Connecting Outdoor Learning Experiences to Our Schools and Our Homes: An International Study of Teachers' Understandings of Energy in Ecological Systems and In Our Lives

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Abstract

Teachers' understandings of the ecological concept of energy, including the flow of energy through natural systems, how people get and use energy, and the consequences of energy use, were examined in this exploratory study. Twenty classroom teachers in the United States, Germany, and Italy were interviewed. A wide range of levels of understanding was found. However, a common lack of understanding in regard to how people get and use energy and the consequences of doing so was apparent. This is particularly troublesome since outdoor learning experiences like the earth education program Earthkeepers depend on teachers to help students transfer the understandings gained in the outdoor program back to the classroom. Several important questions are posed for further investigation.

Introduction

At least since Barry Commoner's landmark environmental book *The Closing Circle* (Commoner, 1971) was published, the need for people in our societies to have a solid grasp of ecological knowledge has been pointed out repeatedly. Documents from the early days of environmental education (Stapp, 1976; UNESCO/UNEP, 1978; Van Matre, 1974) have all included some form of ecological knowledge as an important component. The need for ecologically literate societies is at least as great as, if not greater than, it was thirty years ago. We become aware, seemingly daily, of more and more environmental issues. At the same time, our realization of the complexity of these issues is becoming more and more clear. We cannot possibly teach everyone about every issue. We don't have the time or resources. More importantly, it doesn't make sense to do so. Being ecologically literate ought to include understanding how the ecological systems work so that when issues arise, people can apply their knowledge of ecological systems and concepts, such as the flow of energy, to formulate an understanding of the particular issue in question. Certainly, understanding an issue is important, but this is hardly possible without an understanding of ecology, so that one can understand the implications of the issue.

Are we any closer to having an ecologically literate society than we were thirty years ago? People may be more aware of environmental issues than they were in the past. Such issues are constantly in the news. Environmental education programs typically help people learn about the issues and strategies for dealing with them. We don't appear to have done as well, though, with helping people understand the ecology underpinning these issues and how these concepts relate to our daily lives. For example, understanding how we get and use energy is important. People are better able to make wise decisions about their use of energy if they understand how energy is captured by green plants and then is used by plants and animals, how energy was at times in the past stored in fossil fuels, how we use these fossil fuels, and what happens when we burn them. Energy flow is one key ecological concept underpinned by the laws of energy conservation, and understanding these is an important part of

understanding how life works, how the ecological systems of our planet operate. It is clearly an important part of being ecologically literate.

A newly released study illustrates how poor understandings of energy are. Only 12% of adults surveyed in the United States passed a basic quiz on energy knowledge (National Environmental Education and Training Foundation, 2002). Similar results were found when we investigated understandings of energy, along with other ecological concepts, with elementary school classroom teachers and university preservice education students. Few were able to provide accurate explanations (see Table 1). In the southwestern US city in which these teachers and students live, well over 90% of the electricity comes from coal-burning power plants. The rest is supplied by the grid and could be from a variety of sources, including water and nuclear. Very few of these teachers and future teachers had a good understanding of where we get our electricity. A similar lack of knowledge was found in responses to questions dealing with where the energy in our food comes from.

Table 1

Where does the electricity for the lights in this room come from? Please trace it back as far as you are able.

Source	Primary Teachers	Preservice Students
Power/electric company	17	14
Water/hydroelectric	3	5
Nuclear	2	0
Fossil fuels (natural gas, coal)	3	1
Alternative sources (solar/wind/geothermal)	0	4
Other responses (steam, energy waves, God)	0	3

Earth education programs, in contrast to environmental education programs that treat environmental knowledge primarily as knowledge of issues, are designed to help participants learn basic ecological concepts, the central ideas of how life works, and to see how those apply to their personal lives (Wohlers & Johnson, 2003). For example, in the Earthkeepers program (Van Matre & Johnson, 1988) primary students learn about the flow of energy, the cycling of matter, the interrelationships between living and nonliving things, and the changes that are constantly occurring everywhere. While the initial learning takes place outdoors in a natural area, the concepts are brought back to the classroom. Classroom teachers help students see how these ecological concepts apply to the students' lives. Such transfer of understanding is an important part of learning (Bransford, Brown, & Cocking, 2000), and it is an essential element in earth education programs (Johnson, 2003; Van Matre, 1990). If teachers are to do so, they must have good understandings of the concepts.

While there have been numerous studies of teachers' understanding of science concepts (for example, see Atwood & Atwood, 1996; Carlsen, 1991; Smith & Neale, 1989; Summers & Kruger, 1994) and environmental issues (Cutter, 2002), and other studies have looked at students' knowledge of ecological concepts in earth education programs (Black & Reeve,

2000; Keen, 1991; Martin, 2002, 2003), there is a notable lack of published reports of studies of teachers' knowledge of the ecological concepts taught in earth education programs.

The present study was designed to investigate the ecological concept knowledge of teachers. Results presented here deal with one of those concepts, energy flow. Two aspects were explored – energy flow in ecosystems and energy use in human society. Energy flow in ecosystems deals with how green plants capture sunlight energy and pass it along to animals though food chains or webs, with energy being used along way, resulting in energy loss to the chain or web. Energy flow in human society deals with how people get and use energy both in terms of personal energy from food (food chain or web energy) and in terms of other ways of using energy (often fossil fuel energy), such as electricity or transportation.

Methods

Three groups of teachers were involved in the study. First, interviews were conducted with all three grade five classroom teachers in a public primary school in a medium-sized city in the southwestern United States. The school is in a low socioeconomic area and has a high percentage of English language learners. Close to the beginning of the school year, the students in these teachers' classrooms were taught ecological concepts while participating in the Earthkeepers program for three full days at a state park just outside of the city. Earthkeepers includes specific activities for each of the four major concepts, following the I-A-A learning model of concept teaching (Johnson & Mayer, 2002; Van Matre, 1979; Van Matre & Johnson, 1997). Additional components of the program include building positive feelings for the natural world through first-hand experiences and processing what was learned by selecting ways of using less energy and fewer materials as well as finding ways of keeping in contact with natural places. The initial three days serve as a springboard for the follow-through in the classroom. University faculty and graduate students facilitated the learning at the state park with the help of the classroom teachers. Back in the classrooms, the follow-through was under the guidance of the teachers. While a university faculty member and a graduate student led monthly study group sessions designed to help build the teachers' understandings and help with the follow-through portion of the Earthkeepers program, the teachers were responsible for helping students to connect the ecological concepts, such as energy flow, from the natural world to the school and home.

In order to assess the participating teachers' knowledge of ecological concepts and understandings about the application of those concepts, interviews were used. One-on-one, semi-structured interviews (Kahn, 1999) were selected for this study to allow for probing to follow up on incomplete answers. Initial interviews with the three teachers were conducted at the start of the school year, before the teachers and their students participated in the Earthkeepers program.

Second, individual semi-structured interviews were conducted with eleven outdoor teachers and student teachers at a large residential environmental learning centre in the eastern United States. All were involved in leading the Earthkeepers program. While classroom teachers accompanied their students and assisted during the three-day program, the centre educators and student teachers actually did the teaching.

Third, to see if similar ideas and understandings about energy flow exist in European teachers, individual interviews were conducted with three teachers in Germany and three in Italy. While the teachers were not involved in the Earthkeepers program, they taught students of the age for which the program is designed. Each interview was conducted in the teacher's first language and then was transcribed and translated into English.

Results

Since this was an exploratory study designed to get a sense of the ideas that teachers have about energy flow, the sample of teachers interviewed are not necessarily representative of all who teach students of this age. The results are intended to give a picture of the different kinds of understandings encountered. Numbers of participants who responded in a particular way are not given. Such numbers would be meaningless in this case. Instead, descriptions are given which may point the way to further investigations, including those that could shed light on how common these understandings are.

Energy in ecosystems

There are several key components to understanding energy flow in the natural world. Most participants understood that energy in food chains or webs comes from the sun and that green plants capture this sunlight energy. These participants also understand that this stored sunlight energy is passed on to animals that in turn pass it along to other animals.

> *The primary source of energy for every living thing is the sun. A very small part of solar energy that comes every day on the earth goes into living systems, giving possibility to produce organic substances. This happens through photosynthesis. Photosynthesis is the process used by plants to produce their energy using CO2 and solar energy. Then energy passes through the different living things organization levels and comes up to us.*

> *Energy flows from the sun into plants through photosynthesis. This is eaten by plant eater, herbivores, and omnivores which are in turn eaten by the animals that eat those plants.*

Some participants were less certain about the source of the energy found in food, or indeed what exactly the energy is.

> *Well, how does the energy get in food? Oh my word, yes, energy in food, I would say, I know, I have absolutely no idea. Protein or sugar or etc., which then is transformed in one's body.*

> *Oh dear, well, in fruit, in general, it's the vitamins that are in there naturally. I mean, not what is put in chemically these days, but what is in there naturally.*

There was a mix of ideas when looking a bit deeper at energy flow in ecosystems. Participants were asked whether one would expect to find more plants, animals that eat plants, or animals that eat other animals in an ecosystem and how energy was involved in

determining the relative abundance. Some participants were able to give explanations that demonstrate a basic understanding.

> *More numerous things are plants. In fact plants are at the beginning of food chain or, better, food web. Plants receive directly sun energy and so are called producers. On them are depending the primary consumers and then secondary and tertiary consumers that are far and far from the beginning of energy way, and so have less energy to use. In fact going on from producers to consumers, energy is spent and lost.*

Other participants were less certain or had explanations that reflect incomplete or unusual understandings of energy in ecosystems.

> *Living beings are food for things in the higher level, and give them their energy, but in the higher level there are less living things. Maybe that happens because lower living things are smaller and more simple and so need less energy and can be in a higher number.*

> *I would say there would be different numbers at the bottom of the food chain in order for them to survive since they are at the bottom. But if there are, for example, fewer beings at the top of food chain, no natural enemies, then there would be not necessarily a population control of that sort, so there would also be numerous numbers there as well. I would say at the bottom and at the top.* ***(Interviewer: At the bottom it would be...?)*** *Like bacteria or the insects, for example.* ***(Interviewer: And their numbers would be...?)*** *Numerous.* ***(Interviewer: And then at the top?)*** *Numerous.*

Some misconceptions about energy were also revealed. First is the idea that energy comes not only from the food we eat but also from other sources such as water or soil. Second is the idea that we can also get energy by doing things like resting or exercising, reflecting a different use of the term energy. We have found that both are fairly common beliefs among children, and it is interesting to see them show up in teachers as well.

> *Well, then I would say that eating food, drinking water or via the sun, this is also somehow a way of taking in energy.*

> *Well, on the one hand, of course, through their food, but since they, that they (people) also do sport and in general have the feeling of being alive and having quality of life. ... through which one also gets energy, motivation or a special performance one has done.*

Energy in human society

In additional to the stored sunlight energy we get from the plants and animals we eat, we get and use energy in other forms and ways. One aspect of this is where we get that energy. Very common sources of such energy today are fossil fuels like coal, oil or natural gas, which contain sunlight energy from plants and animals that dies millions of years ago. Most participants were not able to identify fossil fuels as a common source of energy, and very few knew the specific source(s) of energy where they live.

Solar? I'm not sure.

I don't know, maybe water? I have never thought about it.

I think it comes from a hydroelectric plant, a power plant? I'm not sure.

Some participants were able to provide a clear explain of what fossil fuels are.

Fossil fuel is fuel with a fossil origin that originated about 300 million years ago from dead microorganisms, trees and other plants, that was transformed during the ages by the action of geological causes. Fossil fuels are oil, natural gas connected to oil and coal. They are widely used by men, and are swiftly finishing because of the high energy costs of our society's way of life.

Others were less certain.

Fossils, that makes me think about skeletons or so and things that one has found, imprints of former animals or something like that. Fossil fuels, a good question.

Well, fossil has something to do with animals and fuel is something you burn, and I don't know if this means that you burn dried camel dung and keep yourself warm.

Using energy from fossil fuels has harmful consequences that contribute to air pollution, acid rain, and global climate change. Energy from other sources like nuclear fission or hydroelectric dams has problems as well. Cutting back on energy use to help lessen these consequences is an important goal of earth education program like Earthkeepers. Participants in the present study agreed that using less energy is important. However, when asked to give reasons for using less electricity, most were only able to talk about the need to save money or resources.

Because this way you can save energy.

There is only a limited amount of fossil fuels, water, natural gas, etc. on the Earth. If we use all of these resources then we would not be able to survive after depending on them for so long.

... because economically it saves money.

... because energy is limited; unless it's solar, it is going to use natural resources.

Not all participants had such limited explanations. Some were able to talk about the adverse consequences of using electricity.

Oh, well, the light switch is the direct connection to our climate change. This means, if the light is on like in this room, energy must be available for it and in Germany up to 70% of this still happens through fossil fuels, ... and CO_2 is the first portion of climate change.

Interestingly, more participants were able to talk about the consequences of using energy in transportation.

> *Using private motor vehicles is a part of a bigger problem, once again connected to "driven needs" and the high energy costs that this world is having. Fuel combustion is not only the main cause of air pollution (and, of course, everybody's health problems), but it's the cause of "greenhouse effect" too. CO2 produced by combustion, together with CH4 and other few gas called "greenhouse gas", accumulates in the atmosphere and entraps solar rays reflected by earth. This warms up world temperature, and creates a lot of other connected global problems.*
>
> *Oh, difficult! Try to reduce the use of motor vehicles should be very important... but is very difficult to do. That's basic for reducing air pollution and to reduce the production of thin dust and other material that are deadly for men. It's a daily problem in lot of towns, also small ones, where the pollution levels are often exceeded, but it's also a problem for all the other places, because pollution that vehicles produce has no borders.*

Summary and discussion

In order to help students apply understandings about energy, teachers need to have some basic understandings themselves. It was apparent from our interviews that in general these teachers understood how energy flows in an ecosystem fairly well, though not all had very complete understandings when it came to what happens to energy as it flows through a food chain or web.

The teachers' understandings of how we get and use other forms of energy such as electricity indicate larger gaps in knowledge. It is clear from the responses that very few had an understanding of how the energy they use is generated. More importantly, while everyone agreed that using less energy is a good thing, most were not able to discuss the negative consequences of energy use beyond simply saving money or resources.

If outdoor environment learning experiences are to be more than just fun days away from school, there must be connections back to students' lives in school and at home. Teachers are vital links to making that happen. This exploratory study raises questions about how well teachers are able to do this. There is certainly evidence here to suggest that not all teachers have the knowledge and understandings of energy flow to be able to help their students apply that concept to school and home.

This study suggests several important questions that need to be investigated. How common are the range of levels of understandings and the misconceptions found here? Are similar levels of understanding and misconceptions found when looking at other ecological concepts? Do teachers who work with programs that teach these concepts understand them better than those who don't? Where do teachers learn these concepts? Can instruments or protocols be developed that will provide an accurate picture of teachers' understandings? How can those involved in outdoor environmental learning programs use such instruments and protocols to find out the level of understanding of teachers with whom they work and

help those teachers enrich their understandings? If we are to ensure better connections between outdoor learning and classrooms, we need to seek answers to such questions.

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