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**Uncovering 9th Grade Understandings of Energy via Concept Sketches: A Learning Tool
for Students and Educators**

By

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Abstract

This project explores the use of concept sketches as alternative forms of assessment in determining students' understandings of energy concepts. A review of the literature indicates that students have difficulty understanding basic energy concepts. Studies also suggest that adults demonstrate low energy literacy, including basic knowledge of energy concepts. These findings demonstrate a massive hurdle to overcome in solving challenging environmental issues such as climate change. Consumers of energy are handicapped in their ability to make informed decisions related to their energy use because of their lack of knowledge regarding where energy originates and the processes necessary to make it into a usable form. Improving energy education in K-12 education is one proposed solution for overcoming this barrier. One aspect of this solution includes the development of assessments that uncover students' prior knowledge of energy in real-world contexts. In this study, concept sketches are defined in the literature and then utilized as an alternative form of assessment. This type of assessment requires participants to trace electricity back to the original sources of energy through a series of sketches and descriptions. Findings indicate that this may be a useful method for identifying participants' prior knowledge of energy sources and energy flows. They also demonstrate that concept sketches could be used more than once in an energy curriculum to assess students' knowledge and serve as a learning tool for these concepts.

This paper is dedicated to my family

Acknowledgments

I would like to begin by expressing thanks to my family. I would not have made it to this point in my education if it weren't for the generous support and thoughtful guidance that my family has provided. I am thankful that my parents raised me with deeply rooted values related to the environment and an appreciation for the simple things in life. This has driven me to explore the natural beauty of the West and to pursue opportunities like teaching. Through teaching, I am able to demonstrate my passion for the natural environment and give students the opportunity to explore it in similar ways that I did growing up.

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Chapter 1

Introduction

The extraction of fossil fuels, driven by an increasing demand for energy, is a process that most Americans know little or nothing about. For example, a study conducted by the National Environmental Education and Training Foundation (2005) examined America's understanding of energy and found that only 36% of people surveyed knew that the majority of electricity consumed in the United States is produced by burning coal.

The fact that a significant portion of American citizens cannot identify fossil fuels as our primary source of energy is troubling. It is as if Americans are not able to identify the main ingredients of a cookie. Both cookie and fossil fuel ingredients, in their raw forms, must undergo several transformations before they become energy that we can use. Moreover, both cookies and fossil fuels have great potential to provide energy for humans (albeit, in different ways), and both come with potential hazards to human health. However, the process of making cookies is familiar to many people because it is something they learned about through simple hands-on experiences – which is not the case concerning the process of fossil fuel extraction and electricity generation. Unfortunately, these energy concepts cannot be learned from a recipe book like cookie baking, however it is imperative that they are learned and understood by all members of society.

In order to educate the public about the causes and consequences of climate change in relation to their day-to-day lives, people must understand the underlying energy concepts. Creating new, updated, and more thorough energy curriculum is the first step in this process. Several programs in the United States are recognizing the need for energy curriculum and are funding projects to promote this development. One example is The Sequestration Training and

Education Program (STEP), which awarded a grant to the University of Wyoming's Science and Mathematics Teaching Center by the Illinois State Geological Survey to develop energy-related curriculum. This project was focused on developing innovative and creative energy curriculum along with strategies that engage middle level students.

Research Topic

As a contributing member of this project, I assisted in developing the curriculum, observed its implementation in the classroom, and conducted this research project, which incorporated looking at ways of uncovering students' understandings of energy concepts. My focus and role in this project was to specifically develop an assessment that aligned with the objectives of the curriculum. A concept sketch assessment tool called *Trace it to the Source* became the main instrument in answering the questions that guided this research. To better understand the objectives of this project, it is helpful to review the methodology and goals that were a part of developing the larger curriculum project.

The curriculum was designed for students to work collaboratively and individually in activities that foster a deep understanding of energy concepts relevant to real-life application. The energy curriculum, titled *Energy Literacy for a Sustainable Future*, was comprised of three units that included:

1. Basic concepts about energy sources and production
2. Addressing the problem of increasing carbon in the atmosphere
3. Internalizing the energy challenges and empowering students to take action in solving complex issues

Within each unit, students were given opportunities to construct their own knowledge of energy concepts through hands-on activities that were intended to promote scientific inquiry and self-reflection.

Rationale

In the first year of my graduate school education, I gained valuable teaching experiences in the setting of Grand Teton National Park. In field education, I learned to be creative in the ways that I facilitated lessons and assessed students' understanding of natural science concepts. One method of assessment that I found especially useful in demonstrating the concepts that my students learned was called *path maps*. Path maps are simplified sketches of the sequences of events that occur throughout a lesson or series of lessons. This alternative form of assessment was the inspiration for my search for something similar being done in formal K-12 education. After reviewing the literature for assessment tools within science education, I discovered concept sketches. The definition of *concept sketch* used in this research came from Johnson and Reynolds (2005) who stated that it is "a simplified sketch illustrating the main aspects of a concept or system, annotated with concise but complete labels that (a) identify the features, (b) depict the processes that are occurring, and (c) characterize the relationships between features and processes" (p. 85-86).

Although concept sketch use is not widely published in the literature, several researchers discuss the positive impacts that resulted from implementing them in the classroom (e.g. Johnson & Reynolds, 2005; Reusser et al., 2012; Semken, 2012). They suggest that concept sketches engage students in an active learning process, they are good indicators of students' prior knowledge. In addition, when used as a formative assessment, they assist students in a personal construction of knowledge. In Johnson & Reynolds's (2005) study, concept sketches are used to better understand geology concepts and these researchers suggest that concept sketches could be easily applied to other subject areas. Other research suggests that the science education community, specifically energy education, is in need of alternative forms of assessments like

concept sketches. This is because traditional forms of assessment, commonly in the form of multiple choice or other written formats, are not sufficiently demonstrating students' prior knowledge of science concepts and the conceptual benchmarks involved in understanding these concepts (DeWaters & Powers, 2011; Lee & Liu, 2010).

This research is intended to begin addressing the gap of this need for alternative forms of assessment, particularly in energy education.

Philosophy

In my own education and experiences, I have gained in-depth knowledge and practice of place-based education techniques. According to Sobel (1994), place-based education emphasizes hands-on, real-world learning experiences to teach concepts in all subjects. In this approach, the local community and the environment are important contexts for teaching that assist in making learning more applicable and valuable to students' lives. This philosophy has guided my research. Concept sketches are hands-on, they emphasize real-world learning experiences, and they can facilitate discussion around a local community scale and much larger global scales.

Research Questions

The research questions addressed in this study are:

1. What do concept sketches elicit about students' understanding of energy concepts?
2. How can concept sketches be used as a learning tool for assisting students in understanding energy flows?

The Greater Context-My Motivation

The problem with the public not knowing the "ingredients" or processes that are involved in electricity production is that it limits people's ability to make informed decisions, because they are not able to weigh alternatives while making decisions related to their energy usage. It is

common knowledge that some cookie ingredients make them unhealthy as a primary diet or source of energy. For example, consuming large amounts of sugar for extended periods of time will create serious health problems. In a similar way, the consequences for overlooking, belittling, or remaining ignorant about energy sources could potentially have much greater effects on Americans' lives than the personal health problems that a steady diet of only cookies can bring.

Researchers Costello et al. (2009) discussed the implications that climate change will have on the environment and human health in the 21st century. They argue that climate change is occurring due to anthropogenic (man-made) carbon dioxide being emitted daily into the atmosphere. Although some of the carbon in the atmosphere is natural, humans have also been contributing more since Industrialization. Increased levels of carbon dioxide in addition to other greenhouse gasses in the atmosphere, such as water vapor and methane, are trapping greater amounts of energy from the sun that would normally escape into space. As a result, the earth's cooling rates are being affected and overall surface temperatures are rising (Costello et al., 2009). Greater amounts of energy within the earth's atmosphere have the potential of creating extreme weather events that could include floods, droughts, heat waves, and severe storms (Schwartz and Randall, 2003). Additionally, it is predicted that the increased severity and frequency of these storms could result in significant declines in human populations. Researchers mention several challenges that humans will face with the effects of climate change including food scarcity, contaminated water, disease, and shelter (Schwartz and Randall, 2003).

Chapter 2

Review of the Literature

Introduction

Advancements in technology are increasing faster than the ability of the general public to understand them (Hurd, 1998). This disparity leads to an uninformed consumer that may not understand the choices hidden within each consumer choice. Without being aware of the consequences of their consumption, consumers cannot make educated choices. Although advancements in science and technology are necessary for growth, whether or not that growth is sustainable will depend on our ability to make informed consumer decisions (Dias, Mattos, & Balestieri, 2006). Current environmental concerns, including the effects of climate change, are primarily due to the behavior of consumers; if humans change consumption habits, the state of the environment will be vastly improved (Pearce, 2009).

One of the consumer choices with the greatest impact on the environment is the consumption of energy. Fossil fuels account for 85% of global energy use, and when burned to generate electricity, this process emits carbon dioxide in the atmosphere and contributes to climate change (Bachu, 2000). One way to create informed consumers of energy is to educate Kindergarten through 12th grade (K-12) students about sources of energy. If students learn fundamental physical science concepts, they will gain a basis for explaining natural phenomenon (Krajcik, 2013). This knowledge will help students understand the origin of these energy resources, their limits, and the importance of conserving them.

Science Education

Changes in science and technology have prompted professionals in the field of education to review both curriculum and teaching practices (Krajcik, 2013). This has resulted in the

revision and adaptation of scientific curriculum for students including what they should understand, why they should know it, and the best methods for teaching the material (Krajcik, 2013). In the Next Generation Science Standards (NGSS), released April 2013, Energy is one of the core disciplinary ideas that has expanded to include more than just a basic understanding of physical science concepts (Achieve, 2013).

Energy is the root of human enterprise, success, and economic productivity but it also creates challenges for the planet. The process of energy production, from the source to the consumer, involves complicated steps that even the individuals with years of formal education may struggle with. Yet, even young children understand how to plug in a cord and harness electricity. In this way, energy concepts affect every single human being, in many different ways and on different scales. The ramifications of energy production and usage are scientific, but also influence the realms of politics, resource management, and public opinion.

Energy Literacy

Several studies report difficulty that students and adults have with comprehending basic energy concepts and applying them to everyday situations. In a study conducted by Goldring and Osborne (1994), 75 British secondary students were given both quantitative and qualitative questionnaires to assess their knowledge of basic energy concepts. The quantitative questions included simple energy calculations in a physics context and the qualitative questions included explanations of energy concepts like conservation and generation. Their findings suggest that 50% of the students in the study lack a basic understanding of energy concepts. These data were also supported by student interviews (Goldring & Osborne, 1994).

In a larger study involving 955 Middle and High School students from New York State, DeWaters & Powers (2011) piloted an assessment survey that was developed to analyze and

evaluate energy education programs. The survey included questions that probe students' content knowledge, energy-related attitudes, and behaviors. Other research suggests that these three components are essential in assessing energy literacy, which is a broader term for energy understanding that includes real-world application (Goldring & Osborne 1994; Bittle et. al, 2009). DeWaters & Powers (2011) found that out of the 955 students in their study, less than 1% scored above 80% on the energy-related knowledge portion of the assessment. The 75th percentile score was only 53%, indicating that students lacked knowledge of basic energy concepts.

Although students struggled with the energy concepts portion of the assessment, they scored higher on the attitudes and beliefs section. When asked about their feelings regarding energy use in America, 72% of the students in the study felt that Americans should conserve more energy. Also, 64% of the students felt that U.S. citizens should use more renewable energy sources to generate electricity. DeWaters & Powers (2011) concluded that students are aware of energy-related issues and felt a need to do something, but they lacked basic understanding of energy concepts that potentially inhibited them from changing their behavior.

Energy Education

Several researchers including Osbaldiston & Schmitz (2011), Dias et al. (2006), and Zografakis, Menegaki, & Tsagarakis (2008), see energy education as the most effective long-term investment for dealing with an energy crisis. They argue that by understanding the causes and effects of energy production and usage, students are able to make more informed decisions. They feel that ultimately, whether they are economic or environmentally driven, students will amend their own energy usage in a way that benefits the entire planet (Zografakis et al., 2008). Researchers see teachers as agents of change that not only address energy content, but also

encourage positive attitudes and build from values that are foundational and unique to each individual (Dias et al., 2004). In other words, teachers are not just teaching basic material, but connecting it to students' lives. They are helping each student to develop their own ideas about energy conservation because of the personal effects it will have on them in particular. By creating an emotional and psychological connection to energy concepts, teachers facilitate real and permanent impacts on how students will make their own decisions about energy conservation (Dias et al., 2004).

Researchers Zografakis et al. (2008) demonstrated that it is possible to change students' energy-related behaviors through energy education. Their study included 321 students and their parents from primary and secondary schools in Crete, Greece. The students and their parents were surveyed before and after the students' involvement in an energy curriculum, which included project-based learning, hands-on experiences, and a variety of educational tools like games and drawings used by the teachers. The survey was comprised of questions that were aimed at finding out if students and parents were demonstrating behaviors that reflected energy conservation. Their results suggested that students and parents were consciously making more energy-efficient decisions, such as monitoring their electricity usage, investing in more efficient appliances, and minimizing wasteful water use, after the energy education project was implemented.

In another study, Dias et al. (2004) provided additional arguments in support of energy education. They suggested that energy education is an example of a much-needed long-term solution for creating citizens that practice rational use of energy. Dias et al. discussed several barriers that exist within countries that further emphasize the need for adopting energy education

as a long-term solution. They cite Weber (1997) in defining these barriers that are classified into the following categories:

1. Institutional: responsibility of the government and local authorities.
2. Market: uncertainty in the proposals of negotiation during sales of energy and related products.
3. Organizational: present within organizations, especially firms.
4. Behavioral: present in individuals, in their values and, consequently in their attitudes.

The variety and extent of these barriers highlight the complexity that is inherent in addressing issues related to energy use. DeWaters and Powers (2011) also demonstrated the complexity of the issue when they stated, “our reliance on energy-rich sources of fossil fuels has created the underpinnings of modern society, enabling mobility, industrial growth, domestic comfort, unprecedented lavish food supply, and economic prosperity”(p.1). Dias et al. (2004) claim that although several challenges exist, it is obvious that education should be utilized as an avenue for creating change in the way that societies use energy.

Understanding Energy

Lee and Liu (2010) would argue that the development of energy understanding is a complex process partly because students tend to have prior conceptions about energy in several different contexts. For example, their research indicates that students consider energy as “human related, depository, activity-related, or as an ingredient, product, function, or fluid-like substance” (p. 668). In their study, Lee and Liu (2010) proposed the *knowledge integration theory* as the backbone of their research. They defined knowledge integration as “students’ knowledge and ability to elicit and connect scientifically normative and relevant ideas in explaining a scientific phenomenon or justifying their claim in a problem” (p. 669). They used this theory as a way to determine the extent to which students understood scientific concepts and

how they related to other issues and ideas. Using this framework, the authors constructed an assessment that measured how well students learned energy concepts as they progressed through physical, life, and earth science contexts in middle school grades. When assessing energy understanding, Lee and Liu asked questions that related to energy source, transfer, transformations, and conservation. The scoring of the assessment was based on the number of links that students made between relevant prior ideas and new normative ideas in answering the questions. The more connections students made between their prior knowledge and new information, the more fully they understood energy concepts.

Assessment

In order to understand why energy literacy assessments are revealing mediocre understanding of energy concepts, it is necessary to look at some of the larger policies that affect assessment and guide instruction in classrooms across America. The following is a brief look at the assessments and standards literature to reveal important changes within the public school system in the last decade.

No Child Left Behind. The passing of The No Child Left Behind Act (No Child Left Behind [NCLB], 2002) in 2001, made an impact on all of K-12 education. Researchers Simpson, LaCava, and Garner (2004) stated that NCLB is one of the most significant governmental interventions in United States education history. Within NCLB is the requirement that all students in elementary and secondary education perform at a proficient level on state academic assessment tests (NCLB, 2002). Since the implementation of NCLB, each state is held accountable for Adequate Yearly Progress (AYP), meaning that schools need to set and meet goals to raise their performance based on standards set by the state. Researchers Simpson et al. (2004) discussed some of the challenges that have followed the passing of this act by congress.

According to Simpson et al., achieving the required scores on standardized tests is especially difficult for the estimated 6.6 million students that are eligible for special education services. This puts pressure on teachers responsible for raising student performance levels, regardless of their students' situation. Supporters of NCLB claim that by holding schools accountable of attaining measurable goals, high-quality education will reach all children within the United States educational system (Mathis, 2003). Critics, on the other hand, see several issues with the widespread implementation of standardized assessments. The pressure of increasing test scores on a yearly basis has potentially created a negative influence on educators and students. Shepard (2008) explained that standardized assessments are hindering the ability of educators to administer assessments that support student learning. The role of assessment, as discussed in Shepard (2008), should be an imbedded tool within classroom instruction, rather than an externally initiated measurement of student progress.

Evolving forms of Assessment

By the 2013-2014 school year, the requirements of the NCLB legislation will reach the end of its lifetime and a new educational reform act will be developed that meets the needs of students in a context applicable to current events. This raises important questions within educational research regarding assessment. In the literature, researchers suggested a shift from traditional assessments like standardized tests to alternative forms of assessment before NCLB was enacted (Anderson, 1998). Even before the legislation took affect, academics, politicians, teachers, and the public were discussing traditional (e.g. standardized testing) versus alternative tools for assessing teaching and learning (Dikili, 2003).

Traditional vs. Alternative Assessment. Anderson (1998) discussed the differences between traditional and alternative assessment in her research. She suggested that traditional

assessments are meant to measure student learning, whereas alternative assessments can be used as tools for supporting or enhancing student learning. In her argument addressing the need for educators to adopt alternative forms of assessment, she outlined the philosophical beliefs and theoretical assumptions that clearly distinguished alternative from traditional assessments. A recurring theme in Anderson's work is the idea that learning is individualistic and therefore should be accompanied with an assessment that facilitates a personal construction of knowledge. In other words, the ways of measuring student success should match the ways in which students learn. Assessments should identify whether or not students have made fundamental connections to the material, but not necessarily be able to regurgitate rote information. This idea of making connections between material, prior knowledge, and personal experiences comes from the constructive theory of learning.

Constructivist Theory of Learning. The Constructivist Theory of Learning is not a new idea. Its roots can be traced to education and psychology theorists John Dewey (1958) and Lev Vygotsky (1978). Their progressive approach to education stemmed from the idea that teaching should be inquiry based, implying that students learn the most when they connect new ideas to prior experiences and knowledge becomes constructed.

Effects of visual learning. One way to apply the constructivist theory of learning in the classroom is to have students create visual representations of their knowledge. In a study by Hsieh and Cifuentes (2003), students who constructed visualizations to help them study scored significantly higher on a comprehension post-test than students who studied the same material without using visualizations. They defined these student-generated visualizations as, “graphical or pictorial representations of sequential, casual, comparative, chronological, oppositional, categorical, and hierarchical relationships among concepts” (p.90). Visualizations, such as these,

can be created in several different forms including drawings, diagrams, charts, tables, graphs, timelines, etc.

Common visuals used in education. Textbooks often contain visualizations that are intended to assist the reader in understanding concepts within the text. For example, a textbook explanation of the water cycle may include an illustration that pictures the movement of water molecules from the atmosphere to rain to a river to groundwater and so on. Mayer, Bove, Bryman, Mars, and Tapangco (1996) showed that diagrams and illustrations when combined with concise annotations were beneficial for the reader of a textbook in helping them to retain and transfer the knowledge presented. Mayer et al. (1996) argued that annotated illustrations can also be independent from textbooks and still serve as effective tools for promoting understanding of scientific processes. Even without extra text, they can provide a visual representation that conveys as much – if not more – information.

Concept Sketches

Another term used to describe annotated illustrations is a concept sketch (Johnson & Reynolds, 2005; Reusser et al., 2012; Semken, 2012). The common definition of a concept sketch within the literature states that they are “a simplified sketch illustrating the main aspects of a concept or system, annotated with concise but complete labels that (a) identify the features, (b) depict the processes that are occurring, and (c) characterize the relationships between features and processes” (Johnson & Reynolds, 2005, pp. 85-86). This definition is used to describe the main instrument used in this study.

Johnson and Reynolds (2005) described several ways in which concept sketches have been used in a geology class and the positive impacts on student learning that have resulted. One particularly useful method they described was the process of students generating their own

concept sketches rather than copying instructor-generated sketches. When Johnson and Reynolds asked students to construct concept sketches to describe plate-tectonic boundaries, they found that the sketches engaged students in an active learning process, which was beneficial for retaining and transferring knowledge. They also suggested that sketching facilitated a personal construction of knowledge, which was supported earlier in the literature as being a successful learning theory (Hsieh and Cifuentes, 2003).

Instructors of a 2008 Geomorphology class at the University of Vermont found that concept sketches were very beneficial in demonstrating the depth of their students' prior knowledge. The sketches were used to quickly identify student misconceptions and allowed instructors to adapt their teaching to address confusion. Students commented that the concept sketches were especially useful in helping them synthesize material that would normally seem unrelated on a more traditional exam (Reusser et al. 2012).

Concept Sketches in Energy Education. In a search for concept sketches being used in energy education, I found an activity that was adopted by the Climate Literacy and Energy Awareness Network (CLEAN). The mission of CLEAN is to provide a reviewed collection of educational resources that focus on developing students' understandings of climate and energy science. One activity in their collection is called *Power Source* and it involves students creating concept sketches that trace their electricity to as far back as they know. The author of this activity, Semken (2012), explained that he used this activity as an introduction to energy sources and electricity production in an introductory geology course. He felt that concept sketches were great indicators of students' prior knowledge of energy sources and the process of electricity distribution.

Conclusion

Modern society relies on energy and electricity. Most of the resources used to create electricity are finite, and the processes involved in extracting and producing them creates impacts on the environment. Despite the fact that it affects all of society, the general public has very little energy concept knowledge. One avenue for creating long-term change is through education. By educating students about energy concepts related to their every-day lives, they will understand the implications of their energy decisions. Hopefully this will lead to more conscious behavior, meaning that people will want to use less energy to reduce their impact on the environment.

Energy education includes many difficult concepts. In an effort to make these concepts easier to understand, education professionals are writing and testing curriculum that is relevant and applicable to the real-world. An important aspect of educating students about energy concepts is being able to assess their prior knowledge and their progress in developing an understanding of these concepts. While there are different methods and perspectives behind assessing students in the classroom, this study looks at an alternative form of assessment due to its reported effectiveness in demonstrating prior knowledge and misconceptions. This assessment is a concept sketch, and it allows students to demonstrate their knowledge of energy concepts in a personalized way that is creative and constructive. It is also supported in the literature as an effective tool for enhancing the learning process. At this time, the application of concept sketches as an assessment of energy flows is not documented in the literature. This study aimed to provide further evidence of this type of application and discuss its successes and challenges.

Chapter 3

Methods

Setting

This study took place in a rural western city with a population of approximately 30,000 and home to a major state University. The University affects the culture, economics, and demographics of the town and its inhabitants, and sets it apart from nearby areas. With access to endless outdoor opportunities, a multitude of community events, and a thriving University, the city has much to offer despite a relatively small population.

The location of the study was in a public junior high school with a total enrollment of approximately 650 students. The school includes grades 7 through 9 with an approximately equal number of students in each grade. The student population consisted of more than 75% Caucasian and about 17% Hispanic, with the remaining population composed of Asian, African American, multi-national students, and those that declined to record their ethnicity.

Population and Participants

The participants of this study were recruited from 9th grade students between the ages of 14 and 16. This group was further determined by class enrollment and section assignment. There were approximately 143 ninth grade students enrolled in earth science classes during the 2012-2013 school year and 70 of them volunteered to participate in the study. All of the assessments and interviews were integrated into the regular curriculum and were completed by all students. Volunteers for the study agreed to allow their work to be collected and analyzed by the researchers, and participated in interviews. Students were told that the research and collection of data was for the purpose of helping to better understand the engagement and learning outcomes

of the newly developed curriculum. Subjects were not identified by name, appearance, or nature of data, and they did not receive incentives for participation.

Instrument

The concept sketch assessment tool called ‘Trace it to the Source’ represented in Figure 1 is the main instrument used to answer the questions that guided this research.

Trace it to the Source!

Prompt: You charge your iPod or phone by plugging it into a wall socket. Where does this electricity come from? Take a minute to think about the original sources of electricity and the steps that occur before they power your electronics.

Step 1. Start by brainstorming and organizing your thoughts on the front side of the paper.

Step 2. On the backside, create a series of drawings to represent the steps that occur in the question above.

Step 3. Make sure your sketch is organized and as detailed as you can make it. Include descriptive words, phrases, and sentences to help someone understand your drawings and what you are thinking.

Figure 1. Concept Sketch Assessment Instructions

In developing the prompt, I used the general idea of tracing electricity to its source from an activity that was adopted by the Climate Literacy and Energy Awareness Network (CLEAN) (Semken, 2012). This activity is called *Power Source* and it involves students creating concept sketches that trace their electricity to as far back as they know. The author of this activity, Semken (2012), explains that he used this activity as an introduction to energy sources and electricity production in an introductory geology course. Similar to this study, I was interested in using this concept sketch idea to uncover students’ prior knowledge of energy sources and electricity production. Therefore, I intentionally wrote the prompt in Figure 1 to be simple and

open-ended. It was not intended to lead students toward specific criteria for their answers; instead it was intended to uncover what students understand about where their electricity comes from and elicit the level of detail that they could incorporate in explaining this process.

The instructions for creating a concept sketch are also included within the prompt. Researchers Johnson and Reynolds (2005, p. 87) suggest that when students complete a concept sketch, they should follow these steps:

1. Interact with and observe the prompting materials;
2. List what they think are the key features and processes, versus those things they observed that are nonessential;
3. Decide how the various aspects are related;
4. Brainstorm how to depict the system; and
5. Draw and annotate the sketch.

These steps are somewhat specific to the geologic formations that students were asked to illustrate in this case, but they worked as a foundation for the instructions imbedded in Figure 1.

Piloting the Assessment

After completing a rough draft of *Trace it to the Source!* I needed to try it out on a group of students to determine if my prompt was eliciting the responses that I intended. I used a group of graduate student colleagues for this task. Although, I did not enforce a time limit, they completed the assessment in less than ten minutes. This became an important factor that I considered when administering the assessments to the actual research participants. It demonstrated that participants may not actually read through the entire set of instructions (i.e. in Figure 1, step 3, which states: Make sure your sketch is organized and as detailed as you can make it). It also indicated that students may not be able to provide detailed sketches because they lack a complex understanding of the prompts. I addressed this issue in the administration of the

assessments by requiring students to take at least 10 minutes to work on the assessment before they were allowed to turn it in.

The pilot assessments using my colleagues provided a range of responses. The most basic concept sketch among my colleagues included the following steps: (a) coal is mined; (b) coal is transported by truck to a power plant; (c) electricity is transmitted through power lines to a house.

The most complex concept sketch incorporated the following: (a) sun, wind, natural gas, and water are sources of energy; (b) coal and natural gas are transported to power plants to be burned and converted to electricity, wind turns a turbine, water turns a generator, and nuclear fission occurs at a nuclear power plant; (c) the electricity from power plants gets distributed through power lines, a transformer, fuse box, and finally it goes to the outlet. These responses were important to consider when developing the criteria and point scale that define the next instrument: the rubric.

Rubric. After examining these responses, I identified categories for which to assess their complexity, and based each category on a five-point scale. The categories were determined based on observations of the piloted round, references to energy understanding in the literature, and discussions with committee members. Lee and Liu (2010) describe the development of energy understanding. Their definition includes several aspects of energy such as energy source, transfer, transformation, and conservation. After investigating energy understanding in the context of electricity production, I chose energy sources, electricity generation, transmission, and transportation to be the most important components in understanding this process.

To better understand how the rubric was developed and used, I will discuss its application to the most basic sketch in the pilot run. Beginning with the first category, Energy Sources, the

most basic sketch included one source of energy, giving it one point out of the possible five points in this category (see Figure 2). The next category, Electricity Generation, was scored based on whether or not the concept sketch represented how the energy source in the first category was transformed into electricity. In this concept sketch example, a power plant was drawn as the destination for the coal, which I interpreted as one point for demonstrating electricity generation. In the Transmission category, each point is given for the accurate illustration of a step in the process of transmitting electricity to an outlet in a house. Referring back to the example concept sketch, only one point was assigned for demonstrating that electricity is transmitted through power lines to a house. Other examples of steps in this process are provided under the category heading in Figure 2. The final category in the rubric is Transportation. This category was added because it represents another important component in the process of getting a primary energy source to a power plant. The example concept sketch illustrated a truck transporting coal from a mine to the power plant. According to the transportation category, this sketch would earn three points for illustrating one form of transportation. The scoring is different in this category due to a fewer number of possible responses.

CATEGORY	5	4	3	2	1	0
Energy Sources (Coal, natural gas, uranium, water, petroleum, wind, sun)	Illustrates and Identifies at least 5 sources of energy	Illustrates and identifies at least 4 sources of energy	Illustrates and identifies at least 3 sources of energy	Illustrates and identifies at least 2 sources of energy	Illustrates and identifies at least 1 source of energy	Concept sketch makes no reference to sources of energy.
Electricity Generation (Coal fired, hydroelectric dams, nuclear power plant, natural gas fired, wind turbines, solar panels)	Illustrates and identifies electricity generation from at least 5 different energy sources	Illustrates and identifies electricity generation from at least 4 different energy sources	Illustrates and identifies electricity generation from at least 3 different energy sources	Illustrates and identifies electricity generation from at least 2 type of energy source	Illustrates and identifies electricity generation from 1 type of energy source.	Concept sketch does not represent electricity generation.
Electricity Transmission (Transmission lines, substation, distribution lines, transformer, fuse box, electrical lines through house)	Illustration demonstrates 5 steps in the electricity transmission process.	Illustration demonstrates at least 4 steps in the electricity transmission process.	Illustration demonstrates at least 3 steps in the electricity transmission process.	Illustration demonstrates at least 2 steps in the electricity transmission process.	Illustration demonstrates at least 1 step in the electricity transmission process.	Concept sketch provides no means of electricity transmission.
Transportation (Train, pipelines, trucks)	Illustrates 3 different types of transportation for getting primary energy to the generation facility.	Illustrates at least 2 different types of transportation for getting primary energy to the generation facility.	Illustrates at least 1 type of transportation for getting primary energy to the generation facility.	Attempts to illustrate transportation but is inaccurate in the type used.		Concept sketch does not provide a transportation stage.

Figure 2. Concept Sketch Rubric

Procedures

Implementing the concept sketch assessment. Students were given their first concept sketch assessment before beginning any of the energy course work. As mentioned in the introduction to this study, the energy curriculum titled Energy Literacy for a Sustainable Future, was comprised of three units that generally included:

1. Basic concepts behind energy sources and energy production
2. Addressing the problem of increasing carbon in the atmosphere
3. Internalizing the energy challenges and empowering students to take action in solving complex issues.

The concept sketch assessment was administered before the first unit for the purpose of this research-eliciting students' prior knowledge of energy concepts. On average, students completed their sketches in about ten minutes. The sketches of those students who volunteered to participate in the study and had returned signed consent forms were collected for analysis. Then classes progressed through the first unit of the energy curriculum, where students learned about the history of energy, electricity generation, energy flows, and the pros and cons of energy sources. Some of the activities that students participated in were hands-on. They included stations that involved building a generator, physical placement of energy related events on a timeline, and the creation of diagrams and posters. In one activity, students were split into groups and assigned an energy source to research. Similar to the concept sketch assessment, their task was to illustrate the flow of energy from its primary source to its eventual transformation to electricity. After all groups completed their poster, each energy source was displayed on the wall in the classroom as resources to refer to in the final units.

Following unit one, students again completed Trace it to the Source! concept sketches. The purpose of this round was to see if students created more complex concept sketches and to better understand whether the concept sketches were useful as learning tools for understanding energy flows. The posters of energy flows were still on the wall during this second round and are considered as a potential limitation in the comparison of the first round of concept sketches and the second. Another limitation considered was the addition of allowing participants to see the grading rubric while completing their second round sketch. This decision to incorporate the rubric in the second round was a necessary change due to the observations I made of students expressing greater interest in completing assignments for a grade.

Interviews. After the first round of concept sketches, approximately 30 participants were randomly chosen for interviews. A maximum of three students were interviewed at a time. The purpose of the interview was to compare the students' verbal explanation of their sketch to their hardcopy drawing. The verbal explanation offered another perspective for assessing students' understanding of energy concepts. It also provided a way to assess the effectiveness of the assignment prompt in eliciting the "correct" answer in student sketches.

During the interviews, students were each given their own concept sketch to refer back to in answering following questions:

1. Can you walk me through your concept sketch, and explain your thoughts?
2. If you could add anything to your concept sketch now, what would it be?
3. What activities or lessons helped you understand energy flows?

Each interview was audio recorded, and later analyzed for common themes in student answers and explanations. Particular attention was given to how students' verbal explanation differed or expanded upon their sketches.

Following the final round of concept sketches, there was a second round of student interviews. Six students were randomly chosen from the study participants, and were interviewed three at a time. Similar to the first round, the second round of interviews addressed how well students' verbal and illustrated explanations corresponded to one another. Students were asked the same questions, and audio recorded. Several students participated in both rounds of interviews. Observations from interviews were used in conjunction with sketches to better understand students' actual knowledge of energy concepts and the effectiveness of the assessment in demonstrating student understanding.

Analysis. I started out by reviewing each participant's concept sketch from Round one. After making general observations about the sketches it became clear that energy sources were where there was the most discrepancy among students, and offered a definitive way to group the sketches. Therefore, the sketches were separated into four main categories: those that (a) did not provide an energy source, (b) used fossil fuels as an energy source, (c) used renewable sources of energy, and (d) used both fossil fuels and renewable energy sources. Within each category, sketches were also analyzed and compared to one another focusing on common themes, similarities, and differences.

Chapter 4

Results

Round One Sketches

The first round of concept sketches were divided into four categories, based on the primary sources of energy that the students illustrated in their sketches. These four categories were defined as: (a) non-renewable energy sources, (b) renewable energy sources, (c) both non-renewable and renewable energy sources, and (d) no energy source. The most students ($n = 21$) illustrated no primary energy source in their concept sketch. Nineteen students used *either* renewable or non-renewable resources, and six students used *both* types of primary energy sources (See Figure 3).

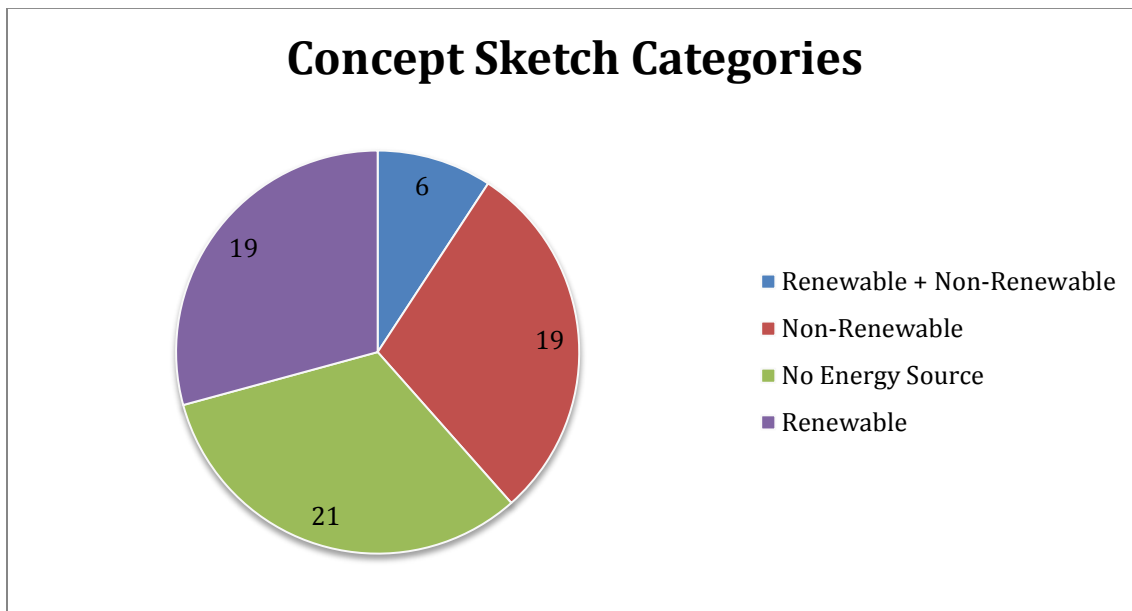


Figure 3. Concept Sketch Categories. Categories of concept sketches found in round one, distinguished by the type of energy source depicted in the drawing.

Since primary energy sources were the most distinguishing factor among the sketches, dividing them in this way allowed for further analysis within each group. To do so, the steps each student illustrated in their drawings were identified as a sequence – for example “power

plant →power line→wires in house” is a sequence describing an energy flow from a power plant to a home. Although each student’s sketch was unique and descriptive, the sequences have been simplified to synthesize data for analysis. For each primary source of energy, at least four sequences were identified among the sketches in that category. The sequences found for each category are described in Figures 4 through 7.

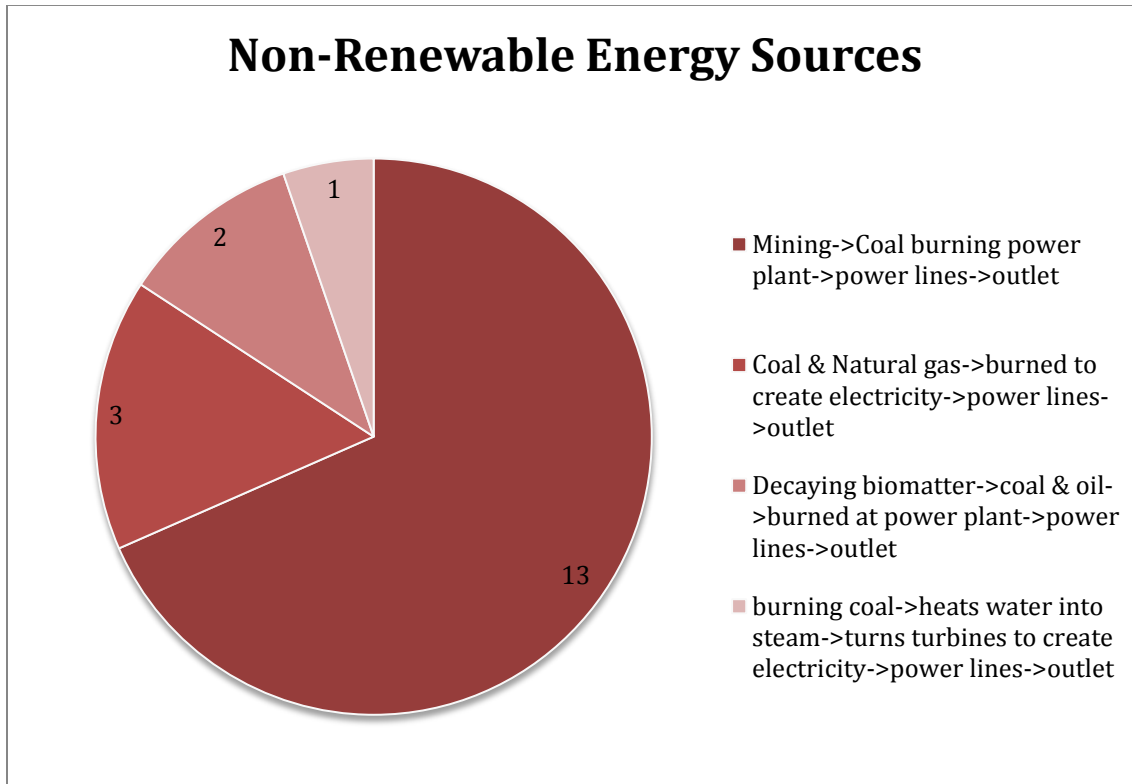


Figure 4. Non-renewable energy sources. Sequences found in concept sketches that illustrated non-renewable energy sources.

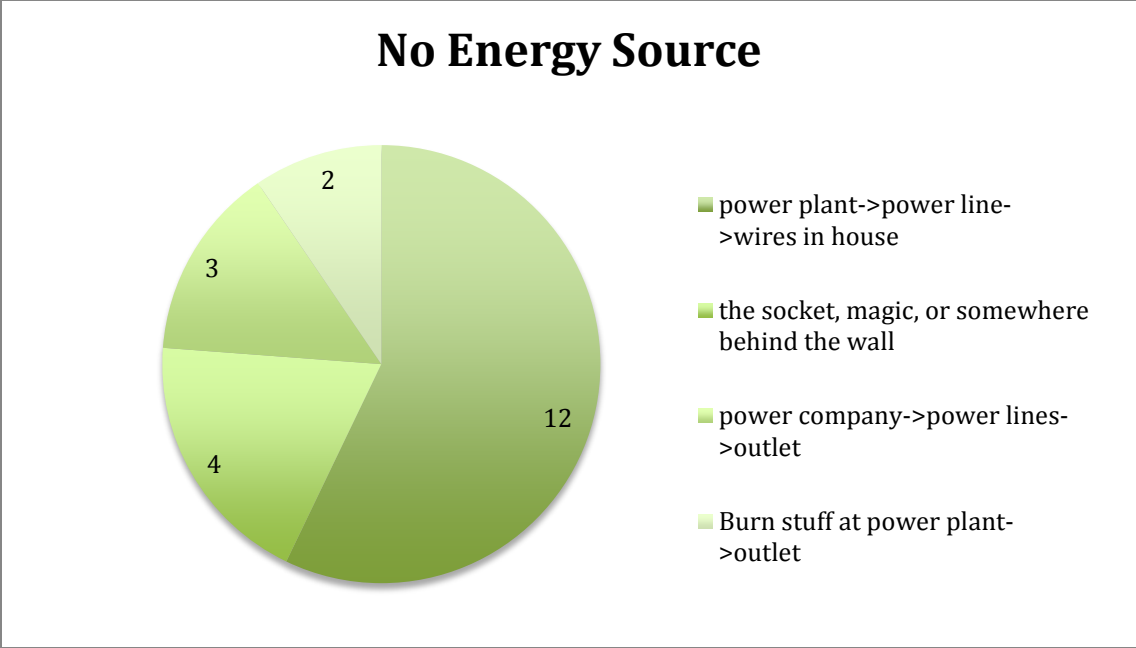


Figure 5. No energy source. Sequences found in concept sketches that did not represent an energy source.

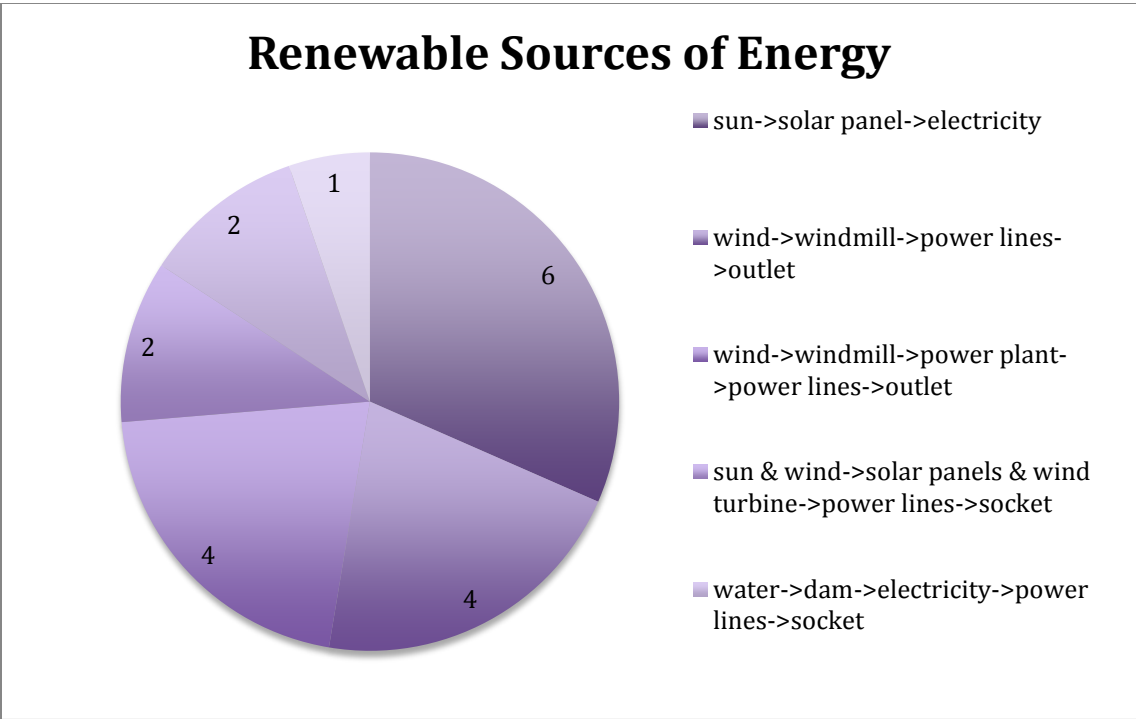


Figure 6. Renewable sources of energy. Sequences found in concept sketches that illustrated renewable sources of energy.

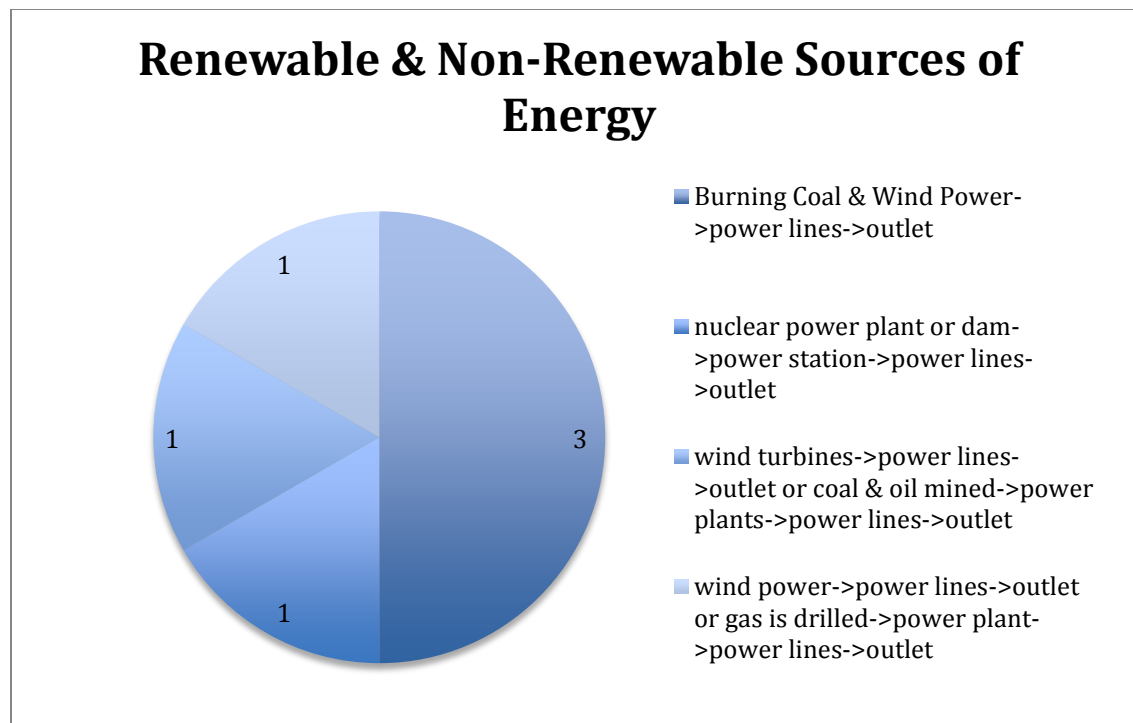


Figure 7. Renewable & non-renewable sources of energy. Sequences found in concept sketches that illustrated both renewable and non-renewable sources of energy.

Most students failed to illustrate any energy source in their concept sketch. In these sketches, the most commonly identified sequence was “power plant → power lines → wires in a house” (Figure 5). Here “power plant” was used to show where energy originated, and was not an actual energy source. Students in this category also referred to “magic”, “socket”, and “the power company”, as other primary sources of energy.

Students who used just non-renewable energy sources most often used the sequence “coal mining → coal burning power plant → power lines → outlet” (Figure 4). They also referred to decaying matter as the source of non-renewable sources, as well as the processes of burning, steam generation, and energy transformation. However, these concepts were present only in a few sketches.

The category of renewable energy sources generated the greatest number and variety of sequences among the students' sketches. After simplifying and combining them, there were five general sequences found in this category (Figure 6). Students were relatively evenly split among three main sequences:

1. Sun → solar panel → electricity (6 sketches)
2. Wind → wind mill → power lines → outlet (4 sketches)
3. Wind → wind mill → power plant → power lines → outlet (4 sketches)

In the rest of the sketches, some students used both sun and wind power, and a few included methods of energy transformation.

The final category – sketches utilizing both renewable and non-renewable energy sources – included just six sketches (Figure 7). Three sketches used the sequence “Burning coal and wind power → power lines → outlet”. The other three sketches utilized more steps, and one of the three mentioned water as a source of energy.

The First round of sketches was then compared to the Second Round based on the scores that the sketches received after they were graded with the rubric. The Second round contained more complex sketches through visual observation and their complexity was reflected in higher average scores. After the scores were compared from Round one and Round two, a more in-depth analysis of several sketches was included.

Comparing Round One and Round Two Concept Sketches

The averages of the total scores in Round one and Round two are shown in Figure 8. Round one concept sketches received an average score of approximately three of 20 possible points. The average of the concept sketches in Round two was approximately 10 points out of 20 possible points.

In Figure 9, the average number of energy sources that students identified in their sketches is displayed for Round one and Round two. In Round one, the average was less than one, meaning that a number of students were unable to identify an energy source in their concept sketch. In Round two, the average number of energy sources identified was approximately four.

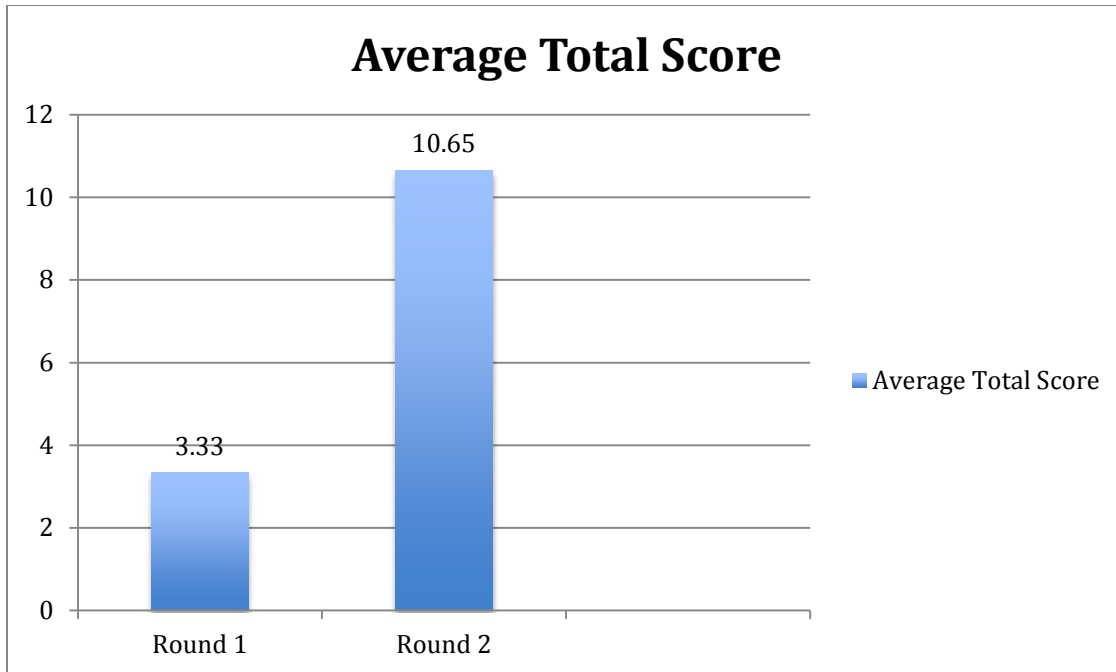


Figure 8. Average total scores of concept sketches

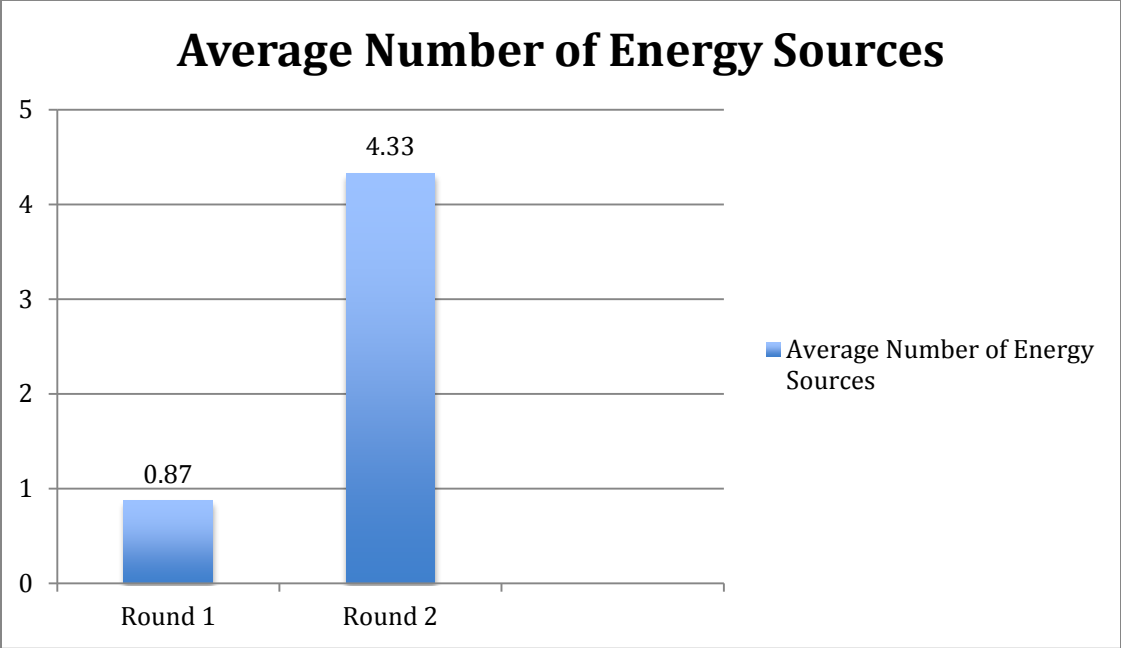


Figure 9. Average number of energy sources in concept sketches.

For a more in-depth analysis, the Round one and Round two concept sketches were compared for one randomly chosen student from each category described in Figure 3. The students have been designated A, B, C and D.

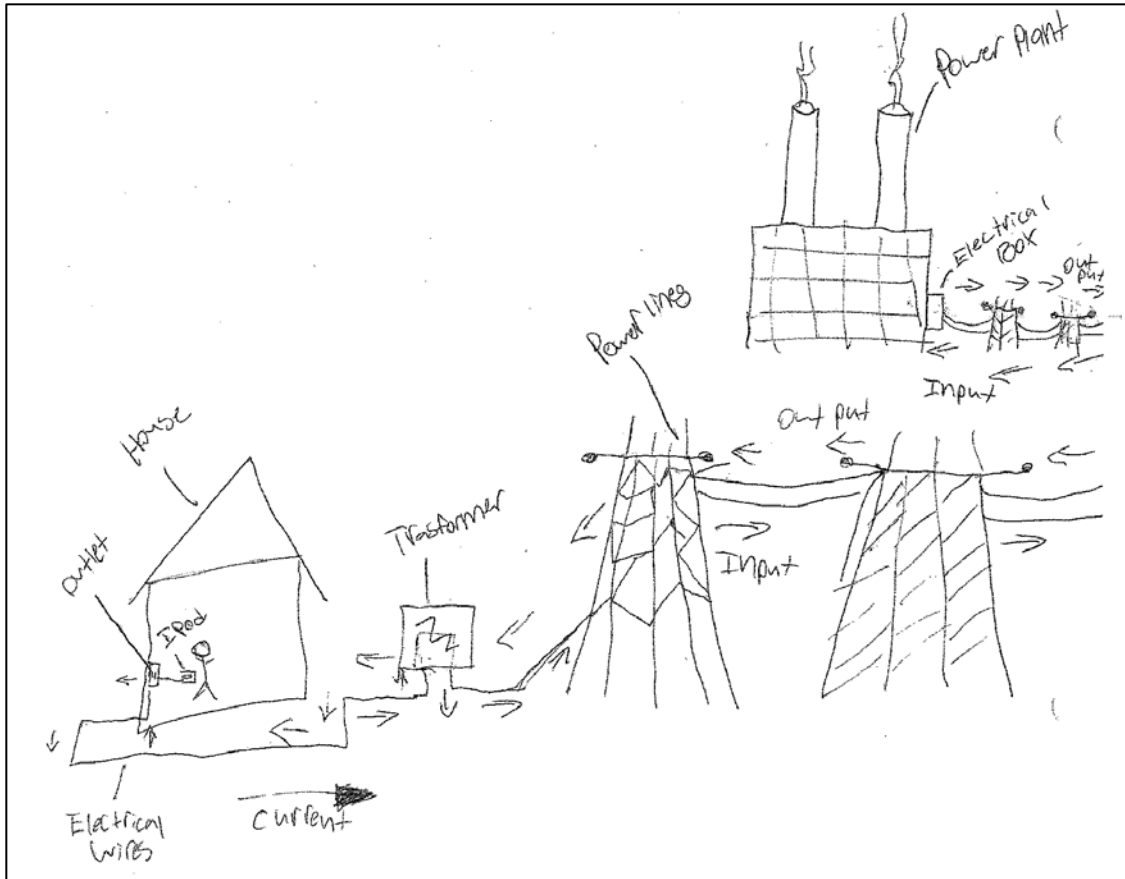


Figure 10. Student A Round One Concept Sketch

Student A. Student A produced a sketch in Round One with no energy source (Figure 10). Using the grading rubric (Figure 2), the sketch received an overall score of 3/20. It did not receive any points for energy sources, as the sequence begins with a power plant. Since the power plant was assumed to be producing electricity, the sketch scored one point for electricity generation. For energy transmission, the student illustrated three main forms: power lines, a transformer, and wires to the home/outlet. This category received three points. Finally, no points were earned in the transportation category due to the fact that there was no illustration of transportation in the sketch.

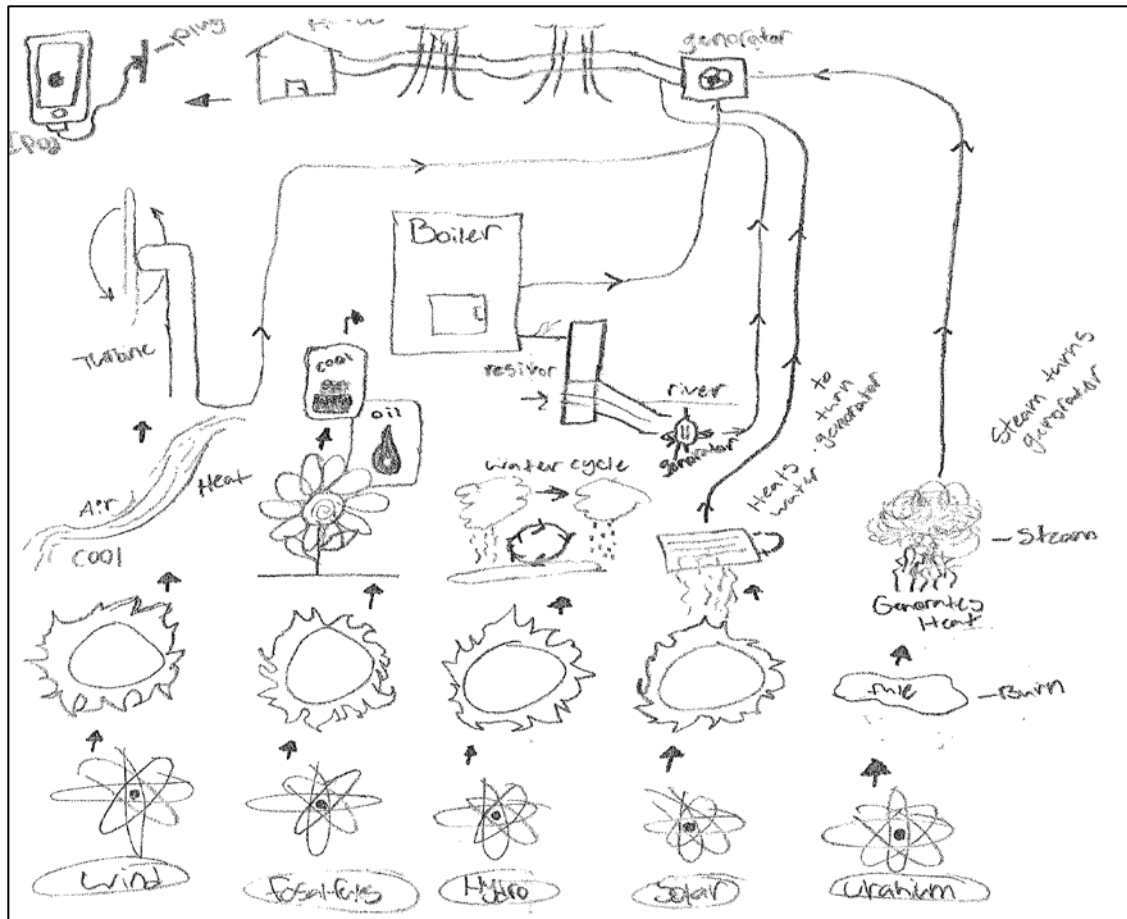


Figure 11. Student A Round Two Concept Sketch

In comparison, Student A produced a concept sketch in Round two that received a total of 11/20 points (See Figure 11). The sources illustrated were wind, fossil fuels (coal and oil), water, the sun, and uranium giving it five out of possible five points for energy sources. For energy generation, the sketch illustrates a wind turbine, a boiler for burning coal/oil, a dam with generator, solar panels, and a steam-driven generator – earning five out of five points on the grading rubric. Energy transmission received only one point. This was due to the fact that the students’ only representation of transmission was power. Finally, the sketch did not receive any points for energy transportation, as methods for moving energy resources were missing.

Overall, Student A demonstrated an increase in total score of seven points between Rounds one and two. The increase was greatest in the categories of energy sources and generation, where Student A increased five and four points, respectively. In addition to the quantitative rubric, Student A's sketch in Round two was a much more complete picture of energy flows.

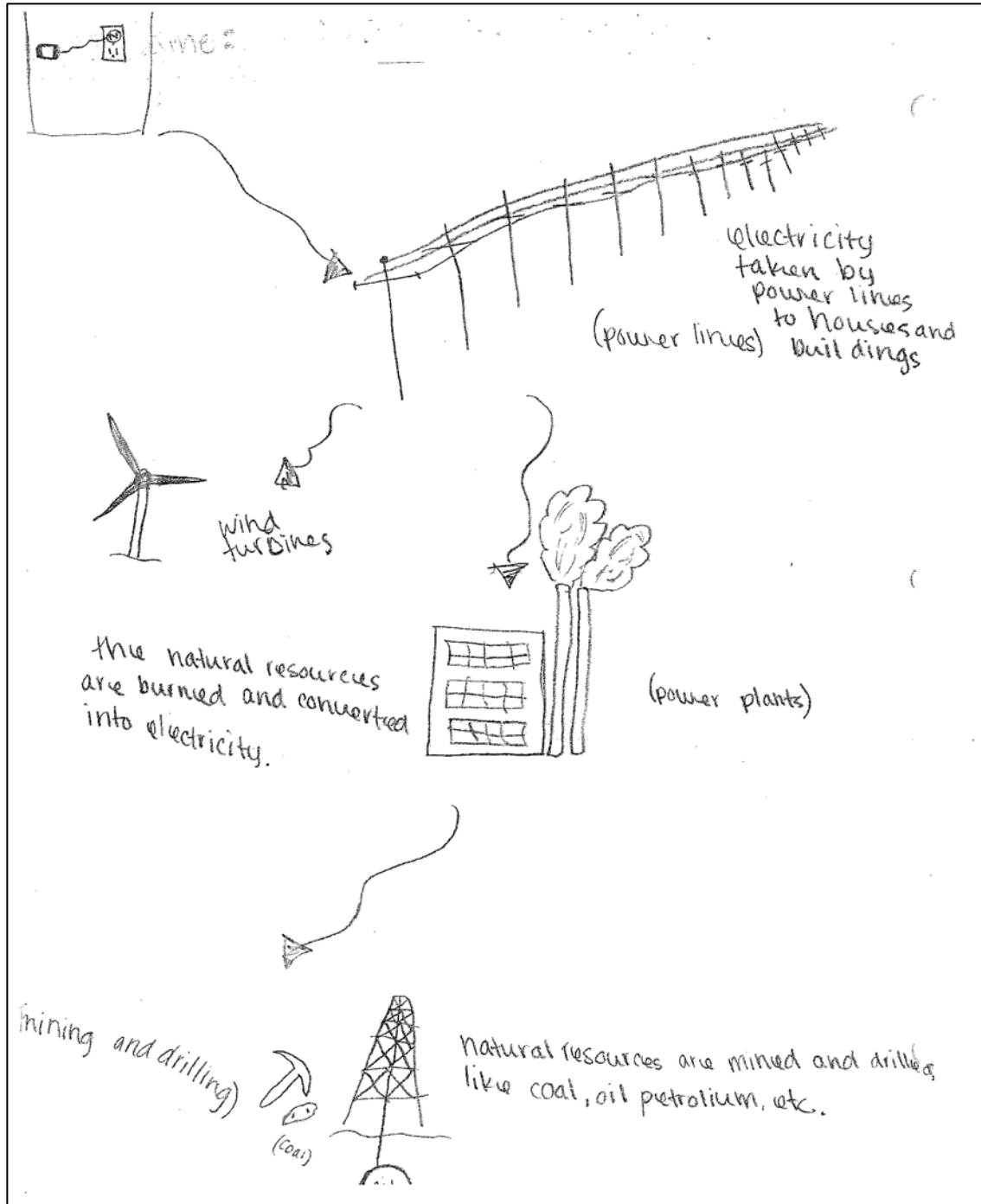


Figure 12. Student B Round One Concept Sketch

Student B. Student B was selected from those students who used both renewable and non-renewable resources. In Round one, the sketch received a total of 6/20 points. Student B used three energy sources: wind, coal, and oil (Figure 12). Two points were earned for energy

generation: a power plant burning fossil fuels and a wind turbine. Power lines were the only representation of energy transmission, earning one point on the grading rubric. There was no form of energy transportation shown.

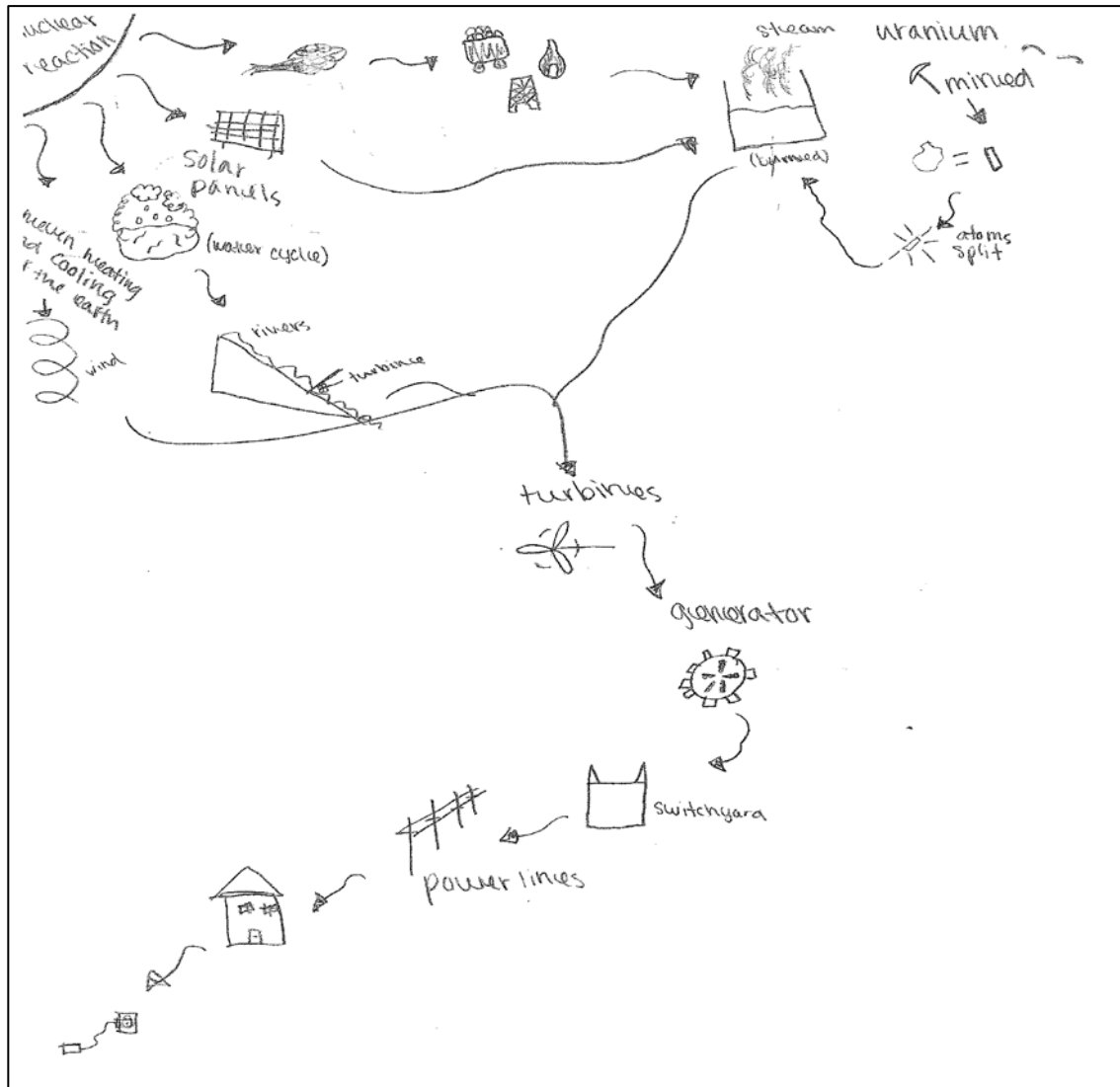


Figure 13. Student B Round Two Concept Sketch

In Round 2, student B produced a concept sketch shown in Figure 13 that received a total score of 12 out of 20 points. All five points were earned for energy sources, as the student illustrated sun, water, fossil fuels, uranium, and wind. The concept sketch also includes five sources of energy generation: solar panels, a wind turbine, a dam, burning fossil fuels, and

splitting atoms. Student B earned two points for electricity transmission, as power lines and a switch yard demonstrated two steps in the transmission process. There were no forms of energy transportation.

In comparison to Round one, Student B's concept sketch in Round two had a total score increase of six points. The area of greatest increase was in energy generation, where three more methods were used in Round two.

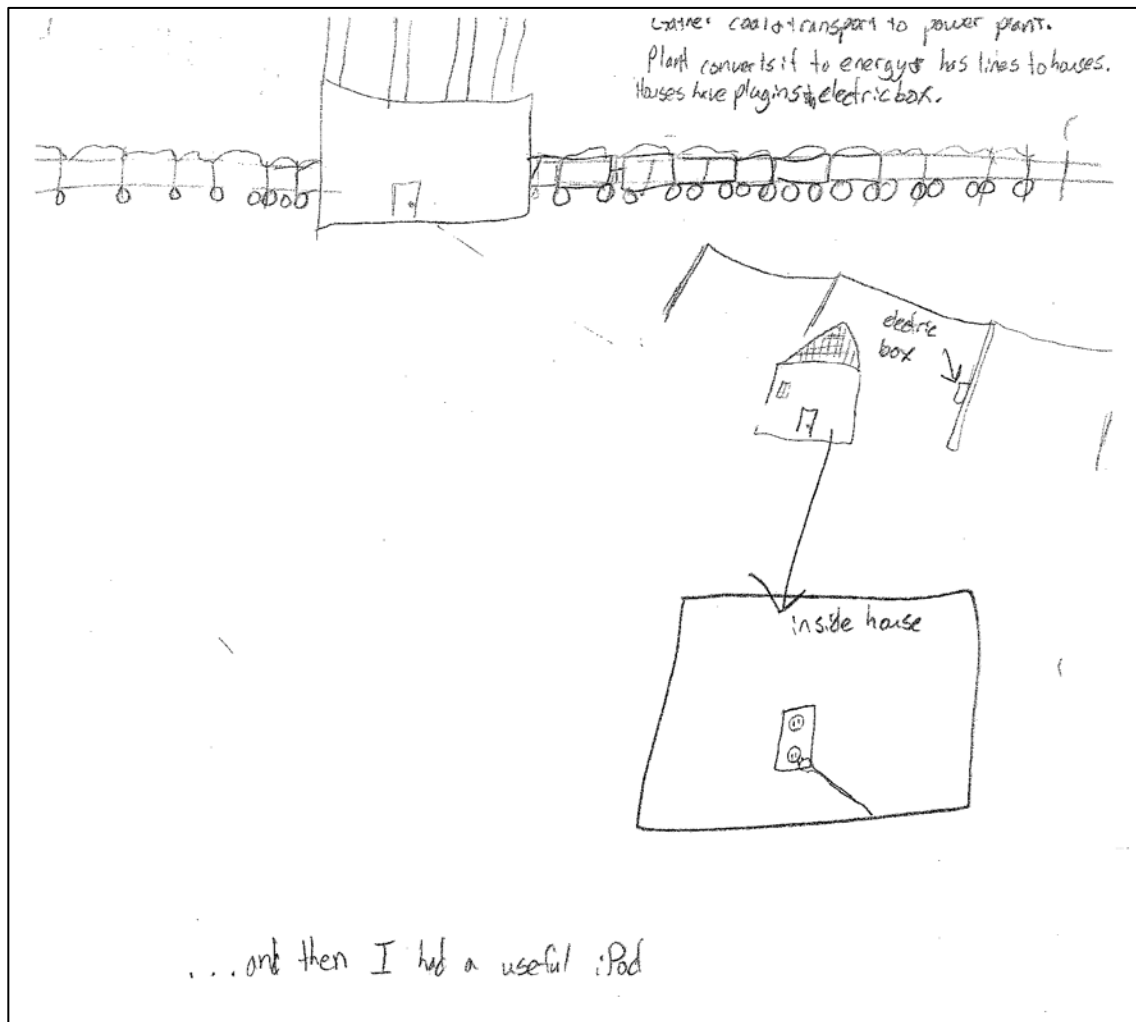


Figure 14. Student C Round One Concept Sketch

Student C. Student C was selected from the category of sketches that started with a non-renewable energy source as shown in Figure 14. In the first round, this student's sketch received

a total of 7/20 points. Student C received one point for illustrating coal as the energy source. One point was earned for including a power plant that received the coal. In the transmission process, this student gained two points for illustrating power lines and an electric box at the house. Finally, transportation was demonstrated by the coal train, which adds another three points as indicated on the rubric.

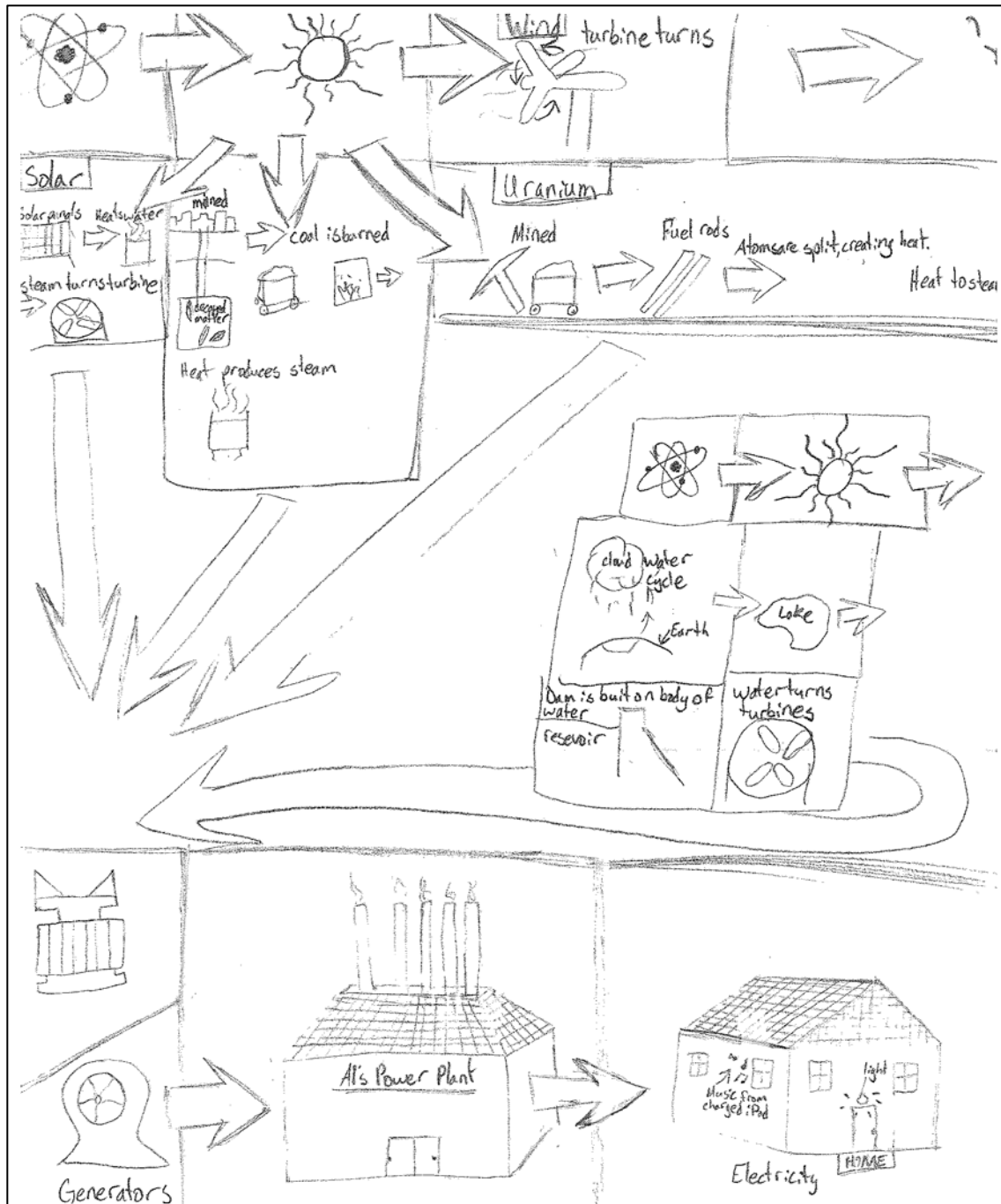


Figure 15. Student C Round Two Concept Sketch

In Round two, represented in Figure 15, student C received a total of 13/20 points. The sketch earned five points for illustrating wind, uranium, sun, coal, and water as energy sources. Five points were also recorded for illustrating electricity generation via wind turbines, splitting

of atoms, solar panels, burning of coal, and a dam. There were no steps represented in the transmission process, so this category received a zero. A final three points were earned for the illustration of a coal train as a method of transportation.

Student C increased their score by six points from Round one to Round two. The two areas where this student improved their score the most were energy sources and electricity generation.

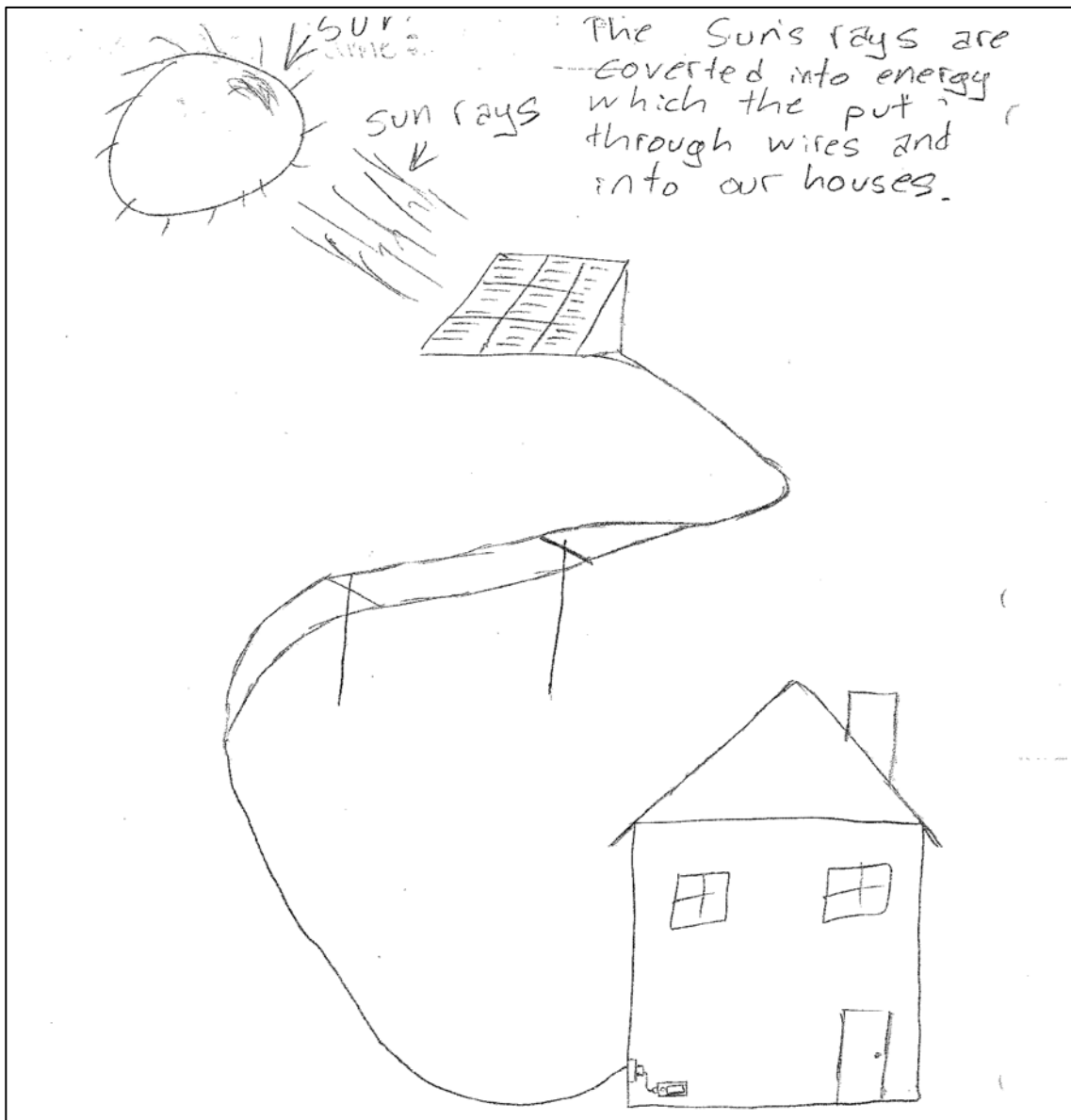


Figure 16. Student D Round One Concept Sketch

Student D. Student D was selected from the sketches that were categorized under renewable energy sources. In the first round, this student received a total of 3/20 points. One point was counted for including the sun as an energy source. The second point was earned with the illustration of a solar panel, which represents electricity generation. The power lines represent one step in the transmission process and added another point to the total. The sketch did not represent transportation.

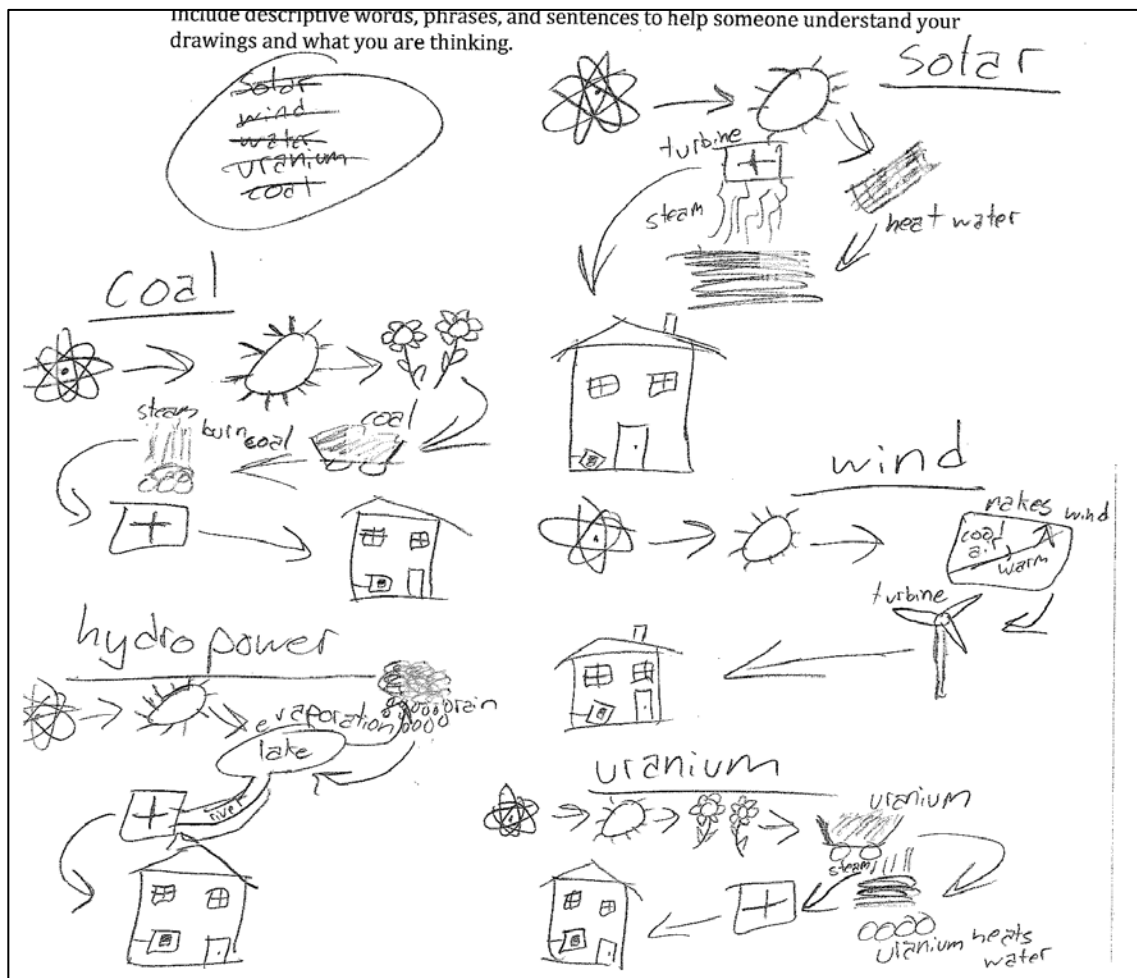


Figure 17. Student D Round Two Concept Sketch

In Round two, Student D received a total of 12/20 points. All five points were earned for energy sources, as the student included sun, wind, uranium, water, and coal. The concept sketch also included four types of electricity generation: solar panels, wind turbine, nuclear power, and

coal power. Student D did not earn points in the transmission process. The sketch includes a train car for transporting coal, which earned three points on the rubric.

Student D increased their concept sketch score by nine points from Round one to Round two. All categories except electricity transmission gained points in the Second round.

The results indicated that in the First round of concept sketches, 21 out of 65 students were unable to identify a primary energy source. In Round two, the average number of energy sources that students were able to identify was approximately four. A closer look at the comparisons of individual sketches from Round one and Round two indicates a difference in complexity. The average total scores for Round two were higher than Round one. The sketches in Round two indicated several gaps in the process of getting primary energy sources transformed to electricity in a usable form. The transmission and transportation aspects of the sketches were generally lacking in detail, and therefore received lower scores.

Chapter 5

Discussion/Conclusion

Introduction

This study was intended to begin to address a large gap identified in the literature in the practical realm of energy education. The gap is apparent in the development and implementation of alternative forms of assessment, also referred to as informal assessments and assessment learning tools (Anderson, 1998). As addressed in the literature review, energy education is being adopted by and required in schools across the United States as a long-term solution to rational energy use (Dias et al., 2006). Studies have shown that students struggle with understanding basic energy concepts, which indicates that this topic is complex and there is a need for educational tools that assist in developing this knowledge (DeWaters & Powers, 2011). This study explored the practical use of concept sketches as an informal assessment tool in a curriculum focused on energy.

Discussion of the findings

The findings of this study begin with a broad perspective of the student participants' understanding of energy as elicited by concept sketches. In the initial breakdown of concept sketches in Round one (represented in Figure 9), the average number of energy sources that students were able to identify in their sketches was actually between zero and one, indicating that most students had trouble identifying even one original source of energy. This is striking, considering that participants live in an area of the country that has some of the most abundant energy resources. For the students who did not reference any source of energy (Figure 5), energy seems to be a mysterious and invisible entity and was even referred to by some as "magic". For these students, their baseline understanding of energy concepts is very low. This is an indication

that any energy related instruction must start from the very beginning – a fact that was easily highlighted by the concept sketch.

Origins of energy sources. Students who identified one or more non-renewable energy source (Figure 4), often used coal. However, where the coal comes from was absent from their illustrations. A more complete sketch would have indicated that the formation of coal began millions of years ago with the sun supplying energy to plants that eventually died and formed coal. In the area of renewable energy resources, students in Round one were able to illustrate those objects familiar to them – they often see wind turbines and solar panels, which were the most commonly drawn “sources” of renewable energy. However, they did not seem to understand how these objects captured primary energy sources (i.e. wind, sun, water), which were then transformed into electricity. This is important because in order to fully comprehend the ultimate ramifications on people and the planet they must understand the complete energy flow, starting with these primary energy sources.

Process behind generating electricity. In addition to origins of energy sources, another concept that students struggled to illustrate in the Round one concept sketches was electricity generation. For example, power plants seemed to be a miraculous place where energy somehow gets transformed into electricity, though few students could explain what was actually happening. Others illustrated a wind turbine or burning coal as a source of energy, but did not demonstrate how the energy is transformed to electricity that powers their iPods. This could be due to the fact that it seems to be common knowledge that electricity comes from power plants. This is, after all, who bills us each and every month for our electricity usage – but there is little understanding as to where the power plants get their energy.

Understanding electricity generation is important not only to fully understand energy flows, but also because it requires the transformation of primary energy into usable electricity, which is a large contributor of carbon dioxide emissions. Rising levels of carbon dioxide in the atmosphere is one reason the earth is experiencing climate change, an issue of utmost importance for current and future generations (Bachu, 2000). Understanding how electricity generation, carbon dioxide emissions, and climate change are connected to human behavior is the first step in educating people about how to make more responsible choices for the planet. Trace it to the Source! helps students to actually *see* the ways in which they are connected to these concepts: the simple daily activity of charging a cell phone may seem like a meaningless task, but uses energy, creates carbon dioxide, and contributes to climate change that adds up in a big way.

Gaps in understanding energy flows. One reason that students may not have bridged the gaps between energy sources, generation, and their home outlet is because they did not understand forms of energy transportation and transmission. More often than not, these steps were completely absent from the first round of sketches. In sketches showing non-renewable energy sources, few students illustrated coal being taken from a mine to a coal-burning power plant. Additionally, wind turbines were drawn directly into power lines, without any indication of how “wind” became “power”. Others drew power lines that bypassed transformer boxes and fuse boxes and went directly into home outlets. This demonstrated that these students had very simple ideas of how energy and electricity travel and change from one place and form to the next.

Transportation is a key component in the process of creating electricity. In the first round of concept sketches, only a handful of students illustrated a form of transportation. This was most likely due to the fact that most students were unable to illustrate a primary energy source,

which also indicated that they did not understand the process of extracting and transporting energy sources.

Understanding concepts of transportation and transmission are important because areas of energy extraction are typically very far from where the electricity is generated and eventually used. Therefore, just getting energy requires energy; students should understand that this process is complex and there are impacts associated with the seemingly endless supply of electricity that is used every day (Zografakis et al., 2008).

Implications

This assessment requires students to describe energy flows in their own words and drawings. Concept sketches expose prior knowledge and misconceptions – which was especially evident in Round one sketches. This is valuable information for teachers in applying the constructivist learning theory in their classroom.

Even the students were able to recognize how useful the sketches were. When comparing doing a concept sketch to a book assignment, one student remarked:

It's better than reading it out of a book because then you remember it better because you are drawing it out. It would be harder to visualize in a book. With drawing pictures it is easier to see and really know how energy actually goes through a whole process.

Another student has a similar view on the assignment:

The process of sketching makes you think about how things work and where they go and about the steps. It gives you a visual, like when you are trying to think back to how it works it is helpful to have pictures.

Concept sketches as learning tools. Concept sketches can be even more powerful learning tools when they are returned to students with feedback for revision and reflection. In this study, the first round sketches were given back after several energy lessons and students were given the opportunity to revise their sketches. Though few students were motivated to actually revise their sketch, being able to look at their previous ideas and misconceptions was useful for them to recognize mistakes and improve future renditions.

Another idea for implementations of the concept sketch activity would be to allow students to work in groups to revise one another's sketches. Researchers Johnson and Reynolds (2005) suggest that a collaborative approach to this activity is useful in that it adds another strategy for assisting students in the learning process. An intermediate round of sketching that includes revision and group work could act as a bridge to a final – third round – individual sketch to grasp students' final understanding at the conclusion of the unit.

Formative approach. Comparing the concept sketches from Round one and two highlights their effectiveness as a teaching and learning tool. Simply comparing the average numerical scores of students in Round one to Round two expresses the success of the activity. Students in Round one scored an overall average score of just 3.33 (see Figure 8), while those in Round two scored an average of 10.65 points. While students in Round two were still well below optimum scores, they had much more complete sketches and complicated sequences. For example, students were able to identify many more energy sources in Round two than in Round one. In Round one, the average number of sources identified was less than one, indicating that most students had no prior knowledge of even what an energy source was. In contrast, in Round two students identified, on average, 4.3 energy sources – many students identified all five sources covered in class.

Comparing the Round one and two sketches of individuals provided a more qualitative analysis of concept sketches as a possible educational tool. It was easy to see areas of improvement. For example, in Figures 12 and 13, the first and second round sketches of a single student are shown. The student showed coal and oil being mined and drilled in the Round one sketch (Figure 12). In Round two, the same student begins the sketch with a nuclear reaction in the sun, which then provides energy to plants, which eventually die and become coal (Figure 13). Looking at the same set of sketches, the Round two sketch includes much more energy generation processes like wind turbines and steam generators. In contrast, the Round one simply refers to a “power plant” where electricity is somehow generated. The second sketch is a much more complete overall picture of energy flows from beginning to end.

In another set of Round one and two sketches, the increase in student understanding is evident in looking at the overall number of sequences present in the sketch. In Round one (see Figure 10), the student illustrates one main energy sequence: power plant → power lines → transformer → outlet. However, in Round two, the student draws five total sequences, each beginning with a different energy source (see Figure 11). By drawing more sequences in Round two, this student demonstrates a complete understanding of the multitude of energy sources and how they contribute to the electricity that people utilize on a day-to-day basis.

Overall, concept sketches from Round two demonstrated a more complex understanding of energy concepts. The most improvement was seen in identifying energy sources and forms of energy generation. This could be because other concepts, namely transmission and transportation, received less attention during class, as noted in field notes taken while observing the unit being taught. The unit primarily focused on *where we get electricity* and *how energy is transformed into usable electricity*.

New and recurring misconceptions. It is important to note also, that even when students' Round two sketches *looked* more complete, these sketches often had inaccurate illustrations. Some of the Round one sketches were simply lacking information whereas in Round two they illustrated more confusion in some areas. For example one student's Round one sketch (see Figure 14), refers to only one energy source, and there is no mention of how electricity is generated before it becomes electricity entering the home. Conversely the student's Round two sketch (Figure 15), appears to be full of information with various sources of energy, forms of generation, and cycles illustrating energy flows. However, the sketch mistakenly illustrates all energy sources and flows going to a single power plant and into the home. In reality the electricity generation for each source would occur at a power plant specific to that transformation process. Electricity does not come together from multiple sources until it enters an electricity grid, much later in the transmission process. A more correct representation would have separated out each energy source into a complete sequence on its own.

Limitations

There are several limitations of this study, many of them stemming from the short and compact nature of this project. Several factors arose in the classroom that were difficult to control as an outside researcher. While I was flexible in working with these challenges and remained cognizant of the questions I was trying to answer my research, it is important to elucidate them here.

Comparison of round one and round two. The rubric was initially developed to serve as an instrument for measuring the components included in the sketches. The framework of the rubric was intended to assist the reviewer in evaluating what students have illustrated in their sketches and what the sketches might be missing. Students in this study did not see the rubric

until the second round. It was not handed out for the first round, because the assessment was being used as a baseline to see where their knowledge was at that time.

However, it was handed out in the second round because the teacher told students that they would be receiving a grade for this concept sketch. Thus, it seemed important at that point to let the students see the criteria on which they would be graded. This creates a limitation to the results of the comparisons between concept sketch scores in Round one and Round two. For example, it is possible that participants in Round one knew more energy sources than they actually illustrated in their sketch. In addition, the expectations in the rubric and the pressure of performing for a grade could have influenced the scores in Round two.

Another factor that could have potentially influenced Round two concept sketches was student work that was on display in the classroom. An activity conducted during the unit had students develop posters showing energy flows for each major source of electricity. These posters were still hung on the walls when the second concept sketch assessment took place. Several students were observed looking up at the posters while completing their concept sketch. The teacher did not discourage this; therefore the posters served as a resource for some students and possibly assisted them in learning the material as well.

Sketches are limited-the grader interpretation. One limitation of concept sketches as an assessment tool is that it is difficult to score them without scorer bias. Concept sketches can be limited in demonstrating what students understand when the sketch stands alone from text. It is up to the grader to interpret what the student has displayed in some instances, because not all students provide detailed descriptions of their sketches. The purpose of interviewing students was to better understand if their sketches matched their ability to describe them in a conversation. In most cases, their descriptions lined up with their sketches, but it was difficult to

ask them questions that facilitated this type of discussion. Creating an environment that promoted dialogue around the sketches would be useful for future studies and would assist the facilitator in interpreting students' understandings of these concepts.

Conclusions

A pioneer in the field of environmental studies, Murie (1982) used sketching as a scientific tool for understanding processes within the natural environment. His attention to detail and his ability to portray it in sketches ultimately lead to important movements in conservation. Through sketching, he learned about the roles of species within ecosystems and the dynamics that exist among species at small and large scales. In the 1950's, the work of Olaus Murie was crucial in assisting a nation immersed in post-war development to see the importance of conserving natural landscapes. In this project, I have been inspired by people such as Olaus Murie in their ability to influence people's knowledge of, attitudes about, and behavior towards the environment.

As indicated in the purpose of this study, issues like climate change stress the importance of educating students about natural science in ways that promote understanding and appreciation of the environment. Energy is an increasingly important topic in education that needs to be relevant and applicable to students in their everyday lives. The findings of this study are an important starting point for further research to continue exploring other methods for teaching energy concepts in a real-world context. In terms of the specific questions this research addressed, concept sketches can be valuable as assessment tools in uncovering students' understanding of energy concepts. Concept sketches are not intended to replace other forms of assessment; instead they can act as an additional tool for assessing students' knowledge.

I also explored the use of concept sketches as a learning tool, meaning that their implementation can be repeated throughout an energy curriculum to assist students in understanding energy flows. The analysis of the second round of sketches administered in this study indicated that students were able to create more complex sketches than the first round. Due to several limitations, it is difficult to determine if the process of sketching contributed to an increased level of understanding in the second round, but I encourage future studies to examine this with fewer limitations. Other questions that arose from this study that would be interesting to pursue include:

1. How do concept sketch responses vary when students complete them in groups?
2. What do concept sketches elicit about students' understandings of energy concepts in the long term?
3. Does increased knowledge of where electricity comes from change students' behavior related to their electricity use?

Eventually these questions and others related to this research will lead to more effective tools for teaching energy concepts. Hopefully because of this, students will begin to understand these concepts in ways that lead to more informed energy consumption behavior.

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