due to underlying school factors. It is important to note that the students included in the study were AP students, so may not be representative of all secondary school science students. The assumptions and limitations above demonstrate the complexity of educational research. Every effort was made during the study to address these limitations.

Definition of Terms

Data Rich Learning Environment – A data rich learning environment is defined as a learning environment in which teachers integrate data analysis into the design of classroom instruction to enhance student learning.

Problem Solving Skills – This study defines problem solving skills as the ability to integrate knowledge from a variety of subjects to solve a problem.

Renewable Energy Technologies (RET) – For the purpose of this study, the EPA's (2009) definition of RET was utilized, where RET are defined as technologies utilizing resources that rely on fuel sources, such as the sun, wind, water, biomass, and geothermal, that do not diminish and have short restoration times. Although these technologies still impact the environment, their impacts are small compared to nonrenewable energy sources.

Traditional, Lecture-Based Learning Environment – By design, the lecture-based learning environment in this study was one where students were taught using lecture, class discussions, and activities to reinforce student learning. The lecture-based learning environment was traditional in the sense that this learning environment consisting of lecture, discussions, and activities is traditionally used as the method for teaching APES.

Summary

This study was conducted with two purposefully selected Advanced Placement Environmental Science teachers. Each teacher taught one class about RET in a lecture-based environment (control) and another class in a DRL (treatment), for a total of four classes of students. Two classes (periods 2 and 3) were taught about RET in a lecture-based learning environment (control), while the other two classes (periods 1 and 4) were taught in a DRL environment (treatment) utilizing online data to learn about RET. This research provided an opportunity to examine how online data from the GRIDc project could be implemented in a DRL environment to increase students' knowledge of STEM concepts related to RET and promote students' problem solving skills.

CHAPTER 2: LITERATURE REVIEW

The following review of the literature provides an overview of Science, Technology, Mathematics, and Engineering (STEM) education, with a focus on renewable energy education, and the effectiveness of lecture-based and constructivist learning environments in teaching and learning about STEM concepts. Data-rich learning (DRL) environments are presented as a constructivist learning environment that can be used to teach students STEM concepts related to renewable energy technology (RET) and promote students' problem solving skills.

STEM Education

Science, technology, engineering, and mathematics (STEM) education initiatives are on the rise, with an aim to prepare today's students with the 21st century skills needed to be successful in today's workforce. President Barack Obama supported the STEM initiative and addressed the need for STEM education as one of the nation's educational priorities in his 2011 State of the Union address (Schacter, 2011).

As K-12 schools are considered to be a vital component of the STEM pipeline, preparing students to enter postsecondary STEM education fields and encouraging students to pursue jobs in STEM fields, it is important to investigate the effectiveness of STEM education initiatives. STEM education can be used to engage students in solving real-world problems (Hopkinson & James, 2010), can increase students' interest in science and math

(Hollenbeck & Fisher, 2011), and can increase students' knowledge of STEM concepts (Lou, Shih, Diez, & Tseng, 2011).

STEM education can also potentially benefit those considered to be minorities in science fields. According the 2011 National Science Foundation's "Women, minorities, and persons with disabilities in science and engineering" report, females are underrepresented in science and engineering fields. Male students represent a higher percentage of students that enter STEM fields (Chen, 2009) and research suggests that males have more positive attitudes toward STEM compared to females (Mahoney, 2010). In an effort to determine if problem-based learning (PBL) can increase female students' knowledge of STEM concepts and attitudes towards STEM learning, Lou, Shih, Diez, & Tseng (2011) interviewed forty female 10th grade students involved in the Solar Electric Trolley contest. Results from an attitudinal survey and interviews indicated that the PBL environment helped to increase female students' learning of and attitudes towards STEM.

However, there are some who have voiced concerns over integrating STEM into already established curricula. Brown, Brown, Reardon & Merrill (2011) conducted a survey-study with teachers and administrators to ascertain school faculty perceptions of STEM education. Results from the survey indicate a lack of understanding of STEM and lack of clarity in the vision of STEM education. Further, Williams (2011) discusses potential barriers to implementing a STEM curriculum, including integrating STEM concepts into an already packed curriculum, classroom design changes, and methods to assess students.

Although there are a number of ways to potentially integrate STEM into science classrooms, one method of integrating STEM is utilizing online data to teach students about renewable energy technologies. Shining Star, a STEM education program associated with Indiana University, has shown that providing students with opportunities to engage with scientific data can increase student interest in and knowledge of STEM concepts. This three year curriculum initiative sought to integrate data-loggers into the curriculum. After integrating data-loggers into the curriculum, increases in students' interest in math and science courses and improved standardized test scores were noted (Hollenbeck & Fisher, 2011). According to Hopkinson & James (2010), teaching about sustainable development in STEM related subjects, though potentially difficult, has greater potential for boosting STEM education as the topic is economically and socially relevant.

Renewable Energy Education

On September 8, 2009, President Obama gave a speech to children on education during which he told students they would "need the knowledge and problem-solving skills you learn in science and math to […] develop new energy technologies and protect the environment." Renewable energy education affords students the opportunity to gain fundamental understandings of STEM concepts and an appreciation of the inter-relationships among science, technology, and the environment. Energy is important to our quality of life and economic growth (Kandpal & Garg, 1999); however, many environmental problems our society faces today are related to energy consumption. Approximately one third of our global energy consumption is used to generate electricity, with about 17% of global electric power being produced by renewable energy (The College Board, 2006).

Busby and Carpenter (2009) postulate that teachers are an important part of the solution and should provide students with opportunities to learn about alternative energy resources. Renewable energy education is relatively a new field, and according to Jennings (2009), there is a need to teach students about renewable technologies and the roles these technologies will play in the future. An important feature of energy-education programs is to include discussions of the socio-cultural, economic, and ecological impacts of these technologies (Kandpal & Garg, 1999); however, "our education system has failed to give us a basic understanding of energy supply options and their impact on society and the environment" (Jennings, 2009, p. 435).

Even though energy concepts are often confusing for students (Hong, 2006), energy education as it is currently taught still includes a superficial coverage of topics (Kandpal & Garg, 1999). The "introductory environmental science student is often left with a fragmentary, confusing, and unsatisfactory introduction to energy concepts and terminology" (Hong, 2006, p. 44). Since misconceptions can hinder students' success in solving problems (GE & Land, 2003), it's important to examine common energy misconceptions among students. Lecture based teaching does little to correct alternate conceptions (Barab et al., 2009).

When deciding which method of teaching is best, one must consider the objective of renewable energy education and what the course of study recommends. According to Kandpal and Garg (1999), energy education programs should provide students with experiences that aid in the development of cognitive skills. The National Science Education Standards (NSES) addresses energy as a major concept in science in grades 5-8 and 9-12

(1996). The Advanced Placement Environmental Science (APES) curriculum (The College Board, 2010) dedicates 10-15% of the course to studying energy resources and consumption with topics including energy concepts (energy forms, power, units, conversions, Laws of Thermodynamics) and renewable energy (environmental advantages/disadvantages). According to The College Board (2010), activities should be linked to major concepts in science and allow for students to observe how systems work by collecting and analyzing data. Further, activities should challenge students' abilities to critically think, analyze and interpret data, and apply concepts to solve environmental problems (The College Board, 2010).

In a 2005 paper "Energy, Society, and Education, with an Emphasis on Educational Technology Policy for K-12," Chedid discusses society's dependence on energy, the need for developing renewable energy technologies to potentially avert future an economic and energy crisis, and the importance of education in developing energy technologies. "Education is a key factor for technology development – including technology for efficient, clean, and economical energy generation, transportation, storage, and use" (p. 79). Chedid's position that the solution to the nation's energy problem is education prompted the development of a framework to improve STEM education in K-12 classrooms. In the paper, Chedid describes the design of a project-based activity that highlighted what he called the "next-generation, STEM-rich curriculum" (p. 84). The project-based activity revolved around students learning about STEM concepts related to solar energy. Through the project-based learning activity, students would learn "the science of photovoltaic, to materials technology, to climate and geography, to economics, and to civic responsibilities" (p. 84).

Learning Environments

There are several pedagogical approaches to teaching science. Whereas lecture-based approaches to teaching and learning are considered to be passive learning (Amador & Gorres, 2004; Barab et al., 2009), constructivist approaches are considered to be student centered approaches that actively engage learners and promote a deeper understanding of concepts. According to Savery and Duffy (2001), problem-based learning (PBL) is an exemplar of a constructivist learning environment. Barrows and Kelson (1993), in response to complaints about the status of education and the need for new educational techniques, describe PBL as a total approach to education, one that has the potential to replace traditional lecture based approaches to promote students' conceptual knowledge and higher order thinking skills.

Active learning can take on many different forms from interactive lectures, collaborative group learning, class discussions, or interactive computer-based learning. McManus, Dunn, and Denig (2003) conducted a research study using a counterbalanced design with 60 tenth grade students, to compare student attitudes and learning of science in three different teaching methods. Results from the study indicated positive attitudes and improved science achievement when students self-taught using either teacher-created or student-created instructional materials compared to students taught using traditional instruction, consisting of lecture and class discussions.

Active learning environments have also been studied at the post-secondary level. Lake (2001) evaluated the learning and course perceptions of 170 physiology students taught either in a lecture or active learning course section using course grades and teacher-course evaluation comparisons to compare the learning environments. Lake found that while course grades were higher in the active learning sections, that students perceived they learned less in that environment. Students in the active learning environment also perceived the instructor to be less effective. Students reported no differences in perceptions about course difficulty. Active learning defined in this study was supplementing lecture with class discussions.

Although research studies have shown the benefit of constructivist learning environments, teachers still rely predominately on teacher-centered learning environments. As teaching behaviors do not reflect current trends in science education, it is important to investigate the factors that support or hinder implementing constructivist learning environments. A study on teacher, student, and parent preferences for learning environments was conducted to determine perceptions of stakeholders in the Dutch educational system. Questionnaires were given to 285 teachers, 951 students, and 636 parents to determine preferences for direct instruction, discovery learning, and authentic pedagogy. Results indicate that teachers and parents alike, preferred direct instruction. Multiple regressions analysis revealed that the teacher's own preference for learning was a predictor of the teacher's use of direct instruction as a teaching method. (Roelofs,Visser, & Terwel, 2003) As there are several pedagogical approaches that could be implemented to teach environmental science, it is important to determine which learning environments are most effective (Dettmann-Easler & Pease, 1999).

Data-Rich Learning Environments

DRL- A form of Inquiry Based Learning

Studies on how students best learn science provide a framework for answering the question: Why should students be given the opportunity to learn in a data-rich environment? Edelson (2001) describes learning for use. Learning for use motivates students and allows students to construct meanings about scientific concepts in a meaningful way. Three stages of learning for use are motivating students, constructing knowledge from experience, and organizing knowledge for accessibility and usability.

Although there is an abundance of online data sources for teachers to utilize in their curricula to teach science concepts, few studies have examined the effectiveness of these data sources as a tool for teaching and learning. Smith, Campbell, and Hoopingarner (2004) conducted a study to examine high school students' engagement in an activity using data on the internet to solve scientific problems. Students were immersed in an inquiry activity, requiring students to interpret, evaluate, and apply online data to answer their research question and solve real problems in science. According to the authors of the study, "the internet has emerged in the last decade as a promising instructional tool that schools and teachers have been urged to employ in ways that encourage inquiry-based teaching" (p.9). Used in the manner in which Smith, Campbell, and Hoopingamer (2009) describe, students can engage in data mining in order to investigate issues relevant to their lives.

DRL Environments and Students' Science Content Knowledge

In a study conducted by Kerlin, McDonald, and Kelly (2010), a framework was developed for analyzing student discourse when engaged with textbook data as compared to data from the US Geological Survey (USGS). Analysis of student discourse revealed that students utilizing textbook data were able to interpret and link textbook data to concepts they were learning about in class, but did so using lower inference level argumentative discourse. This was compared to the complexity of student discourse when USGS data were utilized.

Ucar, Trundle, and Krissek (2011) employed a mixed methods study with 79 preservice teachers to determine the potential for online tidal data to be utilized in inquiry-based instruction to improve understanding of concepts related to tides. Quantitative data analysis consisted of a pre- posttest design to access pre-service teachers' knowledge before and after instruction. Qualitative data analysis included post-instruction interviews. Findings of the study support the use of online data to promote conceptual change.

DRL Environments and Students' Problem Solving Skills

Problem solving is defined as being able to make observations and judgments about a problem, as well as, plan, implement, and devise solutions to the problem (Moriyama, Satou, & King, 2002). GE and Land (2004) described problem solving abilities as being able to recognize problems, identify solutions, justify and evaluate proposed solutions. Further they describe the cognitive and metacognitive processes required during problem solving. Both domain-specific (knowledge of specific concepts) and structured knowledge (knowledge of how concepts relate to prior experiences) are part of the cognitive processes required during problem solving. Gijbels, Dochy, Bossche, and Segers (2005) describe the cognitive components of problem solving as declarative knowledge (knowledge of concepts), procedural knowledge (knowledge of principles) and conditional knowledge (knowledge of how concepts link to procedures).

Problem solving requires metacognitive processes. Metacognition is ability to reflect upon, understand, and control one's learning and includes two components: knowledge about cognition and regulation of cognition. Knowledge about cognition includes declarative knowledge (potential strategies), procedural knowledge (how to use those strategies), and conditional knowledge (when to use those strategies); whereas regulation of cognition includes the ability to plan and evaluate (Schraw & Dennison, 1994). In addition to planning and monitoring one's cognition, motivation, perceived self-efficacy, and perceived attraction to task, may also be important in regulating cognition (Gijbels, Dochy, Bossche, & Segers, 2005). When given a problem to solve, students must be aware of what knowledge they already have to help them solve the problem and knowledge they are lacking in, that they need in order to solve the problem. According to GE and Land (2004), students with greater metacognitive abilities are better able to solve problems because they are able to develop more hypotheses when solving problems. Schraw and Dennison (1994) postulate that more metacognitively aware students are better able to perform, because they are more strategic in solving problems. Thus, metacognitive knowledge may be more important than domain-specific knowledge when solving problems (GE & Land, 2004).

In a study examining problem solving abilities among students engaged in a project based technology education class, Moriyama, Satou, and King (2002) concluded that there was a relationship between students' problem solving abilities and the type of learning activity students were engaged in. Although studies as this have shown project-based and problem-based learning environments to promote problem solving skills among students, few studies have investigated the potential of data-rich learning environments in promoting students' problem solving skills.

Tulloch and Graff (2008) conducted a case study with middle and high school students to evaluate the potential use of Green Map as a tool for teaching students geographic concepts and spatial cognition in a data-rich environment. The researchers designed data-based learning activities to accompany the Green Map database to investigate the opportunity for learning using the online data resource. Case study data revealed the potential for data to be utilized in a PBL as an instructional tool for to engage students in problem solving and critical thinking.

Using DRL Environments to Teach about RET

According to Hui and Cheung (1999), the Internet "can be an effective medium for the delivery of good quality education and training for energy efficiency and renewable energy subjects, because of its flexibility, timeliness, and breadth of access" (p. 151). Several online databases afford students the opportunity to investigate STEM concepts in DRL environments. The National Oceanic and Atmospheric Administration (NOAA) and USGS are two examples of agencies that collect and store data online that teachers and students can access; however, the potential of these data sources to be used as instructional tools has not been thoroughly researched. This study utilizes online data from the Green Research for Incorporating Data in the Classroom (GRIDc) website as a tool for teaching about renewable energy technologies (RET) to investigate the impact of data-rich learning environments on students' knowledge of STEM concepts related to RET and students' problem solving skills.

Summary

Today's society requires students to be able to solve complex problems. Renewable energy education is imperative for students, as one of the problems facing today's society is an increased demand and decreasing supply of nonrenewable energy resources, and the environmental degradation associated with using these energy resources. Although renewable energy education is traditionally taught is a lecture-based learning environment, studies have shown lecture-based learning environments to be less effective than inquiry-based learning environments. Developing an inquiry-based activity, using online data provided by GridC project, provides an opportunity for teaching and learning about RET through the integration of STEM concepts in a data-rich environment. DRL environments have been shown to engage students, improve students' knowledge of concepts, and promote students' problem solving skills.

CHAPTER 3: METHODOLOGY

The purpose of this study was to compare a data-rich learning (DRL) environment that utilized online data as a tool for teaching about renewable energy technologies (RET) to a lecture-based learning environment to determine the impact of the learning environment on students' knowledge of Science, Technology, Engineering, and Math (STEM) concepts related to RET and students' problem solving skills.

Research Design

A quasi-experimental, pretest/posttest, control-group design (Campbell & Stanley, 1963) was employed to answer the following research questions:

1. Is there a significant difference in students' knowledge of STEM concepts related to renewable energy between students in the lecture-based and students in the data-rich learning environments? (RQ1)
2. Is there a significant difference in students' problem solving abilities between students in the lecture-based and students in the data-rich learning environments? (RQ2)

Hypotheses

It was hypothesized that students taught in the DRL environment would have a significant gain in knowledge of STEM concepts related to RET and be better able to solve problems when compared to students taught in the lecture-based environment.

Null Hypothesis 1: There will be no significant difference in students' knowledge of STEM concepts related to renewable energy between students in the lecture-based and students in the data-rich learning environments.

Null Hypothesis 2: There will be no significant difference in students' problem solving abilities between students in the lecture-based and students in the data-rich learning environments.

Study Participants

Earth and environmental science are taught in grades 9 through 12 in North Carolina Public Schools. To meet high school graduation requirements, students must take either earth science or environmental science. Earth science is the first high school science course that most incoming freshmen take, while environmental science is usually taken by students in grades 11 and 12 who enroll in Advanced Placement Environmental Science (APES).

Two APES teachers teaching at local high school in Wake County, North Carolina, were recruited to participate in this research study. The teachers included in the study were purposefully selected based on the number of years teaching APES, teaching schedules, and typical coverage of RET in their classrooms. Both teachers had been teaching APES for three years, taught at the same school on block schedule (90-minute periods), spent 3-5 class periods covering RET, and taught about RET using primarily lecture format with supplemental activities.

The first week of school, students enrolled in the participating teachers' APES classes were informed that they had the opportunity to participate in a research study studying the impacts of using online data to learn about RET. The goals of the research study were disclosed to students and parents/guardians prior to participation via an informed consent (see Appendix A). Since the curriculum implemented during the study also served as students' regular class instruction on RET, students were informed that the activities and assignments associated with the study curriculum would be collected for a grade. Although participation in the study was voluntary, students were also informed that even if they did not wish to participate in the study, that they would still be participating in and given a grade for the activities that were assigned for homework and activities completed in-class during the study period. Administered pre- and posttest did not count towards either participating or non-participating student's grades and students for whom informed consent forms were not obtained, data were not included in the study.

In total, 131 students, distributed among four APES classes participated in the study, for a participation rate of 97.8%. While student demographics in individual teachers' classes could not be controlled, students in each class were comparable in terms of overall school demographics. Students included in the study attended a suburban secondary school, with a predominately Caucasian (78.5%) population of students. The school was designated a School of Excellence, with High Growth for the 2009-2010 school year, and had an Advanced Placement (AP) course enrollment of 5% of the student population.

Students participating in the study were primarily juniors (60.9%) and seniors (36.7%), with a larger percentage of female students (58.6%) than male students (41.4%). Self-reported ethnicity was predominately White (77.3%), followed by Asian (11.7%), Hispanic (3.1%), Multi-racial (3.1%), Black (2.3%), and other (2.3%). Table 1 shows comparison in demographic variables in the treatment and control groups.

Table 1

Demographic Comparisons of Control and Treatment Groups

	Control	Treatment
Gender [a]		
Male	34.9	47.7
Female	65.1	52.3
Grade [a]		
Sophomore	4.8	0
Junior	49.2	72.3
Senior	46.0	27.7
Ethnicity/Race [a]		
White	71.4	83.1
Black	3.2	1.5
Asian	6.3	0
Hispanic	14.3	9.2
Multi-Racial	3.2	3.1
Other	1.6	3.1
Courses Taken [b]		
Math	3.73 (.89)	3.31 (.94)
Science	2.56 (.64)	2.53 (.84)

Notes:
[a] Percentages
[b] M (SD)

In order to investigate the potential of using online data as a tool for teaching about RET to promote students' knowledge of STEM concepts related to RET and students' problem solving skill, APES classes were taught in either a traditional, lecture-based learning environment (control) or in a DRL environment (treatment). Prior to the research study, it was determined that due to school administration scheduling, one of the participating teachers would be teaching three sections of APES, while the other participating teacher would only be teaching one section of APES during the fall semester. To ensure both teachers were able to teach one class in the DRL and one class in the lecture-based learning environment, during the timeframe of the study, the teachers switched fourth period classes, so that each teacher would be able to teach two classes of APES. During the teacher training, class periods were randomly assigned to either the DRL or lecture-based learning environment, ensuring both teachers had a class period that would serve as the control (periods 2 and 3) and a class period that would serve as the treatment group (periods 1 and 4). Teacher A taught periods 1 (DRL) and 2 (lecture-based), while teacher B taught periods 3 (lecture-based) and 4 (DRL).

Teacher Training

Teachers received training two weeks prior to the onset of the study to review the curricular materials for both the treatment and control groups, as well as, discuss any questions the teachers had about implementing the curriculum in their respective courses to teach students about RET. The training lasted approximately an hour, during which teachers were provided with an outline of the RET curriculum and timeframe of the study (see Appendix B). The roles of the teachers in each learning environment were outlined and teachers were provided with directions for each day’s activities and assignments. An example of the teacher directions for one of the activities is included in Appendix C.

One week prior to the study, teachers were provided with all the curriculum materials, including a) a binder with the RET curriculum outline and teacher directions b) a flash drive that contained the lecture materials and c) student copies of all of the activities and assignments for the study period. In addition to receiving the lectures in PowerPoint format, a video of the researcher going through the PowerPoint was also included. This video was meant to give teachers an idea of the flow and coverage of RET utilizing the PowerPoint. Teachers were not provided with copies or shown the pretest, posttest, questionnaire, or student information sheet prior to, during, or after the research study in order to reduce the likelihood that teachers would teach to the test, thereby contaminating the results of the study.

RET Curriculum

A three day curriculum was implemented in each of the participating classes to teach students about RET. Students in the control group (n=64) were taught about RET in a traditional, lecture-based environment, while the students in the treatment group (n=67) were taught about RET in a DRL environment, using online data provided by the Green Research for Incorporating Data into the Classroom (GRIDc) project. Teaching about RET using online data from the GRIDc project addresses each of the criteria outlined by The College Board (2010) for lab investigations, including making critical observations, analyzing and interpreting data, and thinking analytically. The GRIDc project will be discussed further later in this chapter.

The RET curriculum that was implemented during the research timeframe was developed by the researcher, a former APES teacher who had taught APES for three years. Decisions about the content and activities to include in RET curriculum for the study period began with a focus on goals and unifying themes mentioned in Chapter 1. Lab criteria were utilized to aid in the design of the DRL environment GRIDc data activity. Activities, assignments, and lectures were created using online resources, APES textbooks, APES printed materials, and released materials from The College Board.

An APES teacher, who had been teaching for 25 years, taught the APES course since its development, and who had served as an APES exam reader for two years, was recruited to evaluate all of the curricular materials prior to the onset of the study to ensure that both the control and treatment groups of students were presented with the same content over the three day study period, and to ensure that the pretest and posttest reflected the concepts being taught to both groups.

The two learning environments the participating teachers utilized to teach about RET are described below.

Traditional, Lecture-Based Learning Environment (Control Group)

Students in periods 2 and 3, designated the control group, were taught in a traditional, lecture-based learning environment. Traditionally, the method for teaching about RET in APES includes lectures, class discussions, in-class activities, and assignments. Following administration of the pretest on day one, students were taught about energy consumption and were given an overview of residential renewable energy technologies in a lecture, discussion format. Embedded within the lecture, were two videos that students were shown. One video was a tour of the North Carolina Solar Center, and the other video was a short clip discussing the amount of energy a solar panel could produce. After the lecture, students completed an in-class activity for which they had to calculate a sample household's energy consumption for a week. Students were assigned a two part assignment to complete for homework on day 1. The first part of the assignment required students to obtain an electric bill to figure out how much energy their household used for a month and the cost per kilowatt-hour. For the second part of the assignment, students were required to track the electrical appliances they used throughout the day and calculate the energy and cost of running those appliances for a day.

Day two of the study, students learned about solar energy, again in a lecture, discussion format. The lecture included an overview of solar energy technology and a discussion of a) the amount of pollution avoided by using solar energy b) solar power versus solar energy c) the efficiency of solar arrays d) components of a photovoltaic system and e) factors that affect the power output of a solar array. Students watched an online lecture that discussed the design of sunspaces for homework on day two, in order to answer three questions about passive solar house designs.

Day three of the study period, students completed a problem-based activity with a partner and day four students took the posttest and filled out the student information sheet and questionnaire. Over the three day study period, three lectures were utilized to teach students about RET. Since this was the method that the participating teachers primarily used to teach students about RET, this group served as the control group to compare the learning effects that students might experience from using online data in a DRL environment.

The three day curriculum primarily focused on solar energy technologies, with a brief overview of the other RET through the video tour of the NC Solar Center. Due to the over-packed curriculum and fast-paced nature of the APES course, the participating APES teachers typically would not devote two days to studying only solar energy technologies. The researcher chose to narrow the focus of the RET curriculum to solar energy technologies to allow both groups to have a deeper understanding of solar energy. The depth of understanding of solar energy was determined by the researcher by evaluating released APES exams and curricular materials provided by The College Board (1998, 2003, 2005, 2006).

Data-Rich Learning Environment (Treatment Group)

Students in periods 1 and 4 were designated as the treatment group. Over the three day study period, students utilized online data obtained from the GRIDc project website. The goal of GRIDc is to work with teachers to create data-rich learning environments, in which, the data from the GRIDc is integrated into the curriculum to develop students' critical thinking and problem solving skills. As part of the GRIDc project, a monitoring system was installed that collects data from various RET at the NC Solar Center, including energy and power readings from photovoltaics, wind turbines, solar thermal, and hydrogen fuel cell systems. In addition to being able to access this data, students are also able to access meteorological data to analyze the effect of variables such as wind speed, temperature, and sun irradiance on the performance of the RET systems. (DeLuca, Carpenter, & Lari, 2010)

The GRIDc online data was utilized to create a curriculum around RET that required students to solve real-world problems in order to teach students STEM concepts and problem solving skills. While learning about RET, the GRIDc data provided students with the opportunity to learn how to manipulate, graph, and analyze data. Since the NC Solar Center had closed due to budget cuts two months prior to the study, students used archived data instead of real-time data to learn about RET systems. The DRL activities created for this study were constructed around the usage of the GRIDc data and were based on the same STEM concepts related to RET that the control students were exposed to during lectures.

Following the pretest on day one, students went to a computer lab to complete an activity that required students to utilize data from the GRIDc project to calculate how much energy was produced by the NC Solar Center's RET over a period of one week, how much energy the solar house consumed during that same period, and what percentage of the solar house's energy was supplied by RET. This activity was primarily designed to allow students the opportunity to begin exploring the GRIDc website to become familiar with accessing and manipulating the data to answer questions about RET.

Prior to beginning the activity, it was intended for students to watch the video tour of the NC Solar Center that the control group watched during lecture, to provide students with an overview of the RET from which data were being collected for students to access and analyze. Due to technological issues with slow servers and video buffering, the video was unable to be viewed by period 1. To ensure both periods 1 and 4 received the same treatment, the video was postponed to day three for both periods. The homework assignment for day one was the same as was assigned to the control group.

On day two, students in the DRL environment spent the 90-minute class period in the computer lab utilizing data from the GRIDc project to answer five questions about photovoltaic (PV) systems. Students were required to access, manipulate, graph, and analyze the data to investigate a) the relationship between power and energy, b) the efficiency of PV power output, c) factors affecting PV power output, and d) the environmental impact of using solar energy technologies, such as PV systems. Besides being provided with a brief introduction to the GRIDc website and instructions on how to access the data, students were not given explicit verbal instruction on which data to analyze or how to analyze the data to answer the activity questions.

Since it was important to be able to monitor and evaluate how students arrived at the answers to the questions, students were asked to write the exact steps they took to answer the questions, including the a) the data source - house, annex, or garage b) averaging period - hour, day, week, month c) fields - variables used for the analysis d) date range and e) output type – graph or table used to manipulate and visualize the data. Figure 1 shows the GRIDc website interface students used to export the data. Students were assigned the same questions for homework on day two as the control group; however, instead of watching an online lecture, the DRL group utilized data from the GRIDc website to answer questions about passive solar house designs.

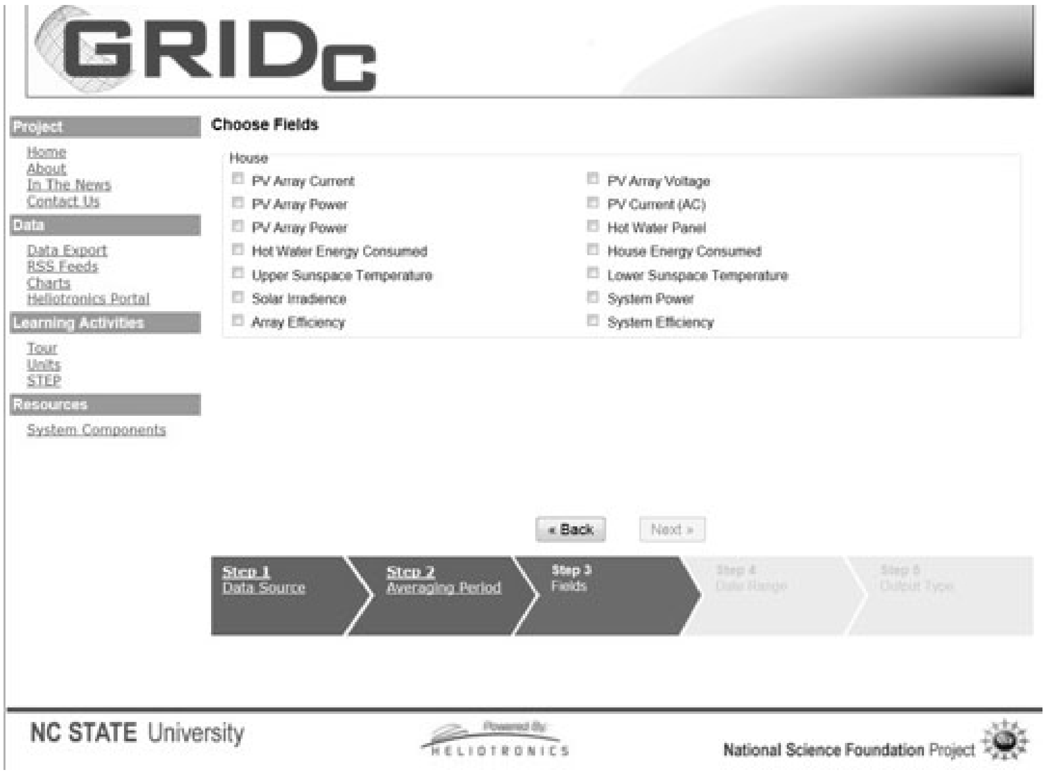

Figure 1. GRIDc website

Over the three day study period, the treatment group accessed the GRIDc data for three separate activities, for which students calculated a) household energy consumption b) the amount of energy that could be supplied by wind and solar RET c) the amount of pollution avoided by using RET d) the relationship between power and energy e) the effects of weather on the power output of solar arrays f) periods for which the solar array produced the most electricity g) the efficiency of solar arrays at converting sunlight into electricity and h) passive solar design features. These were the same concepts that students in the control group were taught in the lecture-based learning environment. Students in the DRL environment were able to work in partners to complete the in-class activities. Day three and four of the study were the same as for the control group.

Data Collection

Pre-Instruction- Beginning Day One

Students in both the control (lecture-based) and treatment (DRL) groups were given a researcher-constructed pretest consisting of 15 multiple-choice and five short answer questions (see Appendix D) prior to instruction about RET to assess students' prior knowledge of STEM concepts related to RET. The questions on the pretest were designed using APES curricular materials. The pretest was administered by the researcher and students were informed by the teacher to try their best, but that the test would not count for a grade. Students took 15-30 minutes to answer the twenty-question pretest. The pretest will be discussed further in the next section of this chapter.

Instruction – Days One and Two

Teachers introduced RET to their respective classes using the DRL instructional approach for one class and a lecture-based approach for the other class. Although student work from in-class activities and assignments during the study period was collected, it was not used to inform this study.

Post-Instruction – Days Three and Four

The third day of the study, students were given a problem-based activity (see Appendix E) to assess students' problem solving skills. Students were given the entire 90-minute period to work with a partner on the problem-based activity. At the end of the period, proposals were collected from students. For the problem-based activity, students were instructed to use what they already knew about renewable energy and what they had learned from either the lectures or from analyzing the online data provided by the GRIDc project.

Students were assigned an AP free response question from a released APES exam for homework on day three. The free response question required students to read a short document and answer questions using the information in the document and what students had learned in class about RET. Students were directed to complete the assignment without using any outside sources and were informed that it was a practice question and would not be graded right or wrong. Students were not given any instruction or coached on how to answer the free response question and had not been assigned a free response prior to this assignment.

The final day of the study, a posttest was administered to both groups containing the same questions as the pretest. To reduce the likelihood that students would simply recall from memory their answers from the pretest, questions and answer choices were re-ordered. In addition to taking the posttest, students were given a reflective questionnaire (see Appendix F) to indicate students' level of agreement with statements related to their learning about RET, problem solving abilities, and 21st century skills. Demographic information about students was obtained the last day of the study using a student information sheet (see Appendix G).

Instruments

Pretest/Posttest

A 20-item pretest/posttest consisting of 15 multiple choice questions and 5 short answer questions was designed to assess students' knowledge of STEM concepts related to RET. Pre- and posttest items were identical and were presented to students during the same time period of the study on day one prior to instruction and on day four, the last day of the study. Items on the pre- and posttest were constructed based on course objectives and the content delivered during the study period. The face validity of the pretest/posttest was determined by the APES teacher recruited to evaluate the RET curriculum. Evaluation of the curricular materials in conjunction with pretest/posttest assessments revealed equal opportunities for students in both groups to perform on the questions. Although three questions were noted for which one group might be more at an advantage than the other group, no significant difference between the groups was found when conducting an independent samples *t*-test on students' posttest scores for those particular questions. Item analysis on the multiple choice questions was conducted to determine item difficulty, discrimination, and item response patterns. Multiple choice questions had a range of difficulty values from 34.4% to 90.6%, with the average difficulty index being 59.9%. The discrimination index for the multiple-choice questions ranged from .16 to .49, with an average discrimination index of .29. Internal consistency was estimated independently for the pretest and posttest using the Cronbach alpha coefficient, and was found to be .36 and .47 respectively. This low variance is likely attributable to students truly being close in their ability levels. Alpha has also been shown to increase with test length. The test utilized for this study included fifteen multiple choice questions, measuring different types knowledge, resulting in low correlation between the test items, likely resulting in an underestimation of the reliability of the testing instrument.

Problem-Based Activity

The problem based activity was designed to demonstrate students' ability to apply the knowledge they had learned about RET during the study period to create an energy plan for residents of North Carolina. Students were asked to consider several points as they outlined their proposal. The points students needed to consider to create their proposal were either directly taught through lecture or indirectly taught through student analysis of the GRIDc data. There were a couple of points students needed to address that were not taught to either group during the study period to get students to think about the social costs of implementing their proposed residential energy plans. Curricular materials for the control and treatment groups were evaluated by the participating APES teachers and it was determined that the desired objective of the problem-based activity was met and that both groups had covered the same concepts needed to address each of the points outlined in the activity. The problem-based activity was designed utilizing the STEM instructional framework described by Setser (2010). Students were given a challenge to create an energy plan for NC residents (see Figure 2). The opening event that set the stage for the problem-based activity was a video tour of the NC Solar Center that the control group of students watched on day one and that the treatment group of students watched on day three prior to the activity. In addition, both groups of students had calculated their household energy consumption for an assignment on day one. For the activity, students were placed in the role of renewable energy environmental planner. The driving question of the activity was how homes in North Carolina could be best designed to reduce residential dependence on nonrenewable energy resources. Working in partners, students utilized prior knowledge and what they had learned during the lesson on RET to come up with an energy plan proposal for NC residents.

A rubric modified from (Ge, 2001) was used by the researcher to score the problem-based activity.

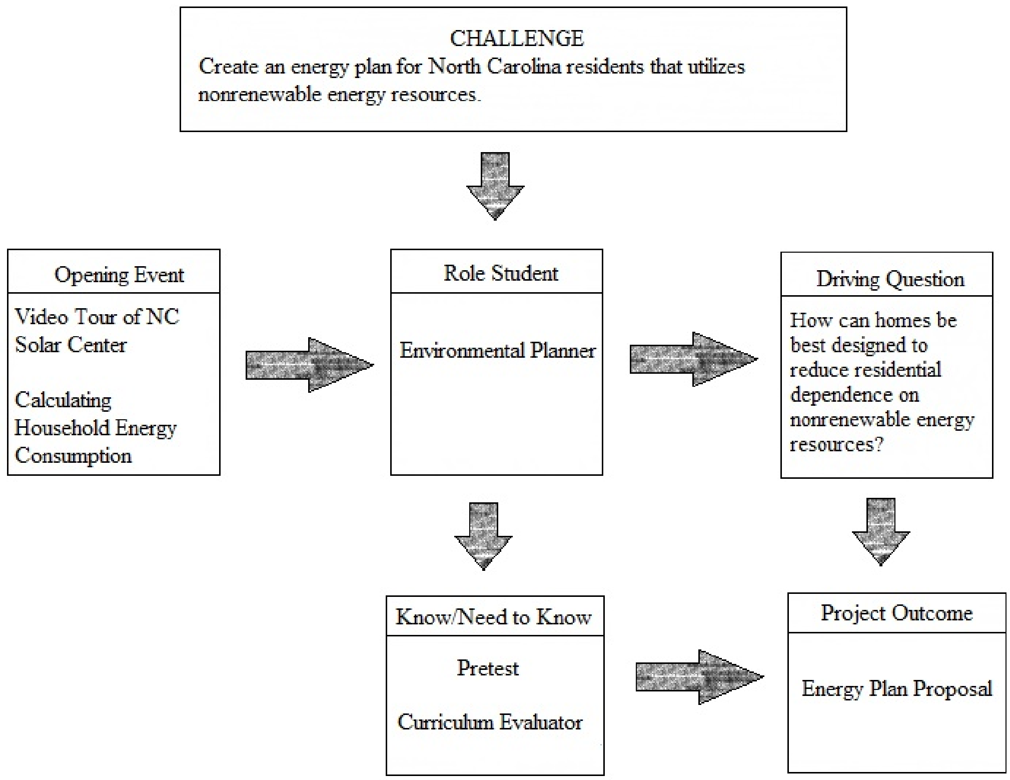

Figure 2. STEM educational framework for problem-based activity

Reflective Questionnaire

The reflective questionnaire was a thirteen-item questionnaire consisting of a) two items regarding group work b) two items rating perceived reasoning abilities c) eight items rating perceived problem-solving abilities and d) one item rating perceived understanding of RET. The questionnaire was modified from Amador and Gorres (2004) to evaluate student perceptions of their learning and development of 21st century skills (reasoning, problem-solving, and ability to work in a group) following learning about RET in either the lecture-based or DRL environments. All thirteen items were rated on a four-point Likert scale, ranging from a score of 1 (strong agreement) to a score of 4 (strong disagreement). The reflective questionnaire was found to be a reliable instrument to assess the perceived effectiveness of instruction. Reliability was demonstrated by a Cronbach alpha coefficient of .90.

Student Information Sheet

The student information sheet was utilized to gather demographic information about the students that might further inform the study. Students provided information about their grade level, gender, race/ethnicity, and math and science courses they had taken in high school.

Data Analysis

Quantitative data analyses were performed to test the hypothesis that students taught in the DRL environment would have a significant gain in knowledge of STEM concepts related to RET and be better able to solve problems when compared to students taught in the lecture-based environment.

Prior to conducting statistical data analysis, student responses for the pretest, posttest, reflective questionnaire, and student information sheet were entered into a Microsoft® Excel spreadsheet. For the multiple-choice test items, student responses (A, B, C, D) were recorded and then coded as either correct or incorrect (1=correct, 0=incorrect). For the short answer test items, points earned for the short answer question were recorded (range from 0-2). Student scores on the pre- and posttest for the short answer section, multiple-choice section, and cumulative test were entered in the spreadsheet.

Total scores on the problem-based activity were also recorded in the spreadsheet. Prior to entering student responses on the reflective questionnaire and student information sheet, responses were coded (see Appendices H and I). Data for students who were absent for either the pretest or posttest were discarded due to lack of having a baseline (pretest scores) or lack of having a treatment comparison (posttest scores). In total, data for three students were not analyzed (n=128). Once data were entered, data were transferred to SPSS Version 18. For all statistical tests, an alpha (α) significant level of .05 was utilized.

From the outset of the study, students in the control (lecture-based) and treatment (DRL) groups were compared using an independent-samples *t*-test to determine if the groups were equivalent with respect to prior knowledge as measured by pretest scores. An independent-samples *t*-test was also performed to ensure equivalence between the two control periods (2 and 3) and two treatment periods (1 and 4).

DRL and Students' Knowledge of STEM Concepts

Pre- and posttest data were analyzed to determine if there was a significant difference in students' knowledge of STEM concepts related to RET between students in the lecture-based and students in the DRL environments. Frequencies and descriptive statistics were analyzed for all students, for control and treatment groups, and for each period. A paired-samples *t*-test was performed to determine whether students' knowledge of STEM concepts significantly differed before and after instruction in each of the learning environments.

An independent-sample t-test was performed to determine if there was a significant difference in posttest scores of the treatment group compared to the control group. Independent-sample t-tests were also performed to determine if there was a significant difference in posttest scores of control periods (2 and 3) to treatment periods (1 and 4), possibly attributable to having different teachers. Analysis of covariance (ANCOVA) was conducted using posttest scores as the response, pretest scores as the covariant, and group as the design factor to test if there was a significant difference in the posttest scores between the control and treatment groups controlling for pretest scores.

Analysis of variance (ANOVA) tests were also conducted to analyze the effects of gender, number of science courses, and number of math courses on students' scores. Students' perceived gain in knowledge about RET after instruction was compared between the control and treatment groups by examining descriptive statistics and performing an independent-samples t-test for responses to that statement on the questionnaire. Differences in students' responses attributable to gender differences were also explored using descriptive statistics and an independent-samples t-test.

DRL and Students' Problem Solving Skills

Students' performance on the problem-based activity and responses on a reflective questionnaire were analyzed to determine if there was a significant difference in students' problem solving abilities or perceived problem solving abilities, between students in the lecture-based and students in the DRL environments. For the problem-based activity scores and questionnaire responses, descriptive statistics and an independent t-test were used to examine differences in responses between the control and treatment groups. Gender differences were also explored using descriptive statistics and independent t-tests for questionnaire responses.

CHAPTER 4: RESULTS

This study sought to determine the impact of a data-rich learning environment on a) students' knowledge of STEM concepts related to RET (RQ1) and b) students' problem solving skills (RQ2). The previous chapter outlined the data analyses used to answer these research questions. The results for each of the questions are presented below.

Sample sizes are shown in Table 2. Absences during the study period were accounted for by only including student data for who both pretest and posttest data were collected.

Table 2

Sample Sizes

Group	Pretest/Posttest	Reflective Questionnaire
All students	128	124
Control	63	60
Treatment	65	64
Period 1[a]	33	33
Period 2 [b]	33	32
Period 3 [b]	30	28
Period 4 [a]	32	31

Notes:
[a] Treatment Group
[b] Control Group

DRL and Students' Knowledge of STEM Concepts Related to RET (RQ1)

Equivalence of Control and Treatment Groups

Prior to conducting analyses to determine the impact of the learning environment on students' knowledge of STEM concepts related to RET, analyses were performed to determine if the treatment and comparison groups were equivalent in terms of their prior knowledge of RET. The results of the independent-samples *t*-test for the short answer, multiple choice, and overall pretest scores indicate no significant difference between the two groups in terms on students pretest scores (see Table 3).

Table 3

Equivalence of Control and Treatment Groups Onset Study

	Cumulative Pre-Test Score	Short Answer Section Score	Multiple-Choice Section Score
	M (SD)	M (SD)	M (SD)
Control	11.41(2.70)	4.65(1.48)	6.76(2.09)
Treatment	11.59(2.95)	4.53(1.51)	7.06(2.28)

Equivalence of control and treatment class periods between teachers was also evaluated. No significant differences in the treatment (periods 1 and 4) or control (periods 2 and 3) were noted, except for a significant difference found between periods 2 and 3 (control) with respect to students' short answer scores on the pretest (see Table 4). Period 2 students ($M=5.20$, $SD=1.20$) scored significantly higher on the short answer questions than period 3 ($M=4.05$, $SD=1.53$); $t(61)=3.32$, $p = .002$.

Table 4

Equivalence of Class Periods Onset Study

	Cumulative Pre-Test Score		Short Answer Section Score		Multiple-Choice Section Score	
Periods 2 and 3	*t*-test = 1.02		*t*-test = 3.32*		*t*-test = -.86	
	11.74(2.59)	11.05(2.82)	5.20(1.20)	4.05(1.53)	6.55(1.97)	7.00(2.21)
Periods 1 and 4	*t*-test = -1.80		*t*-test =-1.16		*t*-test =-1.54	
	10.96(3.31)	12.25(2.41)	4.32(1.26)	4.75(1.72)	6.64(2.60)	7.50(1.85)

Notes:
*$p<.05$

Effect of Treatment

A paired-samples *t*-test was performed to determine if students' knowledge significantly differed before and after instruction in each learning environment. There was a significant difference for both the control and treatment groups in pre- and posttest scores as would be expected (see Figure 3).

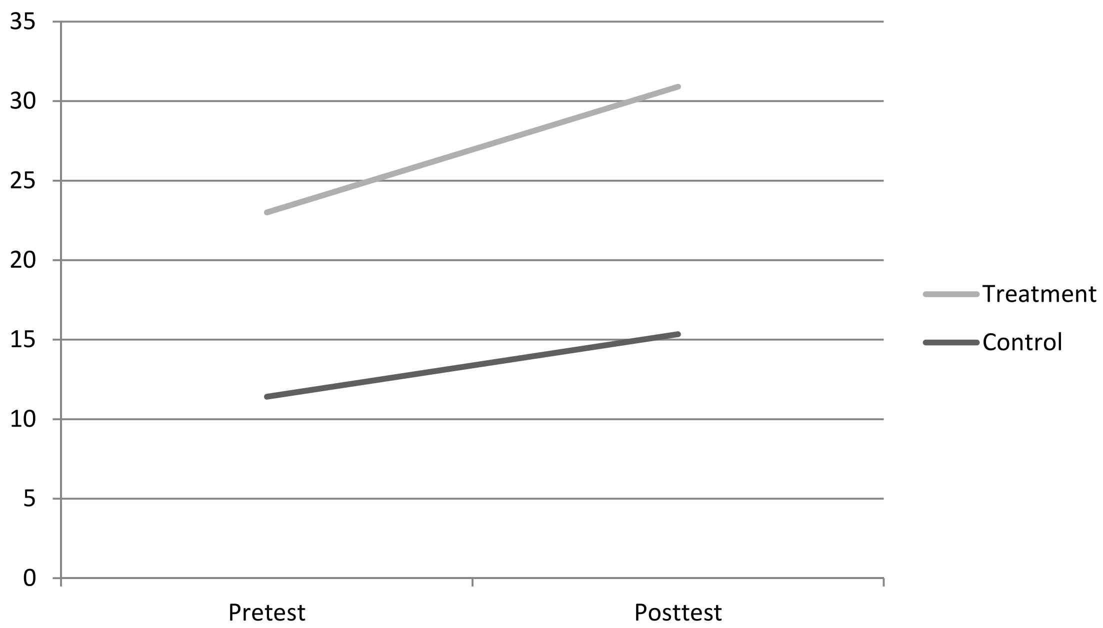

Figure 3. Comparison of Treatment and Control Mean Pretest/Posttest Scores

An independent-samples *t*-test revealed no significant difference in posttest scores for the control (M=15.33, SD=3.33) and treatment (M=15.55, SD=2.61) group; $t(126)=-.433$, $p=.67$. Results from ANCOVA analysis revealed that covariate, students' pretest scores, was not significantly related to students' posttest scores, $F(1,1) = 36.02$, $p=.77$. These results indicate that while students in the DRL environment scored significantly higher from pretest to posttest, the mean posttest scores for students in the DRL were not significantly higher than the mean posttest scores for students in the lecture-based learning environment.

Confounding Variables

One-way ANOVA analysis was conducted to compare pre- and posttest scores of males to females to determine if gender differences were present. There was a significant difference in pretest scores for males (M=12.63, SD=2.86) compared to females (M=10.71, SD=2.52); F(1)=16.20, p=.000 and in posttest scores for males (M=16.65, SD=2.75) to females (M=14.59, SD=2.84); F(1)=16.82, p=.000 (see Figure 4). The mean scores for both the pretest and posttest were significantly lower for females compared to males. ANOVA analysis also revealed a significant difference in students' pretest scores and the number of science courses students had taken; F(4)=2.56, p=.04. Two separate ANCOVA analyses with a) gender and b) number of science courses as the covariates did not show that either variable had a significant effect on students' posttest scores. Although, there were significant differences in students' pretest scores with regards to gender and number of science courses students had taken, gender and the number of science courses a student had taken were not found to be significantly related to students' posttest scores.

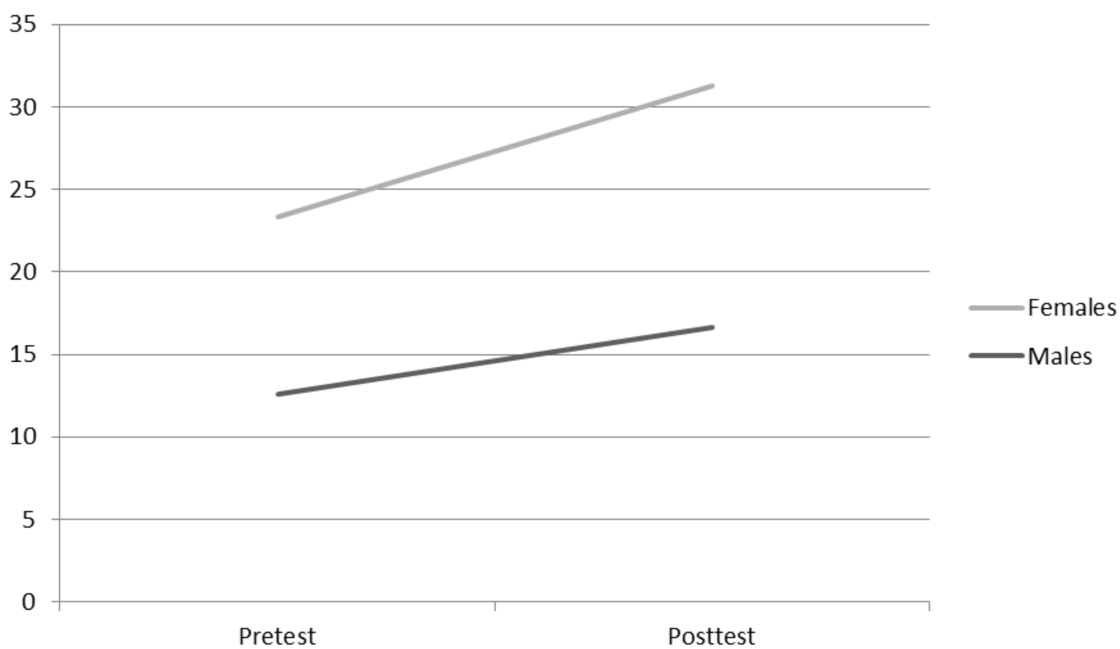

Figure 4. Gender Comparison of Mean Pretest/Posttest Scores

DRL and Students' Problem Solving Skills (RQ2)

Equivalence of Control and Treatment Groups

Due to time limitation of the study, data was not obtained to measure students' problem solving abilities prior to instruction, therefore a baseline was lacking to establish any potential differences in problem solving abilities among students in the control group compared to students in the treatment group at the onset of the study. Equivalence of post-instruction problem solving abilities and perceived problem solving abilities, measured using scores from the problem-based activity and questionnaire, did not reveal significant differences between the control (periods 2 and 3) and treatment (periods 1 and 4) groups that would indicate differences in students' problem solving abilities or perceived problem solving abilities attributed to having a different teacher.

Over 50% of the students participating in the study reported agreement or strong agreement with all items on the reflective questionnaire, except for having an improved ability to solve math problems following instruction. Only forty percent of students agreed that after instruction the student had an improved ability to use math to solve problems. Students reported having the strongest agreement with having a better understanding of RET following instruction and the least agreement with having an improved ability to use math to solve problems following instruction (see Table 5).

Table 5.

Reflective Questionnaire Response Frequencies and Descriptive Statistics

Statements	Student Agreement [a]	Mean (SD)
Ability to defend point of view improved	75.8	2.17(.52)
Ability to determine relevance of information improved	74.2	2.17(.58)
Ability to synthesize knowledge from different areas improved	65.6	2.24(.62)
Better contributor to group	71.7	2.16(.64)
Better identifying what is important in a problem	68.7	2.19(.66)
Better understanding of RET	88.3	1.77(.67)
Discriminate useful/useless information better	56.6	2.21(.69)
Explain reasoning better	71.1	2.20(.57)
More confident making assumptions and estimating when solving problems	59.3	2.27(.65)
More confident in ability to solve real-world problems	59.3	2.32(.62)
More confident working in groups	61.8	2.19(.74)
Problem-solving skills have improved	60.9	2.30(.65)
Ability use math to solve problems has improved	40.6	2.58(.78)

Notes:

[a] Percentage of students that indicated they strongly agreed or agreed with statement.

Effect of Treatment

For the two statements above that had the greatest and least agreement among students, students' self-reported understanding of RET and ability to use math to solve problems, was higher among students in control group compared to students in the treatment group (see Figure 5).

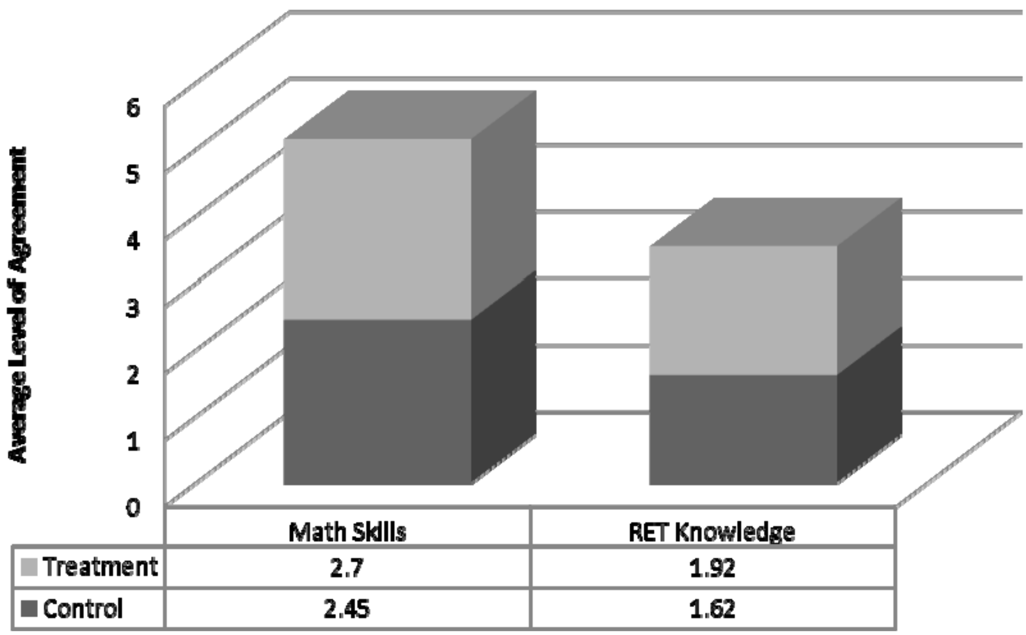

Figure 5. Comparison of Control and Treatment Responses to Questionnaire

Students in the control group had a lower mean value for each of the statements, indicating a greater level of agreement that after instruction, the student a) was a better contributor to a group and more confident working in groups b) was better able to solve problems and c) had a greater understanding of RET (see Table 6). An independent-samples *t*-test was conducted to compare control group responses on the reflective questionnaire to treatment group responses. There was a significant difference in student responses for all statements, except for student's confidence in his/her ability to make assumptions and estimate, improved problem solving skills, and improved ability to use math to solve problems. This suggests that students' perceived problem solving abilities following instruction were comparable in both the lecture-based and DRL environments.

Table 6.

Comparing Questionnaire Responses Control and Treatment Group

Statements	Control Mean (SD)	Treatment Mean (SD)	Independent Samples *t*-test
Ability to defend point of view improved	2.05(.47)*	2.28(.55)	*t*(122)=-2.52, p=.01
Ability to determine relevance of information improved	2.03(.49)*	2.30(.63)	*t*(122)=-2.59, p=.01
Ability to synthesize knowledge from different areas improved	2.10(.60)*	2.37(.60)	*t*(121)=-2.44, p=.02
Better contributor to group	2.02(.57)*	2.30(.68)	*t*(122)=-2.48, p=.02
Better identifying what is important in a problem	2.02(.54)**	2.34(.72)	*t*(122)=-2.86, p=.01
Better understanding of RET	1.62(.61)*	1.92(.70)	*t*(122)=-2.58, p=.01
Discriminate useful/useless information better	2.03(.66)**	2.38(.68)	*t*(121)=-2.86, p=.01
Explain reasoning better	2.02(.47)****	2.38(.60)	*t*(122)=-3.67, p=.00
More confident making assumptions and estimating when solving problems	2.15(.64)	2.38(.66)	*t*(121)=-1.91, p=.06
More confident in ability to solve real-world problems	2.20(.58)*	2.43(.64)	*t*(121)=-2.08, p=.04
More confident working in	2.03(.69)*	2.33(.76)	*t*(122)=-2.26, p=.03

Table 6 Continued

groups			
Problem-solving skills have improved	2.18(.62)	2.41(.66)	*t*(122)=-1.93, p=.06
Ability use math to solve problems has improved	2.45(.75)	2.70(.79)	*t*(122)=-1.83, p=.07

Notes:
Lower values indicate stronger level of agreement.
* p<.05, **p<.01, ***p<.001, ****p<.0001

Confounding Variables

A one-way ANOVA was conducted to compare the number of science courses and number of math courses students had taken to students' responses for each statement on the questionnaire. No significant differences were found. These results suggest that the number of math courses and number of science courses the student had taken prior to the study did not significantly affect students' perceptions of their problem solving abilities or understanding of RET.

An independent-samples *t*-test and one-way ANOVA revealed significant differences in male and female responses to three statements on the questionnaire. Female students perceived themselves to be better contributors to a group (M=2.04, SD=.66) compared to males (M=2.33, SD=.59); *t*(122)=2.55, p=.01. Females also reported having more confidence working in a group (M=2.05, SD=.76) compared to males (M=2.37, SD=.66); *t*(122)=2.55, p=.01. Further, females reported that after instruction, they were better able to identify what was important in problems (M=2.08,SD=.60) compared to males (M=2.33, SD=.71);*t*(122)=2.13, p=.04. These results suggest that both the lecture-based and DRL environments improved females confidence working in groups and their perceived contributions to a group, in addition to female students being better able to identify important information when solving problems.

An independent-samples *t*-test revealed no significant difference in the scores for the treatment and control student scores on the problem-based activity.

Summary

Results from the study do not support the initial hypotheses that students taught in the DRL environment a) would have a significant gain in knowledge of STEM concepts related to RET and b) be better able to solve problems when compared to students taught in the lecture based environment. Comparison of mean pretest and posttest scores indicate that students in both the control and treatment groups had a significant gain in knowledge after instruction, as is expected. Analysis of mean posttest scores between the groups revealed no significant differences, indicating that students in the DRL environment did not perform better or worse than students in the lecture-based learning environment on the posttest.

Further, no significant differences were noted in students' problem solving abilities as measured by scores on a problem-based activity or self-reported abilities on a reflective questionnaire. Although students in the lecture-based learning environment reported significantly higher levels of agreement, that after instruction their reasoning, some measures of problem-solving abilities, and ability to work in a group improved, no significant difference in students' self-reported problem solving abilities or abilities to solve math problems were noted between the control and treatment groups.

CHAPTER 5: DISCUSSION

Concerns over global climate change, environmental degradation, and dwindling nonrenewable energy resources have prompted the need for renewable energy education (Thomas, Jennings & Lloyd, 2008). Renewable energy education affords students the opportunity to learn science, technology, engineering, and mathematics (STEM) concepts in a way that is meaningful to their lives. This study sought to investigate the potential of using a data-rich learning environment (DRL) to improve students' knowledge of STEM concepts related to renewable energy technologies (RET) and students' problem solving skills. The traditional classroom environment for AP Environmental Science is one that utilizes lecture, labs, activities, and assignments to aid in students' learning of environmental concepts.

While there are a number of approaches that support teaching and learning of science concepts, not all approaches are equally effective in developing students' knowledge of science and promoting the 21st century skills, such as higher order thinking skills, necessary for today's students (Artino, 2008). Although science is traditionally taught using a lecture-based approach with a focus on the memorization of facts, several studies comparing this traditional approach to teaching and learning, to more student centered approaches have indicated that the lecture-based approach may not be the most effective method for teaching science to high school students (Holubova, 2008; Wong & Day, 2009).

Research to determine the effectiveness of DRL environments as a method of teaching and learning in high school science classes is limited. For this study, two classes of APES students were taught in a lecture-based learning environment (control) and two classes were taught in a data-rich learning (DRL) environment to test the hypotheses that students' taught in the DRL environment would have a) a significant gain in knowledge and b) be better able to solve problems compared to students taught in the lecture based environment.

Paired *t*-tests revealed higher mean posttest scores compared to pretest scores for students in both the DRL and lecture-based learning environments, indicating that students in both groups had a greater knowledge of RET after instruction. Although mean posttest scores of students in the DRL environment (15.56) were higher in comparison to mean posttest scores of students in the lecture-based learning environment (15.33), differences in posttest scores were not found to be significant between groups. Students in the DRL environment had on average, posttest gains of 3.97 points compared to students in the lecture based learning environment, demonstrating average gains of 3.92 points. The results from this study indicate that both learning environments were comparable in improving students' knowledge of RET as students in both groups demonstrated posttest gains following instruction. Although learning about RET in the DRL environment did not result in a significantly greater knowledge of RET compared learning about RET in the lecture-based learning environment, the results indicate that the DRL environment was as effective as the lecture-based learning environment in improving students' knowledge of STEM concepts related to RET.

Several factors may have contributed to these results. For this study, students were immersed in a DRL environment at the beginning of the school year prior to students having had an opportunity to establish a classroom routine and rapport with the classroom teacher. Students had only been in school for one full week prior to the onset of the study. Further, the DRL was implemented over two 90-minute periods; therefore, it is unlikely that this short duration was conducive to producing significant learning gains among students in the treatment group.

A study exploring Model Based Inquiry (MBI) compared to lecture teaching methods in a physics classroom demonstrated similar results with both groups showing improvements after instruction in student understandings of difficult concepts related to physics, with no significant differences found between the groups. The researchers (Champbell, Zhang, & Neilson, 2001) suggested time might have played role in the results, as students were only engaged in the MBI lesson for a period of two weeks. The present study engaged students in the DRL for a shorter period of time. In order to test the effectiveness of the DRL environment in improving students' understanding of STEM concepts, students should be immersed in the DRL environment for a longer duration of time.

Students' Prior Knowledge

Although the APES curriculum addresses the need for students to understand RET and topics outlined by The College Board (2010) can be taught in any order, RET is usually taught towards the end of the semester after students have learned about earth systems, ecosystems, population dynamics, and uses of water and land resources. The only knowledge base students had to build upon for the RET curriculum, was prior knowledge of the subject matter. Although the treatment group had slightly higher pretest scores, the control and treatment groups were found to be equivalent at the onset of the study in students' prior knowledge about RET.

A study conducted by Gambro & Switzy (1999), found a significant relationship between environmental knowledge and the number of science classes students had taken. The present study found the number of science courses a student had taken to be of significance only in students' pretest scores. Students who had taken more high school science courses did not have significantly higher posttest scores than students who had taken fewer science courses in high school. This suggests that while the number of science courses a student had taken was a predictor of students' pretest scores, the science background of students did not play a role in students' ability to learn about RET in either learning environment. In other words, even though some students may have had prior knowledge of RET from previous science classes to serve as learning hooks, not having those learning hooks did not prevent students who had taken fewer science courses from learning the concepts related to RET. This may also suggest; however, that the RET content was equally difficult for students with a strong background in science as it was for students with a weaker science background. Further evaluation of the North Carolina Standard Course of Study (2004) for high school science courses, revealed Earth Science as the only other science course that addresses RET and that curriculum does not cover RET at the same depth the questions on the pretest addressed. Thus it is likely that other factors related to the number of science courses a student had taken contributed to the significant differences found in students' pretest scores.

Although the number of science courses a student had taken was not found to be a predictor of students' posttest scores, further analysis revealed that students who had taken physics scored significantly higher on the short answer section than students who had not taken physics. Although qualitative analysis of the short answer questions was beyond the scope of this study, students who had taken physics would be more at an advantage to answering the short answer question about the difference between energy and power, as energy and power are included in the physics curriculum (NC SCOS, 2004). The average pretest and posttest scores for this question were lower than the average scores for the other short answer questions. The RET curriculum for both the control and treatment groups covered the difference between power and energy; however, students still performed poorly on this question after instruction. Analysis of student responses for this question revealed that a number of students held alternate conceptions about energy and power. It was also observed during the study that one of the teachers interchangeably used the terms energy and power, indicating a teacher lack of understanding, which may perpetuated alternate students' alternate conceptions of power and energy. Several studies support the findings that students (Saglam-Arslan, 2010) and teachers (Diakidov & Iordanou, 2003; Trumper, 1998) alike hold alternate conceptions of energy.

In addition to learning the units for energy and power, APES students must also use math to complete energy conversion problems in learning energy concepts (The College Board, 2010). Five questions on the pretest/posttest were application questions requiring students to use math skills to solve problems related to energy and power. Prior to the study, one of the participating teachers discussed students' lack of confidence in solving math problems when teaching about energy concepts. Although most students enrolled in APES have taken at least basic algebra, students still struggle with the math in APES. Student responses on the reflective questionnaire support the teachers' observation. For both groups, students least agreed with the statement that after instruction, students had an improved ability to use math to solve problems. Since the reflective questionnaire was completed after students had taken the posttest, difficulties in answering math questions on the posttest likely influenced student responses to this particular statement. No significant difference in students' self-reported abilities solve math problems were found between students in the control and treatment groups.

The number of high school math courses a student had taken was found to be significant on the pretest multiple choice questions and posttest short answer questions. Intuitively, students who had taken more math courses would show significantly higher scores on the multiple choice section of the pretest as it contained five math problems. Further investigation is needed to discover why the number of math classes a student had taken was significant on students' posttest short answer questions, as the short answer questions did not contain any math problems.

Pedagogical and Technical Issues

Although previous research has shown DRL environments using online data provided the GRIDc to increase students' learning and higher order thinking skills (Deluca, Carpenter, & Lari, 2010), several pedagogical and technical issues present in this study could explain why the present study did not yield similar findings. The GRIDc data was unfamiliar to the students and teachers. Teachers participating in the study could have benefited from additional training utilizing the GRIDc website prior to the onset of the study. One of the pedagogical issues associated with the DRL in this study was usability.

Prior instruction from the teacher was not given to students in the DRL. Following a brief introduction of the GRIDc project data and explanation of the goals of the DRL activity, students were given the activity to complete with a partner. It was evident from classroom observations on day one, that students in period 1 did not have a clear understanding of the activity instructions and objectives. On day two of the study, it was necessary for the researcher to provide students in the treatment periods (1 and 4) with an overview the GRIDc website and data collected from the RET available for students to analyze. For future studies, goals of the activity need to be well established prior to students beginning the activity in order for students to get the most out of the learning activity.

Another issue associated with the DRL environment was the wealth of data available for students to access. Day one and two of the study, students needed direction in determining which data to analyze in order to answer the question. Students did not have the background knowledge or analytical skills needed to successfully complete the activity without teacher/researcher intervention. Deciding which variables to utilize may have interfered with students' learning of concepts. In investigating the learning potential for utilizing online USGS data, Kerlin, McDonald, and Kelly (2010) noted similar issues with data complexity.

The DRL activity was designed to guide students in learning specific concepts related to RET; however, the wealth of data might have impeded students' learning of these concepts. One of the participating teachers' reflections at the end of the day was that "students were just looking for an answer to fill in the blank rather than analyzing the data and forming conclusions." From classroom observations and teacher reflection notes, it was apparent that students were utilizing the data as a means to get the correct answer, rather than engaging in metacognition. Redesign of the activity should include additional opportunities for students to explain how they arrived at the answer.

Another technical issue that arose with the DRL activities was the availability of data on the GRIDc website. The DRL activities were initially designed for students to be able to utilize real-time data collected from the RET at the NC Solar Center; however, since the NC Solar Center closed two months prior to the study due to budget cuts, activities were modified for students to use archived data. Archived data were only available for certain days when the RET sensors were actively collecting data; and although students were provided with date ranges for which data were available, this proved to be a distractor to students when trying to access data to complete the activity.

Gender Differences

Research has shown that students' knowledge varies with gender and other factors. A study conducted by Gambro and Switzky (1999) found that females had lower levels of knowledge related to environmental concepts when compared to males. The present study yielded similar results. Female students had significantly lower posttest scores than males and females had lower agreement that their knowledge of RET improved after instruction.

Kim (2001) investigated the impact of a technology and inquiry-based learning curriculum using Green Earth on the content knowledge and attitudes toward science of female, middle school students. One of the concepts the female students learned through the inquiry-based learning activity was about alternative energy. Results from pre and posttests and attitudinal surveys showed that female students had improved knowledge and attitudes toward science after the technology enhanced, inquiry-based learning curriculum. Although that study did not compare knowledge and attitudes of females in the inquiry-based learning environment to another type of learning environment, or compare knowledge and attitudes of females to males, results indicate the potential for technology enriched inquiry-based learning activities to improve knowledge of science and attitudes towards science among female students.

Implications

Utilizing online data to learn about STEM concepts addresses national and state standards calling for inquiry based learning. The nature of the topic presented in this study may have influenced student performance. RET education cuts across many STEM disciplines and requires complex understanding of science, technology, and math concepts. Although the present study did not reveal significant differences between students' knowledge of STEM concepts related to RET or students' problem solving skills in the DRL compared to the lecture-based learning environment, this was a small study involving two teachers from the same school. Further examination is needed to determine the effectiveness of DRL environment to be used as instructional tool.

A more teacher-centered approach to the DRL activities might have led to higher achievement among students in the DRL environment. An alternative approach may be a combination of both the lecture-based and DRL environments, in which students first learn the concepts in a lecture-based learning environment and then engage in DRL activities to reinforce their learning.

Although lectures are considered to be teacher-centered instructional approaches, research studies have shown the value in lecture-based learning. Lectures are often criticized as leading to passive learning of concepts; however, research has shown that lectures can be interactive in nature and lead to active learning of concepts (Gier & Kreiner, 2009). Active learning of concepts is desired because it leads to deeper understanding and greater recall when compared to passive learning (Bergtrom, 2011). Lectures that include class discussions have been found to support active learning of concepts and have produced greater learning gains when compared to traditional lectures (Prakash, 2010).

In addition to the content presented during lecture, students also make meaning from teacher gestures, body positions, and teacher-student interactions during lecture. Thus, lectures present students with multiple meaning making opportunities (Pozzer-Ardenghi & Roth, 2007). How the concept is taught is as important as the concept being taught. Perhaps a better model for DRL environments is one that incorporates lecture-based learning prior to engagement in the DRL activities. In this way students can apply what they have learned during lecture to explain patterns in data.

However, implementing both learning environments might prove difficult for courses that have an over-packed curriculum. The time allocated for the RET unit for this study was comparable to the amount of time the participating teachers typically spend on RET. Introducing a DRL to teach about energy and STEM concepts in courses that do not already cover these topics in the curriculum might be problematic due to the constraints of the curriculum.

Future Research

Students participating in this study utilized data from the GRIDc project to learn about RET. This study sought to measure students' content knowledge and problem solving skills in a DRL environment. Future studies should investigate the potential of DRL environments to increase students' 21st century skills, such as communication and collaboration.

While this study examined students' factual knowledge and conceptual understanding of RET, lacking from this study was feedback from students to evaluate the learning environments. Further research is needed to examine student attitudes toward the learning environment and learning outcomes resulting from DRL activities. Post-instruction attitudinal surveys or interviews could be utilized to investigate whether students perceived the DRL activities to be meaningful activities.

Since research has shown that school level factors can influence students' environmental knowledge (Kuhlemeir, Van Den Bergh, & Lagerweii, 1999), this study was conducted with four APES classes at the same school. This reduced the generalizability of the study. More studies are needed to generalize the findings from this study. The students in this study were students in an Advanced Placement Environmental Science class due to the coverage of RET in the APES curriculum. Future studies might examine the potential of teaching about RET in a DRL environment in other STEM courses.

To determine the long term effects of the DRL environment on students' knowledge of STEM concepts and problem solving skills, delayed post-testing could be utilized. This would allow for the examination of student retention of ideas related to RET following learning in a DRL environment. Future research should also include immersing students in a data-rich learning environment over a longer period of time, possibly allowing for students to engage in multiple data-rich learning activities over the course of several weeks, in order for students to develop mental habits suited to data-rich learning environments.

Summary

Our understanding of the potential for DRL to improve students' knowledge of STEM concepts and promote problem solving skills is incomplete. Although this research study did not find any significant differences in students' knowledge of STEM concepts related to RET or students' problem solving skills in the DRL environment compared to the lecture-based learning environment, DRL learning activities such as the ones employed during this study provide students with authentic learning experiences and the opportunity to build 21st century skills. The implication of this study is that teaching students in a DRL environment is an alternative teaching method that science teachers could utilize to teach students science concepts, that is as least as effective as a lecture-based learning environment. More research is needed to determine the outcome of DRL environments in terms of the extent to which the DRL environment brings about a change in students' knowledge of science concepts, as short-term interventions, such as this study investigated, are not likely to yield significant results.

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APPENDICES

APPENDIX A. Student Informed Consent

Dear Parent/Guardian:

I am presently working with your child's AP Environmental Science teacher to study the impacts of using online data in the science classroom to promote students' knowledge and problem solving skills related to renewable energy technologies. As part of my efforts, students will be given a test prior to and after instruction. This data will help me better understand the potential of online data to be used in science classrooms to engage students and teach science concepts and problem solving skills. This is where I need your help. I would like consent for your child to participate in this study and for me to collect pre and post test data from your child, in addition to collecting class work from the student. Please discuss this decision with your child. If either you or your child decides that he/she should not participate in the study, an alternate activity will be assigned by your child's teacher during the time other students are taking the pre and posttest. Students will still be required to participate in the daily class activities and instruction related to renewable energy technologies. Students who do not wish to participate in the study will not be penalized. Students will not be given a grade for participating or choosing not to participate in the study. No personal information about your child is necessary for my purposes. The student will use a non-identifying ID on his/her pre and posttest. In addition, participating students' class work will be de-identified before being shared with me. I do not anticipate any risks to your child from participating in this study.

Participation in this study is completely voluntary and there is no penalty for declining to participate. You are free to withdraw your child from the study at any time. In addition, students who do not wish to participate will not be included in the research. After the study is complete, I would be happy to share my findings with parents and teachers at your child's school.

Please sign and return this form as soon as possible if you agree to have your child participate in this research. If you have questions, please call me at XXX-XX-XXXX.

Child's Name:
Child's Approval Signature:
Parent/Guardian Approval:
Signature
Consent Date:

Thank you,
Brandi Thurmond
PhD Candidate, NCSU

APPENDIX B. RET Curriculum

Lecture-Based (Control)	DRL (Treatment)
Day One (90-minutes)	
• Pretest • Lecture – Energy Consumption and Residential Renewable Energy Technologies Overview • Household Energy Consumption Activity • Assignment: Household Energy Usage	• Pretest • NC Solar House Virtual Tour • Introduction to GRIDc Project • Household Energy Consumption Activity • Assignment: Household Energy Usage
Day Two (90-minutes)	
• Collect assignment • Lecture – Solar Energy • Assignment: Passive Solar House Designs	• Collect assignment • GRIDc Data Activity • Assignment: Passive Solar House Designs
Day Three (90-minutes)	
• Collect assignment • Problem Based Activity • Assignment: AP Free Response Question	• Collect assignment • Problem Based Activity • Assignment: AP Free Response Question
Day Four (90-minutes)	
• Collect assignment • Post test • Student Questionnaire • Student Information Sheet	• Collect assignment • Post test • Student Questionnaire • Student Information Sheet

APPENDIX C. Example of Teacher Directions

Teacher Notes Day 2: GridC Data Activity

Example of Teacher Instructions to Students:
Today you will be learning about solar energy technologies. For this activity, you will be using data from the GridC project to answer 5 questions about photovoltaic systems. You will investigate the relationship between power and energy, the efficiency of PV arrays and factors affecting PV power output, and the environmental impact of using solar energy technologies, such as PV arrays.

Teacher Directions:

1. Provide students with instruction prior to the start of the activity. (Example of Teacher Instructions to Students above)
2. Hand out GRIDc activity sheet to students. One per group.
3. Direct students to work with a partner (one other classmate) to answer the questions.
4. Students should have the entire 90 minute period to work with the GRIDc data online to answer the questions.
5. Students can write directly on the activity sheet. Students should use their last initial and birthday as their student ID. For example if their last name was Doe and their birthday was January 1, 1994, their student ID would be D111994. Both student IDs should be included on the activity sheet.
6. Students should hand in the activity at the end of class.

APPENDIX D. Pretest/Posttest

Part A – Short Answer

1. Define renewable energy and nonrenewable energy and list two examples of each.

2. List three advantages and three disadvantages of using renewable energy to meet our energy needs in the United States.

3. Write down the amount of energy you consume in one day and rank the top three appliances you use on a regular basis in terms of energy consumption.

4. Explain the difference between energy and power.

5. Describe two ways that solar energy can be used in our homes.

Part B – Multiple Choice

6. If two power stations are generating energy, one operating at 700 MW and generating electrical energy for 1 hour and the other operating at 400 MW and generating electrical energy for 2 hours, which power station generated more power during that time period?
   a. 700 MW Power Station
   b. 400 MW Power Station
   c. Both generated the same amount of energy
   d. More information is needed to determine which generated more power

7. All of the following are features of passive solar design except
   a. Stone floor and wall for heat storage
   b. Using a solar energy collector and pump to supply hot water
   c. Windows on the south side of the house
   d. Summer cooling vents in the roof

8. Which part of the PV system converts direct current into alternating current?
   a. Circuit breaker
   b. House electrical lines
   c. Inverter
   d. Solar array

9. A regular light bulb has an efficiency rating of 3 percent. For every 1.0 joules of energy the bulb uses, the amount of useful energy produced is
   a. .97 joules of light
   b. .97 joules of heat
   c. .03 joules of light
   d. .03 joules of heat

10. Photovoltaic cells produce electricity by
    a. Using a system of mirrors that focus sunlight onto a heat collection device
    b. Using the sun's energy to create a flow of electrons in a material such as silicon
    c. Warming the air which spins a turbine
    d. Breaking down organic molecules and releasing energy

11. How much energy is used by a 100-watt computer running for 5 hours?
    a. 500 kWh
    b. 100 kWh
    c. 50 kWh
    d. .50 kWh

12. The peak power output of the PV array is
    a. Higher when it is hotter outside
    b. Higher during the winter solstice than the summer solstice
    c. Higher during shorter days
    d. Higher during a cloudy day in the summer, than a sunny day in the winter

13. An appliance operates at 120 volts and 10.0 amps for 1 hour. How many watt-hours does it use in that hour?
    a. 1.2 watt-hours
    b. 12 watt-hours
    c. 100 watt-hours
    d. 1200 watt-hours

14. PV array efficiency can be measured using all of the following measurements except
    a. Measure of energy lost when AC is converted to DC
    b. Measure of ability of system to convert sunlight into electricity
    c. Measure of how much available sun energy is converted to AC
    d. Measure of the system output divided by the solar input.

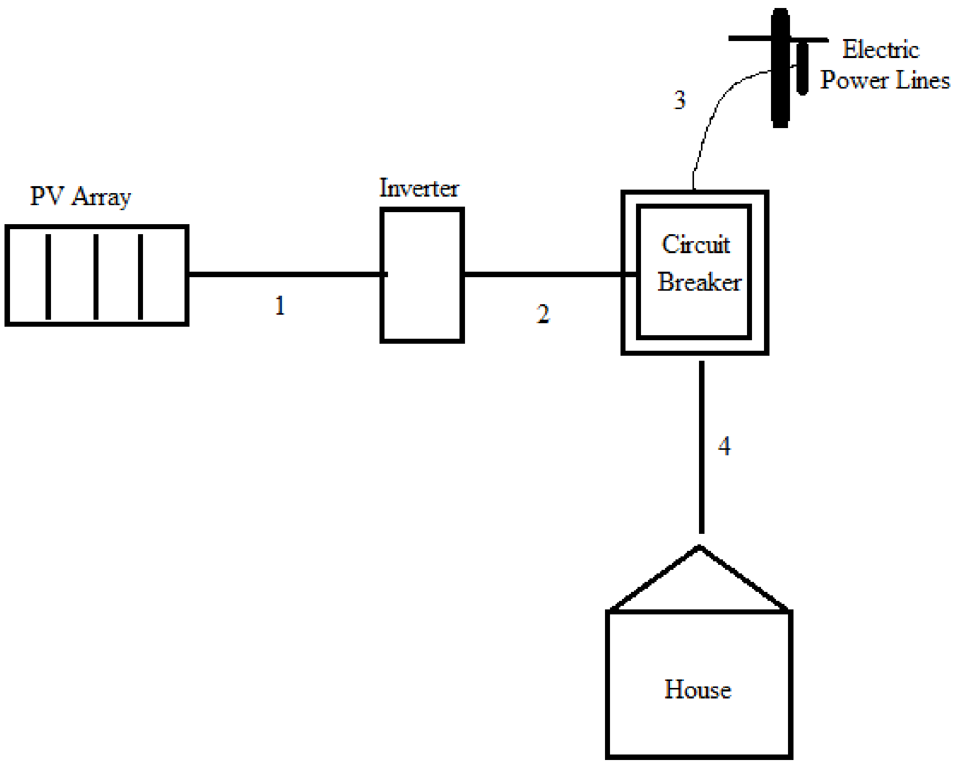
15. An incandescent light bulb consumes .10 kilowatts. If a PV array is operating at a peak output of 2 kW, how many 100 watt incandescent light bulbs could the PV light?
    a. 2000 light bulbs
    b. 200 light bulbs
    c. 20 light bulbs
    d. 2 light bulbs

16. Which of the following is an example of active solar heating in a residential setting?
    a. Extended eves that block the hot summer sun, but allow the winter sun to enter the house
    b. Photovoltaic cells that convert sunlight directly to electricity
    c. A system that pumps water to the roof to be heated by the sun and then stores it in a water tank to be used later
    d. Using heavy insulation in the attic

17. A solar cell converts
    a. Heat energy into electrical energy
    b. Solar energy into electrical energy
    c. Heat energy into light energy
    d. Solar energy into light energy

18. A kilowatt is
    a. A unit of power
    b. A measure of energy
    c. A billing unit used by electrical utility companies
    d. A measure of electrical energy consumed

19. Which numbers on the diagram below correspond to AC wiring?



    a. 1, 3, and 4
    b. 1, 2, and 4
    c. 2, 3, and 4
    d. 1 and 2

20. For which of the following days would the solar array operate at optimal efficiency?
    a. A windy, sunny day during the summer
    b. A hot, cloudy day during the summer
    c. A hot, humid day during the summer
    d. A high atmospheric pressure day during the summer

APPENDIX E. Problem-Based Activity

Objective:

- To research and compare the efficiencies of renewable energy technologies (RET) and the feasibility of those RET in North Carolina.

Problem:

Most residents in North Carolina rely on electric power production for their residential energy needs. As nonrenewable energy resources are in limited supply and lead to environmental degradation, you are charged with creating a proposal for North Carolina residents to supply their energy needs using renewable energy technologies (RET). Using what you already know about renewable energy and based on what you have learned about various types of RET you will create an energy plan for NC residents. As you create your proposed plan, you should consider the advantages, as well as, the challenges residents might face when implementing your energy plan. When outlining your proposal be sure to:

- Give the basic rationale for your proposal. This should be based on what you have learned from our class discussions.
- Compare and contrast your proposal for residential power production to what residents currently use for power production.
- Describe the economic, environmental, and social costs of implementing your proposed plan.
- Consider whether your proposed plan would cost or save residents money in the short and long term.
- Describe the reasons why implementing your plan would be considered a worthwhile investment.
- Describe the potential drawbacks of residents' implementing your plan.
- Discuss the ways that residential energy usage will have to change in order to implement your plan.
- Consider other possible things that might prevent residents from implementing your proposed plan.
- Describe the conditions for which implementing your plan be most beneficial.
- Explain why it would be in the residents' best interest to follow your proposed plan.

APPENDIX F. Reflective Questionnaire

Please indicate whether you strongly agree, agree, disagree, or strongly disagree with the following statements.

After completing the lesson on renewable energy technologies…	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**
My ability to defend my point of view has improved.	○	○	○	○
I can explain my reasoning better.	○	○	○	○
I am more confident working in a group.	○	○	○	○
I am a better contributor to group activities.	○	○	○	○
I am better at identifying what is important in a problem.	○	○	○	○
My problem-solving skills have improved.	○	○	○	○
I am more confident in my ability to solve real-world problems.	○	○	○	○
My ability to determine the relevance of information has improved.	○	○	○	○
My ability to synthesize knowledge from different areas has improved.	○	○	○	○
I can discriminate between useful and useless information better	○	○	○	○
My ability to use math to solve problems has improved.	○	○	○	○
I am more confident about making assumptions and estimating when solving problems.	○	○	○	○
I have a better understanding of the pros and cons of renewable energy technologies.	○	○	○	○

APPENDIX G. Student Information Sheet

Please fill in the following information about yourself.

Grade Level

9th	10th	11th	12th
○	○	○	○

Gender

Male	Female
○	○

Race/Ethnicity

White	Black	Hispanic	American Indian	Asian/ Pacific Islander	Multi-racial
○	○	○	○	○	○

Other ______________________

Science Courses

Please list all of the high school science courses you have taken so far. Do not include courses you are currently enrolled in.

Math Courses

Please list all of the high school math courses you have taken so far. Do not include courses you are currently enrolled in.

APPENDIX H. Questionnaire Coding

Strongly Agree = 1

Agree = 2

Disagree = 3

Strongly Disagree = 4

APPENDIX I. Student Information Sheet Coding

Grade Level

9 = 1

10 = 2

11 = 3

12 = 4

Gender

Male = 1

Female = 2

Race/Ethnicity

White = 1

Black = 2

Hispanic = 3

American Indian = 4

Asian/Pacific Islander = 5

Multi-racial = 6

Other = 7

Science/Math Courses

Regular = 1

Honors = 2

AP = 3