Fourth and Fifth Grade Students Learn About Renewable and Nonrenewable Energy Through Inquiry

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ABSTRACT A classroom of eighteen fourth and fifth graders in the Columbus, Ohio Public School system successfully evaluated how people obtain fossil fuels, how they are limited in nature, and how they can develop renewable energy solutions. Students modeled oil-drilling using: chocolate syrup, rice cereal, a baster, and a clear container. Chocolate oil became more difficult to pump as oil supplies diminished. While pumping, chocolate oil spills contaminated the drill hole and students excavated the polluted substrate. Students next learned more about oil spills by conducting their own clean-ups of vegetable oil in mini tap water oceans. Students learned that 'solving' the problem of the oil spill created new problems, including uninhabitable soapy oceans. This mimicked the failure of current technology to easily remediate oil spills. Finally to cultivate a better understanding of renewable energy, students built and tested solar ovens and discussed their benefits and limitations. After completing these activities, students showed a significant average improvement from their pretest to posttest understanding of renewable and nonrenewable resources. In addition, students were interested and excited to act on what they had learned.

INTRODUCTION

Humanity's consumption of fossil fuels threatens our future. We must act and we must teach our children not only to understand the limitations of fossil fuels, but to understand that achieving a future based on clean, renewable energy requires their involvement. Since the first Earth Day on April 22, 1970, human carbon emissions have increased from 3.9 million metric tons to an estimated 6.4 million (Meadows, 2000). Now, more than ever, increased demand for fossil fuels threatens global relations and global climate (NATO, 2004). Global dependence on oil is projected to last at least 20 more years and competition for this oil will increase significantly by 2030 with demand from Southeast Asia increasing exponentially (NATO, 2004). Both improved education and public policy are critical to the achievement of energy sustainability (Dincer, 2000).

Using Inquiry to Understand Energy Challenges

This study describes nonrenewable and renewable energy fourth and fifth lesson plans and educational outcomes. Lesson plans were developed and evaluated while participating in the National Science Foundation Graduate Teaching K-12 Program (NSF GK-12). NSF GK-12 pairs Science, Technology, Engineering, and Mathematics (STEM) graduate students with K-12 teachers to develop and implement new science curricula (NSF, 2008). STEM graduates participating in NSF GK-12 gain confidence communicating scientific ideas while K-12 students and teachers gain interest in science (NSF, 2008).

One class of eighteen fourth and fifth grade students (11 female; 7 male; 9 Euro-American; 6 African American; 2 Hispanic; 1 Asian) at an urban Columbus, Ohio Public school participated in this study. Permission to evaluate student learning was obtained from the school principal and teacher to evaluate the students as part of the NSF GK-12 Program.

The primary goal of this study is to explain and evaluate fourth and fifth grade geoscience-based lessons addressing major energy challenges. Science educators are charged with the goal of conveying important energy concepts to students because they are central to our global politics and economics (Rule, 2005). Bennett and Heafner (2004) suggest that student development of environmental awareness must include, "inquiry, implementation, and reflection". Hands-on lesson plans with time for reflection enhance student critical thinking abilities and give them more freedom in their scientific investigations (Council, 2000). Each lesson included features inquiry-based explorations.

The developed curriculum focuses on exploring three major energy challenges including: 1) understanding the limitation of fossil fuel reserves 2) learning the environmental costs of fossil fuel use and 3) understanding the benefits and limitations of renewable energy. In completing the lesson plan sequence, students did not explore every facet of each energy challenge, however, they gained a better understanding of each one.

METHODS

Curriculum Evaluation

To evaluate the curriculum students completed an identical ten-question pretest and posttest assessing their knowledge of renewable and non-renewable energy (Table 1). Questions were taken or modified from the natural resources test in the Columbus, Ohio Public Schools *Grade 5 Science Curriculum Guide* (CCSSD, 2005). These questions centered on identifying the students' abilities to distinguish the difference between renewable and nonrenewable resources. The test format included selecting the correct multiple choice response as well as free response. After completing the pretest students completed the series of activities within a five-week time period beginning in April 2007. The posttest was given six days after the completion of the final activity. Results were analyzed quantitatively by comparing statistical differences between mean pretest and posttest scores.

Quantitative results do not reflect the full breadth of student learning, but rather the science standards they satisfied while completing the lessons (CCSSD, 2005).

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TABLE 1. NATURAL RESOURCES PRE/POST ASSESSMENT- GRADE 5 ANSWER GUIDE (MODIFIED FROM CCSSD, 2005)

1. Because oil, natural gas, and coal were formed millions of years ago from the remains of plants and animals, they are called: a. animal fuels b. plant fuels **c. fossil fuels** d. plant and animal fuels
2. Forests are being cut down for timber. Many people believe new trees should be planted in these areas after the old trees are removed. Which of the following does not support this belief? a. new trees would prevent erosion b. new trees would provide oxygen **c. new trees would use up the soils supply of nutrients** d. new trees would provide habitats for organisms
3. Two students are discussing fossil fuels. The first student says fossil fuels are formed from the remains of dead plants and animals. The second student says we cannot easily create more fossil fuels. Who do you agree with and why? Explain your answer. ***Students should agree with both students. Fossil fuels are derived from the remains of plants and animals and it takes millions of years for heat and pressure to create fossil fuels. Because of this, we cannot easily create more fossil fuel.***
4. All of the following are nonrenewable resources except: a. oil b. coal **c. air** d. natural gas
5. Fossil fuels are frequently used. List two possible advantages and two disadvantages to using fossil fuels[1]: ***Advantages: provides energy for heating, transportation, lighting, and industry, and are low cost and widespread. Disadvantages: they are non renewable and cause pollution, running out of them will be very hard for us unless we find other renewable energy sources to replace them.***
6. All of the following behaviors support the maintenance of renewable resources and the extension of nonrenewable resources except[2]: a. replanting trees b. using solar power[2] **c. using paper plates** d. carpooling
7. All of the following are renewable resources except[3]: **a. fossil fuels** b. trees c. sunlight[3] d. fresh water
8. Humans have the ability to conserve resources. Which of the following does not support the conservation of resources? **a. recycling only when it is convenient** b.using the front and back of paper c. reducing the use of water d. voting for legislation that protects plants and animals
9. Sewer water can be purified and used again to help conserve water. If water is not correctly purified, it can make people sick. Which of the following is true? a. The solution to one problem cannot cause another problem. **b. The solution to one problem can cause another problem.** c. Problems cannot be solved. d. Solutions never work.
10. Technology is any tool or machine designed to help people in some way. Technology often improves people's lives. Which of the following is a disadvantage of technology? a. Technology helps to solve problems. b. Technology helps people travel faster. **c. Modern technology is costly and not available to everyone in the world.** d. Technology allows people to communicate better.

Notes:
[1] redirected question to fossil fuel use rather than the advantages and disadvantages of recycling
[2] replaced 'air 'with 'solar power'
[3] replaced 'air 'with 'sunlight'

Students explored additional concepts to avoid developing common misconceptions about fossil fuels (Rule, 2005) and to achieve a greater understanding of renewable and nonrenewable resources.

TEACHING METHODS

All three lessons were introduced with a small group brainstorming activity. Small-group brainstorming activities engage students in non-threatening reflection that improves collegiality (Kelly, 2000). Furthermore, brainstorming naturally captivates and motivates students to want to begin their own scientific investigations (Huber and Moore, 2001). The first two lessons focused on building and evaluating models. The *Standards for Science Teacher Preparedness* state that models provide scientific explanations (NSTA, 2003). Inquiry-based use of models must include giving student time to reflect on the validity or deficiencies of their models (Council, 2000). Therefore, after completing model investigations, students were given time to reflect on how representative their models were of what they were modeling. Teacher Preparedness Standards also suggest that students need to be able to

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understand the societal importance of technology (NSTA, 2003). Students were given time to reflect on the societal importance of solar energy technology after they built their own solar ovens. Furthermore, they explored how other renewable energy resources were important to society, especially in the future as fossil fuels become more depleted.

Lesson One: Drilling For Oil

To introduce the exercise, the teacher asked groups of 3 to 5 students, to brainstorm for ten minutes and list a minimum of ten things they use every day that require oil, coal, and natural gas. The students were provided a few examples to get them started (e.g. electricity, transportation). Each group reported their findings back to the entire class until the list represented most of their daily fossil fuel burning activities. Next, the instructor asked students why oil, coal and natural gas are considered fossil fuels? They were teacher guided to think first about fossils. Several students understood from the K-4 science curriculum that fossils were the preserved remains of plants and animals buried for millions of years (NRC, 1996). The teacher used this explanation to further explain that some buried plants and animals transformed from their original form and became fuel.

Students were informed that they were going to construct a model of an oil reservoir to understand how oil was stored and extracted from the ground (Figure 1). Before beginning the class split into small groups, and the teacher showed the students the materials that they would use to construct their models. Provided supplies included:

- Porous rice cereal (Chex®)
- Chocolate syrup diluted with water (1:1)
- Smashed brownies (a layer that syrup won't sink through)
- Marshmallows
- >8" tall transparent bowl or container
- Baster
- Waste bowl
- Stopwatch

To begin, the teacher took the students outside and demonstrated the difference between permeable and impermeable surfaces by pouring a glass of water on blacktop and over a sandbox. The teacher asked them to discuss, Why does the rain sink into the soil but not the playground blacktop? Each group identified that water could travel through the spaces between the sand, but there was no space for water to travel through in the blacktop. Next, the teacher told the students that the first layer of their oil reservoir model needed to represent a layer of rock that oil could not travel through, similar to blacktop. They were asked to put 1 to 3 inches of this layer into their transparent container. Some groups struggled with what material to use and the teacher suggested that they choose between rice cereal or brownies. Most students selected brownies after discussing the holes in the rice cereal. After the students added the first layer the teacher asked them to examine their layer from the side of the container. The students were reminded that by looking at their model from the side they would be able to see all the layers that they had added.

Next, the teacher asked the students to create a layer that could hold oil, this would be their oil reservoir. The teacher reminded the students to consider that this layer was analogous sand in the sandbox. Many groups selected rice cereal. For those groups, the teacher asked the students to crush the cereal up before putting 3 to 5 inches in the container to facilitate easier pumping. After emplacing the reservoir layer, the teacher asked the students to fill their reservoir with oil. The students poured diluted chocolate syrup into the rice cereal. Building a model out of porous cereal minimized the confusion many students have previously experienced looking at text book drawings depicting oil stored in a big empty holes (Rule, 2005) because students could see oil filling in the empty spaces within the reservoir rock. The teacher then asked the groups to put a layer on top of their oil reservoir to represent the overlaying rock and soil. Marshmallows were a good representation of loose topsoil and unconsolidated material (e.g. till) that overlays most of Ohio. In addition their white color contrasts with the other layers and the chocolate oil. For most groups, marshmallows were the only option left. Students rapidly completed their model by adding a top layer of 1-2 inches of marshmallows above chocolate oil-bearing rice cereal

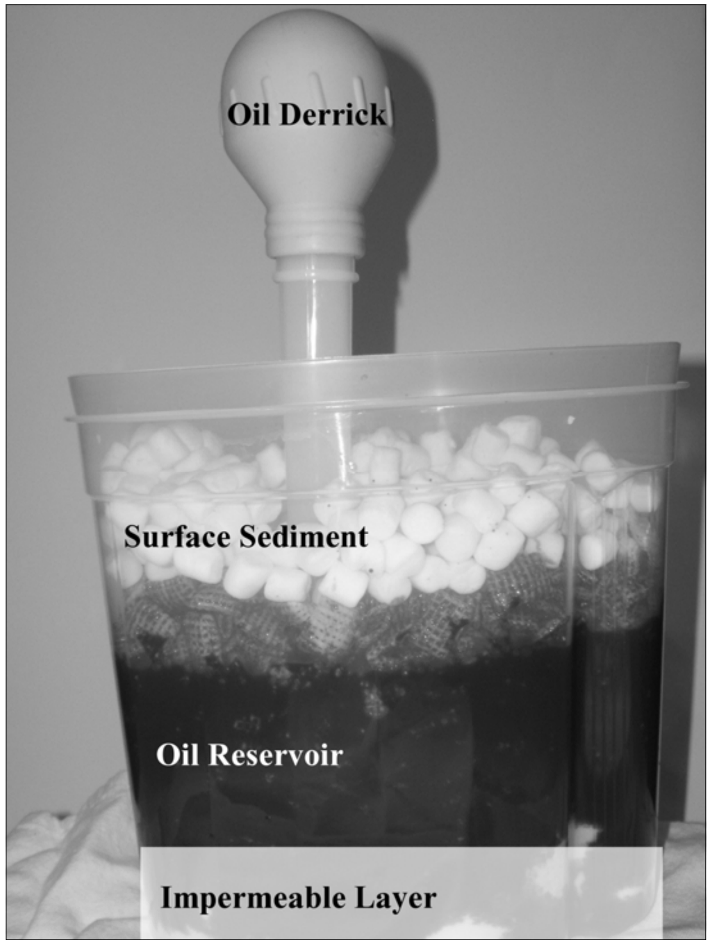

FIGURE 1. Model of an oil-drilling site on land; the bottom layer is an impermeable smashed cake layer (white added for contrast), the middle layer is the reservoir (porous rice cereal), and the surface layer is made of marshmallows. A baster suctions the chocolate oil from the reservoir.

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FIGURE 2. The surface layer is clean before drilling for oil (A). Students observed pumping resulted in leaks (B). This mimics oil spills occurring at older rusty derricks, or during the transport of oil.

layer. After completing their model construction, each student was then asked to draw and label his or her group's model. The teacher provided a list of defined vocabulary words for students to use in their models including oil reservoir, impermeable layer, topsoil and rocks.

After drawing their models, groups were given a baster and told by the teacher that they would now play the role of an oil company. To begin the teacher had the students had excavate the drill site by removing a 1-inch circle of the marshmallow soil and rock. Once they had excavated a drill hole they were told to push their baster derrick into the chocolate oil layer (Figure 1). Then the students were asked what happened to the marshmallow soil near their pumping site. They noted that chocolate oil spilled near the hole. The students were informed that oil spills were uncommon at most drilling sites, but may happen if the derricks get rusty. The students were then asked to remove the chocolate contaminated marshmallows before they began extraction (Figure 2). They were told that their oil company would be fined for the damage caused by any oil spills. Cleaning up land oil spills is very expensive, in the U.S. (1997), one ton of spilled oil costs over $73 K to remediate (Etkin, 1999). Students were informed that many land oil spills occurred in the 10 to 15 transfers typically made during the transportation of our oil supply between, pipelines rail, tank and truck (Fingas, 2001).

Groups were then asked to hypothesize how much oil they would be able to extract in ten minutes, while taking care to minimize spills. Each student recorded their hypothesis before their group was allowed to begin to pump. The teacher then passed out stopwatches to each group. After starting their stopwatches, group members took turns extracting oil and putting it into a waste bowl. As soon as most groups had difficulty pumping (~3-5 minutes), the instructor asked the students to pause their stopwatches. The teacher then asked them to discuss in their groups why was it getting more difficult to extract the chocolate oil? Students noticed that there was less oil to extract and therefore, less made it into the baster with each effort. The teacher then allowed the students their final minutes of extraction. After the ten minutes was over, students were asked to record whether their hypothesis was correct or incorrect based on the model and why. The instructor summarized that like their model, oil drilling usually stops after it becomes difficult to extract small amounts of oil, not because there is no oil left in the reservoir.

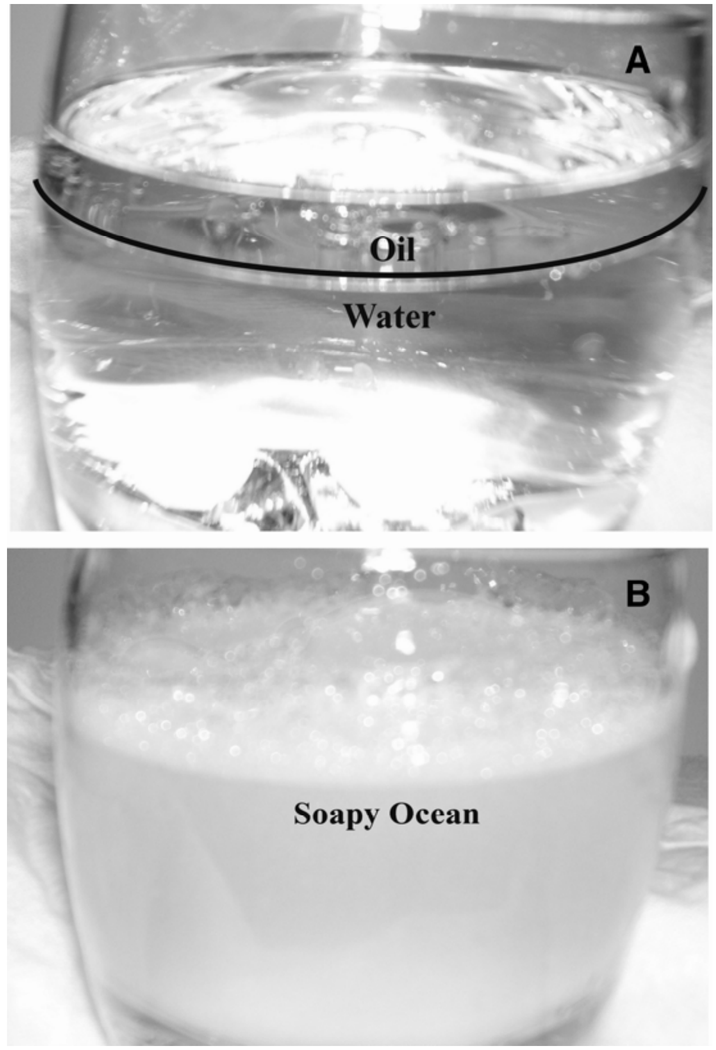

FIGURE 3. A bowl, water, and vegetable oil model an ocean oil spill (A). When students remove the oil using kitchen items, new problems arise (e.g. suds are created while removing the oil with hand soap (B).

Finally, the teacher asked the groups to reflect on their model design and how they might improve it in the

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future. To best do this they were asked to also put together a list of the similarities and differences of their model with a real oil reservoir. Students identified that real oil reservoirs were very large and some of them were located underneath the ocean. The teacher reminded students that retrieving oil from existing oil reservoirs became more difficult with time and that new reservoirs were difficult to find, and therefore, some were now drilled in the ocean. By creating and evaluating their models, the students understood that fossil fuels are becoming increasingly difficult to find and recover. Tim Appenzeller's 2004 article "The End of Cheap Oil" states the grim reality, "*Humanity's way of life is on a collision course with geology—with the stark fact that the Earth holds a finite supply of oil.*" The understanding that oil would eventually run out caused some students distress. When students expressed worry, the teacher let them know that they would eventually discuss other types of energy that were unlimited in supply that would be the key to our future energy needs. They were also told that conserving energy at home was something they could do to make our nonrenewable fossil fuel supply last longer. Several students went home and encouraged their families to conserve energy. This included a few eager reports, such as "*I made sure the lights were off when I left a room*" or "*I asked my parents to drive less*".

Lesson Two: Cleaning Up an Ocean Oil Spill

After gaining exposure to the challenges of recovering oil, in this lesson students developed a greater understanding of the magnitude of environmental cleanup challenges associated with oil spills. This module was adapted to a fourth and fifth grade inquiry-based lesson from an existing middle school and high school web-based lesson (Branca, 1997). The list of suggested materials and protocols are for conducting remediation are different from Branca (1997), with the exception of the use of vegetable oil and tap water. This adapted lesson met the NSTA standards of identifying the role of science and technology in solving community health issues (NSTA, 2003). Prior to this lesson, many students had preconceptions of ocean oil spills, but did not understand that scientific knowledge and technology is necessary to conduct cleanups. The 1989 Exxon Valdez oil spill on Bligh Reef, Prince William Sound, resulted in 42 million liters of crude oil contaminating a formerly pristine shoreline. Damage to the regional ecosystem lasted long after the spill with 55,600 kg of oily subsurface sediment uncovered in 2001 that was still causing damage to organisms reliant on that substrate (Peterson et al., 2003). In this oil spill model, students learned that cleanup is difficult, and that removing the oil may lead to other water quality issues.

To begin the teacher provided students with pictures and newspaper clippings featuring ocean oil spills. All materials were pre-screened to ensure that the students were not exposed to anything too graphic. Students were then asked to look through the material and record a paragraph reflecting on the origin of oil spills and the damage caused to nearby beaches and wildlife. After students had recorded their answers, the teacher asked the students to discuss what they had found. During this synthesis, the teacher made sure students addressed that oil spills were caused by the accidental spilling of oil during the transport or during large storms such as hurricanes that damage offshore drilling sites. The instructor further detailed that oil spills threaten and destroy habitats for fish and birds living in the water and beach.

After this completing the preliminary exercise students were told that they would be charged with cleaning up their own mini-ocean oil spill (Figure 3). After breaking into small groups, the students were given an assortment of materials that they could choose to first model an oil spill and then clean it up. Provided supplies included:

- Large bowls (1 per group of 3 to 4 students)
- Tap water
- Vegetable Oil
- Household items to attempt to remove oil with including: baking soda, dish soap, oatmeal, spoons, forks, sponges, salt, straws, paper towels

Students were first asked to create their oceans using a large bowl and tap water. They were encouraged to not fill their oceans too full to make it easier for them to work with the model later (Figure 3). Next the students were asked to pour one or two capfuls of vegetable oil on their oceans.

The teacher had students familiarize themselves with the oil contamination by having each student stick one finger into their ocean and talking about how their finger felt. To continue, the instructor asked students to think about how oil might affect a seagull that landed in the oil. The students were asked to replicate this effect by touching the backs of their wrist to the oily surface and using only that hand to remove the oil.

Next the teacher asked students to record their hypotheses on what types of kitchen materials might best remove the oil from the surface of their model oceans. Possible materials to select from were supplied by the teacher. Students worked in small groups and tested their hypotheses, and identified the 'best' method for cleaning up the oil. They found that no method restored the water to its original state. For example, if they use dish soap, they dissolved some of the vegetable oil from the ocean surface, but left soapsuds behind. Similarly, paper towels absorbed some of the oil, but also removed a lot of water. Likewise, using spoons was tedious and did not remove all of the oil. After discussing their findings and recording whether their hypotheses were correct, students were assigned to write a press release on ocean oil spills documenting the difficulties of cleaning them up and potential ongoing hazards to ocean water quality. By completing this lesson students learned that oil spills cause widespread environmental damage. They also learned that developing technological solutions are not easy, and one solution may lead to another problem (NRC, 1996).

Lesson Three: Building a Solar Oven to Explore Sustainable Energy Solutions

The U.S. Conference of Mayors developed the "2030

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Challenge" and committed to reducing fossil fuel consumption in new city buildings by 50 percent by 2030 (Beatley, 2007). In the following activity, students tackled small-scale energy challenges of their own. Students gained first-hand experience building solar ovens and met the NSTA standard of knowing the limitations of natural resources (NSTA, 2003).

To begin this activity, the teacher asked small groups of students to brainstorm the differences between renewable and nonrenewable resources. Many students concentrated on nonrenewable resources after completing the previous two activities. After reviewing their lists, students were teacher-guided to think about trees, water, and sunlight as renewable resources that could be used over an over again. Next students were told that renewable resources were already used to meet some of our energy needs instead of fossil fuels like oil, gas, and coal. The teacher asked students to draw examples of renewable energy technologies on the board (e.g. solar panels). Because some students had trouble generating ideas, the teacher asked them to search the internet under parent or teacher supervision. After completing this background review, students were taken outside on a sunny day and asked to construct solar ovens. Provided supplies included:

- Cardboard boxes of assorted sizes and shapes
- Scissors (blunt)
- Duct tape
- Black plastic bags
- Tinfoil

Using the supplies, small groups worked together to construct solar ovens. Students were given approximately thirty minutes to complete their designs. Allowing the students to freely design their own ovens gave students a truly inquiry-based learning experience. The students succeeded with most designs given that ovens were constructed on a warm, sunny, day.

After building ovens, students were asked to record their hypothesis on how long they thought it would take to cook a plate of nachos and why. Next, they were given a plate of tortilla chips and cheese to cook in their ovens. Using stopwatches, they recorded the time it took to melt the cheese and compared their results to what they had hypothesized. Most students were surprised at how fast the cheese melted. However, not all designs melted the cheese at the same rate. The students compared oven designs and discussed why some ovens worked better than others. Those ovens designed with dark interiors absorbed the most heat and cooked the nachos faster than those designed only with tinfoil. The instructor pointed out that like the dark surfaces in their ovens the dark surface on the playground was warmer than the nearby grass because dark colors absorb more light.

The teacher later asked the students to discuss in small groups if their ovens would work as well on a cloudy day. The students all understood that their ovens required bright sunlight. After listening to the student responses, the teacher discussed the limitations of solar energy and pointed out that sunny regions were better able to employ solar energy technologies. Students identified that solar power could be really important to states like California that have few cloudy days, but not as important to states like Washington that were often cloudy. This led to a discussion of the limitations of other renewable energy sources including water and wind power. By completing this exercise students learned that renewable resources provide for some of our energy needs. Yet they also discovered that the types of renewable energy we use in the future will depend on both resource availability and technology. This was an important realization given that our current energy needs cannot be met by present-day renewable energy technology (Hoffert et al., 2002). Furthermore, many students were excited to tell their parents and friends about the nachos that they made in their ovens.

RESULTS AND DISCUSSION

Pretest and Posttest Results

Students gained knowledge of renewable and nonrenewable energy resources through the completion of the described lessons as indicated by an increase in mean test scores from 43.8% to 76.2% (Table 2). A paired t-test reveals that mean pretest scores were very significantly ($P<0.001$) lower than posttest scores. Improved test results coupled with student enthusiasm for the activities suggest that undertaking inquiry-based investigations is an effective way for students to learn about nonrenewable and renewable energy. Students took a genuine interest in how they could improve energy conservation and technology. Not only did students improve their understanding of scientific concepts, but they felt an increased sense of environmental stewardship. Completing inquiry-based activities gave the students an opportunity to reflect on what they had learned. Because of this, students felt that they personally understood the challenges of extracting oil, the consequences of an oil spill, and the need use renewable energy resources while reducing our use of fossil fuels. Many students actively sought to reduce their families' energy use and had a heightened awareness of their own energy use.

CONCLUSIONS

By completing the sequence of activities, students increased their knowledge of renewable and nonrenewable resources and learned that solving energy issues is a complex challenge. Students were enthusiastic and showed significant improvement in concept mastery. Although these activities were tested in one Columbus Public School, they are recommended for other fourth and fifth grade classrooms interested in generating early awareness of our global energy issues. Introducing important energy concepts in an engaging manner that features inquiry left a lasting impression with students. Increased awareness of energy issues will hopefully foster future student interest in related topics introduced in middle and high school including linking fossil fuel use with climate change.

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