What Do Eighth Grade Students Know About Energy Resources?

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Abstract: This study investigated 8th grade students' understandings of energy resource and associated issues including energy acquisition, energy generation, storage and transport, and energy consumption and conservation. A 39 multiple-choice item energy knowledge instrument was developed that aligned to benchmark ideas about energy resources. The assessment was completed by 1,043 eighth grade students in urban school districts in two northeast cities in the United States. Total score reliability (Cronbach alpha) for the assessment was .776. Mean scores for the entire assessment measure indicated low conceptual energy knowledge of the 8th grade students. Subscale means revealed that student understandings of energy resource acquisition, energy generation, storage and transport, and energy consumption and conservation are not satisfactory. Distractor analysis identified many misunderstandings that 8th grade students hold with regards to energy resources. Findings revealed that students did not have a sound knowledge and understanding of basic scientific energy resources facts, issues related to energy sources and resources, general trends in the U.S. energy resource supply and use, and the impact energy resource development and use can have on society and the environment. Curriculum recommendations are discussed.

Keywords: energy resources; energy knowledge; energy literacy; energy conservation; curriculum

Introduction

Energy holds a central role in topical socioscientific issues, such as energy supply, distribution and utilization, consumption, and transport economics (Hinrichs and Kleinbach 2006; Papadouris et al. 2008). Energy pervades all sectors of our society, is needed to create goods from natural resources, and provides many of the services in our personal lives such as housing, food, health, transportation, and recreational activities. The availability of an adequate and reliable supply of energy is important for economic development and improved standards of living. Reliable energy supply is essential in all economies for lighting, heating, communications, industry, transport, and other essential services that are taken for granted in industrialized nations. World energy use increased over tenfold during the 20th century, predominantly from fossil fuels - coal, petroleum, and natural gas (Twidell and Weir 2006).

Furthermore, world marketed energy consumption is expected to increase 49% from 2007 to 2035 (U.S. Energy Information Administration 2010). The use of our energy resources is one of the major factors affecting the environment. Increased use of fossil fuels since the beginning of the industrial age has increased the carbon dioxide concentration in the atmosphere by 30% and has probably also increased the Earth's temperature (Schipper et al. 2001).

The need to conserve finite energy resources is the subject of increasing public awareness, and the debate concerning the possible contributions to the energy economy of sustainable resources has high public profile (Boyes and Stanisstreet 1990). As fossil fuel reserves are being depleted worldwide and energy costs are increasing, the use of renewable and sustainable energy resources is being more widely considered as a solution to our current energy crisis. With environmental issues related to energy use playing a more prominent role in the lives of citizens, it is important that young adults be equipped with fundamental knowledge and understandings about energy resources so as future citizens they will be able to make informed decisions to effectively confront the energy issues that face the environment (Gambro and Switzky 1999).

Education programs in schools should have an ultimate goal of providing students with a conceptual knowledge of energy and the issues related to energy use in order for them to be able to critically analyze and decipher information to effectively make informed decisions as future citizens (Hofman 1980; Van Koevering and Sell 1983; Barrow and Morrisey 1989; Solomon 1992; Farhar 1996). Environmental science topics related to energy resources are quite established in U.S. science education frameworks and environmental science curriculum (Blum 1981; Barrow and Morrisey 1987; American Association for the Advancement of Science [AAAS] 1993; National Research Council 1996). Concepts pertaining to the acquisition of renewable and nonrenewable resources, energy generation, storage, and transport, and energy consumption and conservation are included in the conceptual strand maps of the Association for the Advancement of Science *Atlas of Science Literacy* (2007) as important learning goals that should be achieved by students by the completion of eighth grade.

The purpose of this study was to investigate 8th grade students' knowledge and understandings about energy resources and associated societal uses. This research study explored the following question: What are 8th grade students' understandings of energy resource acquisition, energy generation, storage and transport, and energy consumption and conservation?

Background

A review of the research literature that investigated the conceptual knowledge relating to energy resources and related socioscientific issues for middle school age learners was conducted. Since only a limited number of studies specifically addressed middle school age students' understandings of environmental science issues of energy acquisition, energy generation, storage and transport, and energy consumption and conservation, the literature review was expanded to include all age levels.

The majority of published data indicate a lack of knowledge in our society about non-renewable resources. Rule's (2005) interview study with elementary age students reported misconceptions about the origin and sources of petroleum, coal, and natural gas, gasoline manufacture and storage, and the importance of petroleum in our society. She also found that these misconceptions continue into adulthood. Additional studies of upper secondary learners published between 1975 and 1990 also revealed that students had knowledge deficiencies about the availability and use of fossil fuel resources (National Assessment of Educational Progress 1975; Richmond and Morgan 1977; Holmes 1978; Lawrenz 1983; Holden and Barrow 1984;

Boyes and Stanisstreet 1990). Studies that used knowledge assessment items pertaining to nuclear power use reported that both adults and upper secondary students have incomplete understandings about the viability of using nuclear power as an energy source (Lawrenz 1983; Blum 1984; Arcury and Johnson 1987).

Few studies have investigated conceptual knowledge of renewable resources. Holmes (1978) analysis of NAEP items found that young adults have knowledge deficits about the availability and use of renewable resources. Bang et. al (2000) found that self-reported knowledge levels of American adults about renewable energy sources was low. Liarakou, Gavrilakis, and Flouri (2009) reported that a small sample of content secondary school teachers in Rhodes, Greece had knowledge deficits about the applications and environmental impacts of solar and wind energy and the environmental impacts of renewable energy resources.

Findings from studies that analyzed energy knowledge assessment items reported low understandings about energy consumption and conservation for both secondary students and adults (Holmes 1978; Holden and Barrow 1984; Valhov and Treagust 1988; Barrow and Morrisey 1989; National Environmental Education & Training Foundation and Roper ASW 2002; DeWaters and Powers 2008). Data from these studies found that most students and adults in the USA have incomplete understandings about societal and personal energy consumption patterns. Many do not know which energy sources are used primarily for a given sector (residential, commercial, industrial, transportation), which sources are converted into usable electrical power, are unfamiliar about practical considerations involved in power generation, and lack a fundamental understanding about energy efficiency.

A limitation of many of the previous published studies is that the reported findings are based on using a small number of energy resource-related items as part of a larger environmental knowledge assessment measure. In some studies, subscale reliabilities pertaining to a cluster of energy items were not reported. Researchers have noted the importance of developing a variety of environmental knowledge scales (Arcury and Johnson 1987; Gambro and Switzky 1999). The development of an energy resources knowledge scale measure is quite timely as the American science education community is now working to assess and promote energy learning progressions as part of a new national science education framework (Lee and Liu 2010).

The Energy Resources Knowledge Assessment

We began our development of a comprehensive energy resources knowledge assessment by creating a list of benchmark ideas that are energy resources literacy goals about energy resources acquisition, energy generation, storage and transport, and energy consumption and conservation for eighth grade students (see Table 1). We used the AAAS Atlas of Science Literacy (2007) maps – *Energy Resources* and *Use of Earth's Resources* as a starting point. The *Energy Resources* map is organized around three strands – resources, efficient use, and societal and environmental implications. The *Use of Earth's Resources* is organized around four strands —use of energy resources, needs of organisms for Earth's resources, human impact on the environment, and use of material resources.

Potential assessment items were identified that aligned to the benchmarks by reviewing existing knowledge assessment items published in the research literature that related to energy resources and associated environmental issues (Richmond and Morgan 1977; Holden and Barrow 1984; Stubbs 1985; Arcury and Johnson 1987; Blum 1987; Barrow and Morrisey 1989; Farhar 1996: Gambro and Switzky 1996, 1999; National Environmental Education & Training Foundation and Roper ASW 2002; Rule 2005; DeWaters and Powers 2008) and released items

Table 1. Benchmark ideas about energy resources and associated issues

I. Energy Resources Acquisition 1. Some resources are not renewable or renew very slowly. Fuels already accumulated in the earth, for instance will become more difficult to obtain as the most readily available resources run out. How long the resources will last, however, is difficult to predict. The ultimate limit may be the prohibitive cost of obtaining them. (8C/M10) 2. Energy from the sun (and the wind and water energy derived from it) is available indefinitely. Because the transfer of energy from these resources is weak and variable, systems are needed to collect and concentrate the energy. (8C/M5) II. Energy Generation, Storage, and Transport 1. Energy can be stored in various forms for subsequent use (gravitational, chemical, electrical, mechanical, etc.). 2. Transport of energy depends on the form of energy. 3. Energy resources are more useful if they are concentrated and easy to transport. (8C/M9) 4. People have invented ingenious ways of deliberately bringing about energy transformations that are useful to them. (8C/M8) 5. Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. (8C/M4) 6. Electric circuits are used to distribute energy quickly and conveniently to distant locations. (8C/M4) 7. In many instances, manufacturing and other technological activities are performed at a site close to an energy resource because of losses in transmission. Some forms of energy are transported easily and others are not. (8C/M3) III. Energy Consumption and Conservation 1. Energy is required to do anything (including technological processes, such as manufacturing). (8C/M7) 2. Industry, transportation, urban development, agriculture, and most other human activities are closely tied to the amount and kind of energy available. Different parts of the world have different amounts and kinds of energy resources to use and use them for different purposes. (8C/M6) 3. There are different ways of obtaining, transforming, and distributing energy, and each has environmental consequences. Each of these has trade-offs pertaining to energy dependence and the impacts of organisms (particularly humans) on the environment (8C/M2) 4. There are ways to conserve energy by reducing waste in everyday activities.

Note: AAAS (2007) benchmarks are listed in parentheses.

from the Trends in International Mathematics and Science Study (TIMSS) studies in 1995, 1999, 2003, and 2007 (International Association for the Evaluation of Educational Achievement 1995, 1999, 2003, 2007). Twelve items were identified and each was modified to enhance the item's readability for use with English language learners. In addition, alternative selection items were developed to reflect more recent developments in renewable energy. Additional assessment items were developed to align to the energy resources literacy goals. The initial instrument consisted of forty 5-option multiple-choice items with one correct answer. Misunderstandings and knowledge deficits about energy resources acquisition, energy generation, storage and transport, and energy consumption and conservation found in the literature were included as distractors in the assessment items. Distractor-based multiple choice testing can be used for diagnostic purposes when distractors are built specifically to illuminate common knowledge deficits or misconceptions student might hold in science-related content domains (Briggs et al. 2006; Sadler 1998). Item construct validity was established by having the items reviewed by a panel of 5 earth and environmental scientists and science educators with expertise in energy and associated environmental issues to ensure content accuracy, alignment with the benchmark ideas, and construct validity. Modifications were made to select items based the expert panel's feedback and recommendations. The resulting knowledge assessment items were grouped into three subscales corresponding to three main energy content areas:

(1) Energy Acquisition - Renewable and Nonrenewable Energy Resources (EA) [13 items]

(2) Energy Generation, Storage and Transport (EGST) [13 items]

(3) Energy Consumption and Conservation (ECC) [14 items]

To pilot the instrument, we employed a purposeful sampling strategy using intact classrooms of 3 teachers in two urban schools in Spring 2009, close to the timing of the administration of the 8th grade state science assessment. Understanding energy resources and associated environmental issues are learning goals that are explicitly stated in the sample's state academic standards. Renewable and nonrenewable resources compose an entire section of the academic standards for environment and ecology across all grade levels and include strands pertaining to uses, availability, management, and influential factors. In addition, concepts pertaining to understanding forms and sources of energy, both renewable and nonrenewable, are included in the science standards for 8th grade and concepts pertaining to the spatial distribution of nonrenewable and renewable resources are included in the state's geography standards for 7th grade. These schools were selected because of their close proximity to our institution to enable us to interview the teachers to find out which items students had difficulty understanding. Two hundred fifty-nine eighth grade students completed the pilot instrument.

Total score reliability (Cronbach's alpha) for the pilot assessment was .681. Subscale reliabilities were EA: .520, EGST: .435, and ECC: .243. Item analysis was conducted for each item that included item difficulty, frequency for each response selection, and item discrimination. Each individual item was removed one at a time to determine if its removal improved the reliability of each subscale and the entire assessment. After considering the results from the statistical item analysis, individual questions were also evaluated based on the teacher feedback for items that students had difficulty understanding. One ECC item was removed, minor editing was made to seven question stems to enhance the readability, and 6 selection choices were modified.

The final instrument consisting of 39 items was administered in Spring 2010 to 1,043 students taught by 13 teachers in 5 middle schools located in two cities in a northeastern state in the USA. These middle schools represented public school districts with students of varying degrees of language ability, socioeconomic status, and academic ability levels in science as measured by the state test. Sampling was purposeful to include urban school districts. Total score reliability (Cronbach alpha) for the assessment was .776. Subscale reliabilities were EA: .603, EGST: .565, and ECC: .477. The lower subscale reliabilities were deemed acceptable given the high construct validity of each subscale item.

Data Analysis and Findings

Table 2 displays the summary statistics of the students' energy resources knowledge. Mean scores for the entire assessment indicated low conceptual energy resources knowledge of the 8th grade students. Subscale means revealed that students' have not attained conceptual understandings of energy resources benchmark ideas pertaining to energy acquisition, energy generation, storage and transport, and energy consumption and conservation.

Table 2. Energy resources knowledge assessment results (N=1,043)

	Mean	Standard Deviation
Entire Assessment (39 items)	14.77	5.74
EA subscale (13 items)	5.42	2.47
EGST subscale (13 items)	4.99	2.37
ECC subscale (13 items)	4.35	2.16

Item analyses were conducted that included item difficulty level and item discrimination of each item. Distractor analysis was used to identify misunderstandings that 8th grade students hold with regards to energy resources. Item difficulties ranged from 0.10 – 0.80. Fifteen items had item difficulty levels less than 0.30. Two items had item difficulty levels greater than 0.70. Twenty-two items had item difficulty levels between 0.30 and 0.70. Item discriminations ranged from - 0.01 to 0.53. It should be noted that very difficult content knowledge assessment items have little discrimination (Hobsley, 1999). Point biserial correlations for 38 of the 39 items were significant at the .01 level.

Energy acquisition - renewable and nonrenewable energy resources

Table 3 displays results of select item responses to the energy acquisition subscale. Students' knowledge about nonrenewable energy resources was quite low. Coal was identified as the most abundant fossil fuel found in the USA by 42.0% of the students. Only 36.1% identified natural gas as being a nonrenewable energy resource. Responses to distractor selections indicated that students hold many incorrect ideas about the sources of nonrenewable energy. Only 12.9% of the students knew that petroleum (crude oil) and natural gas come from plankton and sea life that are millions of years old; 34.2% incorrectly identified the source of these fossil fuels as coming from coal fired power plants, 20.3% as swamp remains that are thousands of years old, 16.8% as dead dinosaur remains, and 15.4% from large tanks underneath gas stations. Just 17.3% of the students knew that coal is a fossil fuel formed from swamp plants that lived millions of years ago. In addition, many students do not understand why nuclear power is a nonrenewable energy resource; 50.9% of the students incorrectly thought that nuclear energy is considered nonrenewable because it produces waste that is radioactive.

In general, more students had a better understanding about renewable energy resources than nonrenewable resources. More than half (57.5%) understood that the term "renewable energy resources" meant that resources can be replenished by nature faster than they are consumed. Many students (70.9%) could identify a good location to build a solar power plant; 80.5% correctly identified the sun as the original source of energy for almost all living on our planet; 47.7% knew that areas with geothermal resources include geysers, fumaroles, hot springs, and volcanoes; and 58.1% think that in the year 2250, most of the world's energy will likely come from a mix of renewable energy sources.

Table 3. Select Energy Acquisition subscale item responses (N= 1043)

Item	N	% Response
What is the original source of energy for almost all living things on earth?		
A. Sun*	840	80.5%
B. Soil	13	1.2%
C. Wind	14	1.3%
D. Water	150	14.4%
E. Plant life	26	2.5%
Which of the following is NOT a renewable biofuel?		
A. Wood chips	228	21.9%
B. Petroleum (crude oil)*	530	50.8%
C. Ethanol made from corn	71	6.8%
D. Diesel fuel made from vegetable oil	95	9.1%
E. Methane captured from decaying cow manure	117	11.2%
No response	2	0.2%
Petroleum (crude oil) and natural gas come from…		
A. dead dinosaur remains.	175	16.8%
B. coal fired power plants.	357	34.2%
C. large tanks underneath gas stations.	161	15.4%
D. swamp remains that are thousands of years old.	212	20.3%
E. plankton and sea life that are millions of years old.*	135	12.9%
No response	3	0.3%
The term "renewable energy resources" means resources that...		
A. are free and easy to use.	47	4.5%
B. do not produce air pollution.	80	7.7%
C. are very efficient to use for producing energy.	180	17.3%
D. can be converted directly into heat and electricity.	132	12.7%
E. can be replenished by nature faster than they are consumed.*	600	57.5%
No response	4	0.4%
Which energy resource is nonrenewable?		
A. Solar	116	11.1%
B. Biomass	262	25.1%
C. Natural gas*	377	36.1%
D. Geothermal	206	19.8%
E. Hydropower (water)	80	7.7%
No response	2	0.2%
Which is the most abundant fossil fuel found in the United States?		
A. Coal*	438	42.0%
B. Wood	137	13.1%
C. Nuclear	94	9.0%
D. Natural gas	218	20.9%
E. Petroleum (crude oil)	154	14.8%
No response	2	0.2%

Which fossil fuel is formed from swamp plants that lived millions of years ago? A. Coal* B. Nuclear C. Methane D. Natural gas E. Petroleum (crude oil) No response	 180 97 314 158 291 3	 17.3% 9.3% 30.1% 15.1% 27.9% 0.3%
Areas with geothermal resources include …. A. large lakes that flow into rivers. B. large mountain ranges and forests. C. large tidal ranges and shallow water. D. high wind velocities and open space areas. E. geysers, fumaroles, hot springs, and volcanoes.* No response	 135 171 104 153 477 3	 12.9% 16.4% 10.0% 14.7% 47.7% 0.3%
Nuclear energy is considered NONRENEWABLE because …. A. It produces waste that is very radioactive. B. heat produced in the reactor turns huge turbine blades. C. the power plant must use a lot of water for the cooling process. D. the uranium fuel source are found in rocks that can be mined out.* E. fission generates heat in the reactor just as coal generates heat in a boiler No response	 529 88 125 221 76 4	 50.7% 8.4% 12.0% 21.2% 7.3% 0.4%
In the year 2250, most of the world's energy will likely come from… A. coal and oil. B. natural gas and coal. C. nuclear power from uranium. D. a mix of renewable energy sources.* E. petroleum (crude oil) and natural gas. No response	 89 105 169 606 72 2	 8.5% 10.1% 16.2% 58.1% 6.9% 0.2%

Note: * indicates correct response

Energy generation, storage and transport

Table 4 displays results of select item responses to the energy generation, storage and transport subscale. Data findings revealed that many students do not understand how different energy resources are converted from its source form to usable electricity. Only 19.7% knew that electrical power generation from a hydroelectric dam turbine is an example of gravitational potential energy being converted into kinetic energy. Less than half (40.8%) of the students

Table 4. Select Energy Generation, Storage and Transport subscale item responses (N= 1043)

Item	N	% Response
Which type of electricity generation has the LEAST ENVIRONMENTAL IMPACT?		
A. Wind turbines on the top of mountains.	407	39.0%
B. A dam on a river to produce hydropower.	212	20.3%
C. A coal burning power plant in a rural area.	128	12.3%
D. A nuclear power plant on an island in a river.	145	13.9%
E. A geothermal power plant in a hot earth area.*	146	14.0%
No Response	5	0.5%
What does it mean if an electric power plant is 35% efficient?		
A. For every $35 used in the production of energy, $100 is made into profit.	113	10.8%
B. For every $100 used in the production of energy, $35 is made into profit.	142	13.6%
C. For every 100 units of energy that go into the plant, 35 units are converted into electrical energy.*	379	36.3%
D. For every 35 units of energy that go into the power plant, 100 units of electrical energy are produced.	255	24.4%
E. For every 100 units of energy that go into the power plant, 35 units are lost during energy transformations.	149	14.3%
No response	5	0.5%
Most electrical energy in the United States is produced from…		
A. Coal*	232	22.2%
B. Nuclear	163	15.6%
C. Natural gas	245	23.5%
D. Hydropower (water)	220	21.2%
E. Petroleum (crude oil)	179	17.2%
No response	4	0.4%
Photovoltaic cells convert …… directly into electricity.		
A. coal	75	7.2%
B. wind power	184	17.6%
C. hydropower	171	16.4%
D. light energy*	453	43.4%
E. nuclear energy	156	15.0%
No response	4	0.4%
Which is an advantage that geothermal power plants have over fossil fuel burning power plants? Geothermal power plants…		
A. do not have to transport fuel.*	231	22.1%
B. can be built almost anywhere.	194	18.6%
C. generate waste products that can be easily stored.	265	25.4%
D. are the cheapest way to generate electricity in the United States.	153	14.7%
E. are more efficient to transport electricity to homes and businesses.	196	18.8%
No response	4	0.4%

A network of power transmission lines connected across the entire country is called the…		
A. grid.*	426	40.8%
B. turbine.	100	9.6%
C. generator.	159	15.2%
D. transformer.	100	9.6%
E. power surge.	253	24.3%
No response	3	0.5%
Electricity enters the grid at 350,000 volts. How does this voltage get reduced to 120 volts when it reaches your home?		
A. Transformers step down the voltage before it reaches your home.*	266	25.5%
B. Power surges in the grid reduce the voltage before it reaches your home.	195	18.7%
C. Transmission lines that carry electricity long distances reduce the voltage.	240	23.0%
D. The electrical grid decreases the voltage the further that electricity travels.	172	16.5%
E. Power generators in the grid reduce the voltage before it reaches your home.	166	15.9%
No response	4	0.4%
In a hydroelectric dam facility, water pressure in the reservoir forces water to turn a turbine that generates electricity. This is an example of …		
A. a low energy efficient process of a dam.	157	15.1%
B. energy transport efficiency of the dam.	245	23.5%
C. turbines producing gravitational potential energy to do work.	195	18.7%
D. water gaining potential energy from the reservoir to do work.	235	22.5%
E. gravitational potential energy being converted to kinetic energy.*	205	19.7%
No response	6	0.6%
The best place to build a new factory is at a location near an electric power plant because…		
A. less energy is lost during electrical transmission.*	350	33.6%
B. fewer miles of pipeline are needed to transport fuel.	135	12.9%
C. less kinetic energy is needed for electrical transport.	172	16.5%
D. more efficient electrical lines can be built underground.	217	20.8%
E. the environmental impact of the factory will be reduced.	158	15.1%
No response	11	1.1%

Note: * indicates correct response

knew that the electrical grid is a network of power transmission lines that connect across the USA to transport electricity. Only 25.5% knew that voltage is reduced by transformers before it reaches a home. Responses to select items also indicated that students have incomplete knowledge about energy efficiency and do not understand that energy is lost during electrical energy transmission from a power generating source to a consumer of usable electricity.

Responses to select items indicate that students do not have a complete understanding about the advantages and relative environmental impacts of using different energy resources to generate electricity. For example, only 22.1% knew that an advantage of geothermal power plants over fossil fuel burning power plants is that they do not have to transport fuel. Less than half (46.1%) knew that nuclear power emits less air pollution that coal or petroleum.

Energy consumption and conservation

Table 5 displays results of select item responses to the energy consumption and conservation subscale. Student understandings of energy consumption and conservation were limited. Many do not grasp quantitatively how much energy is consumed during their personal and household activities. Heating and cooling rooms was identified correctly by only 24.7% of the students as the most energy consuming use in the U.S. household; 31.4% incorrectly thought that entertainment (TV, computer, video games) consumed the most household energy when in fact it consumes the least. Many students (39.4%) incorrectly thought that cooking and storing food uses the least amount of energy in an average U.S. home; only 10.1% correctly identified entertainment as using the least amount of household energy. Only 17.6% knew that electricity is measured in kilowatt-hours; 58.1% thought volts was the unit that measures electrical energy. Less than half (48.4%) knew that placing a cell phone in a charger consumes energy when it is not actively charging.

Students did not have a complete understanding about energy resources consumption in the United States. Most (78.7%) students did not know that petroleum is the most consumed energy resource in the United States. Only 29.9% knew that the transportation sector consumes the most petroleum in the USA. Many (73.3%) students did not know that coal is used to produce the most energy in the United States. Only 27.8% knew that coal is likely to be the first energy resource to be depleted in the United States.

Table 5. Select Energy Consumption and Conservation subscale item responses (N= 1043)

Item	N	% Response
The largest energy source that is used by the United States is…		
A. Coal	279	26.7%
B. Nuclear	114	10.9%
C. Natural gas	242	23.2%
D. Hydropower (water)	180	17.3%
E. Petroleum (crude oil)*	222	21.3%
No Response	6	0.6%
Which uses the MOST ENERGY in the average American home in one year?		
A. Lighting the home	242	23.2%
B. Cooking and storing food	98	9.4%
C. Heating and cooling rooms*	258	24.7%
D. Cleaning (washer, dryer, ironing, vacuum)	114	10.9%
E. Entertainment (TV, computer, video games)	327	31.4%
No response	4	0.4%
Which uses the LEAST ENERGY in the average American home in one year?		
A. Lighting the home	134	12.8%
B. Cooking and storing food	411	39.4%
C. Heating and cooling rooms	135	12.9%
D. Cleaning (washer, dryer, ironing, vacuum)	253	24.3%
E. Entertainment (TV, computer, video games)*	105	10.1%
No response	5	0.5%
Which use consumes the most petroleum in the United States?		
A. Electrical	156	15.0%
B. Transportation*	312	29.9%
C. Residential (homes)	136	13.0%
D. Industrial (factories)	330	31.6%
E. Commercial (stores and businesses)	103	9.9%
No response	6	0.6%
Which energy source is likely to run out first?		
A. Coal	290	27.8%
B. Biomass	115	11.0%
C. Geothermal	104	10.0%
D. Natural gas	212	20.3%
E. Petroleum (crude oil)*	314	30.1%
No response	8	0.8%
The amount of ELECTRICAL ENERGY (ELECTRICITY) we use is measured in units called...		
A. Volts (V)	606	58.1%
B. Joule-hours (Jh)	71	6.8%
C. Horsepower (HP)	97	9.3%
D. Efficiency-hours (Eh)	75	7.2%
E. Kilowatt-hours (kWh)*	184	17.6%
No response	10	1.0%

Placing your cell phone in the charger when you are not using it…		
A. is an energy angel activity.	94	9.0%
B. is an energy efficient practice.	131	12.6%
C. uses renewable energy from the grid.	123	11.8%
D. uses more energy than heating rooms.	184	17.6%
E. uses energy when it is not actively charging.*	505	48.4%
No response	6	0.6%
In homes, NATURAL GAS is primarily used for….		
A. lighting the house.	105	10.1%
B. entertainment activities.	108	10.4%
C. the refrigerator and freezer.	93	8.9%
D. microwave ovens and toasters.	105	10.1%
E. heating, cooling, and cooking on the stove.*	621	59.9%
No response	11	1.1%

Note: * indicates correct response

Discussion

Understanding energy resources, its uses, and associated societal issues are important facets of sustainability education and have become an area of foremost importance for those who are responsible for education in school systems. In many countries, education ministers, teachers, politicians, and the general public agree that school curriculum should provide students with the knowledge, skills, and abilities needed to live in a world faced with rising energy demands and shrinking available nonrenewable resources (Trumper et al. 2000). Energy resources are included prominently in U.S. national science and environmental education curriculum frameworks and state standards. These curriculum frameworks and state standards have been established to ensure ample attention to the teaching and learning of particular science and environmental education concepts at particular grade levels (AAAS 2007; National Research Council 1996; North American Association for Environmental Education 2000), and to establish a vision for the kind of environmental and science concepts that should be taught to have enduring relevance to one's life (Millar and Osborne 1998; OECD 2000; Tomorrow 98 1992). Content standards enable curriculum guidelines to go beyond specifying a list of topics, such as

Energy Resources and *Use of Earth's Resources*, and articulate key ideas that are important to learn (AAAS 1993; AAAS 2007).

The success of students achieving standards and curriculum frameworks pertaining to energy resources depends on the development of sound instructional curriculum materials aligned with these goals. U.S. reform efforts in science and environmental education endeavor to align instructional materials and assessments with local, state, and national standards (Knapp 1997; Wilson and Berenthal 2006). Although concepts pertaining to the acquisition of renewable and nonrenewable resources, energy generation, storage, and transport, and energy consumption and conservation have been included as important learning goals in national frameworks and state standards for the past decade, the 8^{th} grade students in this study are clearly not achieving these expected learning goals.

Findings from this study revealed that this sample of eighth grade students did not have a sound knowledge and understanding of basic scientific energy resources facts, issues related to energy sources and resources, general trends in the U.S. energy resource supply and use, and the impact energy resource development and use can have on society and the environment. The energy resources knowledge deficits of U.S. middle school students found in this study are similar to those reported in past studies with primary and upper secondary learners. The eighth grade students in this study have many knowledge deficiencies about nonrenewable and renewable resources, about energy transformation processes from an original energy fuel source to a usable form of electrical energy or other usable form for consumption, and about their personal and household energy use practices.

Although national frameworks and state standards include energy resources as important concepts to be learned by eighth grade in the United States, it appears that the implementation of energy resources curriculum in middle schools may be lacking in conceptually rich and personally relevant learning experiences that align to important energy resources literacy goals of energy resources acquisition, energy generation, storage and transport, and energy consumption and conservation. It has been argued that few middle school curriculum materials succeed in meeting standards (Krajcik et al. 2008). A review of commercially published U.S. middle school science curriculum materials concluded that none of examined curriculum programs would help students learn standards and many topics were not covered sufficiently in-depth (Kesidou and Roseman 2002). Likewise, U.S. state and local district standards (which are used by developers of commercially published U.S. curriculum) have been criticized for superficial coverage of many topics (Schmidt, Wang, & McKnight 2005; Krajcik et al. 2008).

Implications for curriculum development

According to the National Science Foundation report, *Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century* (Pfirman, and the AC-ERE, 2003), in the coming decades, the government and public will be called upon ever more frequently to understand complex environmental issues, evaluate proposed environmental plans, and understand how individual decisions affect the environment at local to global scales. The report calls for raising the environmental literacy of the general public by providing quality earth and environmental science education. An environmental literacy curriculum on energy is forward looking and leverages current global attention on energy resources and related environmental issues.

Today, we face the challenges of many interrelated environmental issues including energy use, climate change, pollution, and waste issues. To meet these challenges, we need to ensure that teachers are equipped with well-designed earth and environmental science curriculum and are well-prepared to provide their students with the best possible education on topics pertaining to energy resources and associated societal issues. Only with sound knowledge and understandings of underlying scientific and environmental concepts can middle school students make sense of relevant real-world phenomena associated with energy use such as the acquisition of sustainable energy sources, energy transformations, energy production and consumption, environmental impacts of energy sources, energy efficiency, and energy conservation.

The next generation of middle school energy curriculum materials could be designed to promote learner understandings in three main areas: acquisition of sustainable and non-renewable energy; energy generation, storage and transport; and energy consumption and conservation. Students could begin an energy curriculum unit by calculating their personal energy use and analyze their energy consumption patterns. In such a learning activity, students would understand that they use energy for many purposes including: lighting, heating, transportation, entertainment, food preparation, cleaning, and communications. Such an activity could enable students to describe ways they could reduce both their personal energy use and their household energy use. Related curriculum learning activities would focus on energy efficiency and energy conservation practices.

Many energy resource issues involve spatial analysis and reasoning skills. Geospatial learning technologies can be used to enhance inquiry-based environmental investigations, promote spatial thinking, and draw on skills crucial to developing higher-order thinking and environmental problem solving (Bodzin and Anastasio 2006; Bodzin 2008; Bodzin and Cirucci 2009; Bodzin, Anastasio, and Kulo forthcoming). In addition to using appropriately designed inquiry-based laboratories, students could complete a series of spatial learning investigations that use geospatial learning technologies such as Geographic Information Systems (GIS) to develop understandings about contemporary energy sources including solar, wind, tidal, hydroelectric, nuclear, geothermal, biomass/biofuels, coal, oil, and natural gas. For example, a GIS could be used to analyze annual average sunshine data to determine optimal locations to build new very large solar power plants. Likewise, a GIS could be used for students to examine wind speed and land use patterns to determine the best place to locate a new wind farm in a particular geographical area. GIS investigations can also be used to investigate fossil fuel production and consumption patterns of different world countries and enable students to analyze per capita resource consumption.

In a culminating activity, students could develop an energy policy for a fictitious island nation for which students are tasked with creating a viable energy policy to meet the needs of its society. Students would draw upon their knowledge base to make decisions about how to sustainably power a country. In the process of making these decisions, students would be confronted with real-world problems including transportation distance, limited infrastructure, and resources in environmentally sensitive or culturally significant areas. Students would recommend the most efficient combination of energy sources and have to justify their choice with the benefits, costs, and environmental impact assessments. By completing such a learning activity, students would gain insight into the many factors that influence the current energy debate.

Conclusion

This study investigated 8th grade students' understandings of energy resource acquisition, energy generation, storage and transport, and energy consumption and conservation. A valid and reliable comprehensive energy resources knowledge assessment measure that aligns to benchmark ideas about energy resources was developed. The energy resources knowledge assessment contributes a comprehensive environmental knowledge scale to the research community that can be used to measure energy knowledge of diverse eighth grade learners. Findings in this study revealed that the study sample of U.S. eighth grade students have low conceptual energy resources knowledge. The limitations of this study include using a sample of 5 middle schools located in two cities in a northeastern state in the USA that included only urban schools. The validity of the findings would be improved by increasing the sample size to include a larger number of classrooms in other U.S. geographical areas and including rural area schools.

The findings reported in this research have many implications related to the development of the new science education framework (National Research Council Committee on Conceptual Framework for New Science Education Standards 2010) currently being developed in the United States. Energy resources and associated socioscientific issues fit prominently within this document. As new learning progressions about energy become developed, the next generation of energy curriculum materials for middle school learners should align standards to conceptually rich and relevant learning experiences that align to important energy resources literacy goals of energy resources acquisition, energy generation, storage and transport, and energy consumption and conservation. Future studies are encouraged to investigate energy resources knowledge and understandings of middle school learners that use energy curriculum with specific design principles, instructional frameworks, or learning technologies designed to promote energy literacy.

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Notes

1. The energy resources knowledge assessment is available online at: http://ei.lehigh.edu/eli/research/erca.pdf

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