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Discerning The Difference between "Feel Good" and "Real Good": Teaching the Complexity of Sustainable Development

Abstract

Environmental issues can serve as a marvelous framework for high-level student analysis of critical scientific and social concerns. We describe a series of activities and discussions that motivate students to explore environmentalism, sustainable development, carbon offsets, and related ideas with an engaged learning format that helps students to reveal the gray areas that exist when deciding upon social policy that is based on the impact of science. We summarize research supporting engaged learning in STEM education, and provide a successful example of this changing educational paradigm. Although we present data to show that students value the paradigm, the paper is intended to highlight the instructional, rather than evaluative, aspects of the model.

Introduction

We live in the geological epoch called the Holocene, meaning "whole new," encompassing much of the history of humankind as a community over the past 11,700 years. Jan Zalasiewicz, a stratigrapher – he studies rock layers – suggested we change the name to the Anthropocene epoch (from the Greek "anthropos," meaning "human being"), recognizing the impact of human activities on the Earth (Kolbert, 2013), The world's 7.2 billion people make individual and social choices that affect all of us, not just in our local ecosystem, but in the worldwide environment, with the possibility of a long-term human future if we make good choices, or dire consequences for poor choices.

Keywords: environmentalism, sustainable development, carbon offsets, STEM, higher order thinking skills

To increase the likelihood that the future generations will exist and, perhaps, thrive, "environmentalism" has become a guiding principle for many of us, though far too often in the K-16 classroom and beyond, we seek easy interpretations of this complex principle. Easy interpretations suggest it is tantamount to a sin to drive a car with poor gas mileage, buy a product with a large "carbon footprint" that generates an excess of Greenhouse Gases, or use Genetically Modified Organisms (GMOs), including vegetables and meat. The way out of this sinful life would seem to be simple – students should make "green" lifestyle choices and support companies that do so. Choose paper, not plastic, or even better, reusable bags (though these are most often made of plastics). Pay indulgences, as in the religious sense, to offset your "carbon footprint." Do these things and lead a "sustainable lifestyle." A leads to B. Case closed. If only life were that simple.

We intended these first 260 words to be provocative because the subject matter is so important for our students and us, and so often misunderstood, largely by oversimplification. We have already mentioned six terms, environmentalism, carbon footprint, Greenhouse Gases, carbon offsets, Genetically Modified Organisms, and sustainable lifestyle (related term: Sustainable Development) that are quickly becoming part of society's vernacular, yet the meaning of each, and the choices we make related to it, is often complex and nuanced. Our goals in this paper are to:

- define and clarify several current terms related to "environmentalism" that are important for the science and societal literacy of our K-16 students;
- outline the debates related to individual and social environmental choices;
- discuss several activities, both hands-on and discussion-based, that compel our students to grapple with these difficult ideas.

Most of the class discussions and activities we present are best applied at the high school and college levels, though the background is useful for teachers at all levels. A recent commentary by Kelter and co-authors in *Science Educator* considered related activities for kindergarten and first-grade students (Molitor, Ryall, & Kelter, 2013).

The Educational Premise: Engaged Learning For Environmental Issues

Engaged learning places students into a challenge-based environment where they have to solve real problems with real outcomes. (Liberal Education, 2007) Some exercises can be classroom-based while others are based on field-work problem solving. Engaged learning is a well-established learning approach that is an effective supplement to classroom learning. A key outcome of engaged learning is self-directed learning and collaboration. (Hung, 2004).

Engaged learning exercises have traditionally been used in conjunction with undergraduate engineering and technology courses, with an emphasis of hands-on interaction with equipment and materials. While sustainability development is more abstract than, for example, working with a welding machine, it is still possible to create meaningful engaged learning activities that challenge students to conduct critical analyses of sustainability solutions. This paper provides examples of learning experiences that have been used at Northern Illinois University to teach a nuanced understanding of the *complexity* of sustainable development. Sustainability education requires a "systems-thinking" competency, defined as "the ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks." (Wiek, 2011). "Inertia" in this context refers to systemic resistance to initiating change, and "feedback loops" refer to system factors that may accelerate or retard the rate of change (for example, release of CO_2 and melting permafrost).

An integral part of our engaged learning approach is the precept that memorization of facts and equations is not as important as in the past. Smart phones and other electronic devices provide instant access to this type of information, and will throughout each student's career. Instead, with our guidance, students learn where to get reliable information, when and how to apply it, and how to understand the potential biases and limitations of information sources. The primary goal is to address the Next Generation Science standard "Scientific Knowledge is Based on Empirical Evidence," and to help the students separate the "feel good" and the "real good" in sustainable development (NGSS Lead States, 2013).

The Content Base

The Key Environmental Terms

- Environmentalism: "[A]dvocacy of the preservation, restoration, or improvement of the natural environment; especially the movement to control pollution" (Webster-Merriam, 2014).
- Sustainable Development: Taking care of today's needs without adversely affecting future generations. A more nuanced definition can be found in the UN Report of the World Commission on Environment and Development: Our Common Future (Bruntland, 1987). We expand on this shortly.
- Carbon Footprint: The total greenhouse gas impacts (CO_2 and others) of an activity, process or system. This is a simplified definition for ease of understanding that masks the complexity of determining an actual total carbon footprint (Wright, 2011). While very reluctant to recommend Wikipedia (since students may not distinguish it from a primary source and the information can change from day to day), the current entry on Carbon Footprint provides a detailed and well-referenced analysis that can help students find primary sources (Wikipedia, 2015).
- Carbon Offset: Paying somebody to reduce their greenhouse gas emissions to compensate ("offset") the purchaser's emission-related carbon impacts (Kollmuss, 2008).
- Genetically Modified Organisms: A cell, plant, or animal with an altered genetic makeup, usually from a different species, due to genetic manipulation (Phillips, 2008).
- Greenhouse Gases: The World Resources Institute definition states: "A greenhouse gas (GHG) or "carbon" offset is a unit of carbon dioxide-equivalent ("CO2e") that is reduced, avoided, or sequestered to compensate for emissions occurring elsewhere" (Goodward, 2010). These gases act like a "greenhouse," trapping infrared energy and releasing the heat back into the earth's atmosphere.

More About Carbon Offsets

According to the World Resources Institute, carbon offsets are an attempt to obviate the carbon dioxide emissions of an activity by planting trees, purchasing solar or wind power, or reducing fossil fuel consumption in some other manner (Goodward, 2010).

There are legitimate uses for a carbon offset, but the promise of real, permanent, additional, verifiable, and enforceable CO_2 reduction is often not met (Schmidt, 2009). Carbon offsets can be purchased to address the CO_2 emissions caused by airplane flight. While admirable to try and reduce individual impacts of CO_2, the efficacy is questionable, and may be doing more harm than good as offsetting, "weakens drivers for change and reduces innovation towards a lower–carbon future" (Anderson, 2012). Even if a CO_2 offset is real, other pollution impacts from energy production needed for the offset impact the local population around the power plants supplying the offset power (coal most commonly, leading to mercury in water and fish, and respiratory and cardiovascular disease from particulate matter emissions).

The expectation of some is that simple changes in personal choices of paper or plastic, or adopting ideas that make intuitive sense such as "local food" will lead to sustainable development. Like purchasing carbon offsets for flights, these personal actions directed towards sustainability also need careful analysis. A more nuanced approach to sustainability requires an analysis of the complexity and implications of individual and societal choices. A goal of undergraduate sustainability education should be to develop individuals who can perform detailed analyses of sustainability options (Sibbel, 2007. This type of systems-thinking can be achieved through engaged learning approaches. Inquiry-based learning is ideally suited for complexity analysis and can transform sustainable development education at the university level from lectures, papers, and tests on concepts into a rich learning experience that prepares students to handle the challenge of implementing meaningful sustainable development.

More About Sustainable Development

The World Commission on Environment and Development (often known as the Brundtland Commission) was convened by the United Nations in 1983 to "propose long-term environmental strategies for achieving sustainable development by the year 2000 and beyond" (p. 1) as well as, "to consider ways and means by which the international community can deal more effectively with environmental concerns" (United Nations, 1997, p.1). In their 1987 report, the commission defined sustainable development as "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations World Commission on Environment and Development, 1987, para 1).

Students need a context for understanding the importance of sustainable development to meeting the needs of an ever-increasing world population (and consumer demands) on a planet, or even a local region, with limited resources (Hansman, 2010). Creative approaches to manage the production of food, water and material goods, along with pollution prevention during production and waste minimization and control, are some components of sustainable development. Industry used to focus on regulatory compliance rather than sustainability, but many companies are finding that sustainable manufacturing also makes financial sense. For example, Ford will be using recycled soda and water bottles as a resource for the plastics needed in making car seats (Buss, 2013).

"Sustainability" can be an imprecise term that can be difficult to quantify. While not inclusive of all sustainability matters, carbon usage (and the related carbon dioxide greenhouse gas pollution) is one such metric for comparing alternative approaches.

For example, less CO_2 is produced from gas-fired than coal-fired electric power plants. This type of metric is useful, but has severe limitations as an overall measure of sustainability. It even has limitations as a measure of greenhouse gas impacts, as factors other than carbon usage can contribute to greenhouse gas pollution. For example, "fugitive emissions" (unintended leaks) of methane can be released to the environment during the development of new natural gas wells, and methane is a more potent greenhouse gas than carbon dioxide. This nuanced content base allows us to guide our students in the field and classroom. Here is a sample of exercises that we have found to be educationally meaningful.

The Exercises

Eat Locally

A single metric of sustainability is central to the idea of eating locally. A popular concept is that eating "local foods" enhances sustainability. Is this a "feel good" or a "real good?" Local foods have been embraced by some as the "100-mile diet," with the concept that "food miles," which focuses solely on the supposed environmental impacts of food transportation, is the most important measure of agricultural sustainability.

Students in an undergraduate engineering technology course at Northern Illinois University (NIU), our large, regional Midwestern campus, were challenged to evaluate the impact of local food production on water resources. The thought exercise was to determine the water requirements for providing a simple breakfast of "local foods" consisting of eggs, toast, apple juice and coffee (for 22,000 students eating 100 breakfasts a year – there is value in keeping the numbers simple). The challenge was to *quantify the water usage impact of local food production*. The reference point was the amount of water distributed daily by the local water district. Our university is surrounded by some of the most productive farmland in the world, so land availability is theoretically not a limiting factor. But water is an essential requirement for both agriculture and food processing, and groundwater is the primary source in our area and is limited. The exercise teaches the difference between the slogan "eat local" and the reality that local food production is a complex enterprise with diverse environmental impacts that cannot be simply quantified by food miles (Stănescu, 2010). Students also learn that it is very difficult to scale up foods from the nearby farmers' markets, and local food may be virtually unsustainable (or virtually impossible to grow, e.g., coffee in Illinois), even in an apparent agricultural paradise.

The potential environmental impacts of food miles have been analyzed in other ways. Persons driving more than 6.7 km to a local farmers market to purchase organic vegetables can result in more carbon emissions than the sum of emissions from large-scale produce operations, including emissions from cold storage, packing and transport to the customer's doorstep (Coley, 2009).

Single metrics are not appropriate for evaluating food sustainability (or many other sustainability issues). Transportation is just one aspect of the food chain. What about other factors, such as energy use, pesticide application, and cost? Deciding how sustainability applies to the produce we eat is a multidimensional discussion for our students. Fruits imported from as far away as New Zealand can be competitive in price and environmental impact with those grown in California, when all the costs are taken into account (Saunders, 2006). The lush New Zealand soil allows for certain fruits to be grown with far less fertilizer than in many regions of the U.S. That must be balanced with the environmental impact of shipping across the seas. These are difficult comparisons to make, fraught with important value judgments – just the kind with which we, and the NGSS – want our students to grapple.

Access to Safe Drinking Water

The local foods exercise highlights the importance of water usage and availability as a critical limiting factor in sustainability. While many take access to safe water for granted, about 2.7 billion people face water scarcity at least one month a year (Hoekstra, 2012). Students were asked to determine how much water they used in a day, and calculate the amount of effort required to carry the water from a small river on campus back to their residence. They had to explain how they would manage this process, how much time it would take, and what they would have to give up to have the time to take care of this essential need. A more "hands-on" approach was taken by a student group on campus having students carry five gallons of water (about 42 pounds) around short laps of the student commons to raise funds for access to safe drinking water in Tanzania (NIU Today, 2013).

Do You Want to Save the World? Build a Better Toilet

Sanitation and safe water availability are closely allied. A critical need is for better access to safe human waste disposal. Both the rich and poor are affected by a lack of access to sanitary waste disposal. For example, Burj Khalifa, located in downtown Dubai and the world's tallest building, did not have access to a sewage system when it was completed, which meant all of the wastewater had to be trucked away every day (Laylin 2011). In developing countries, inadequate access to toilet facilities impacts educational access for young women, and has serious social impacts as the education of girls is one of the more important factors in reducing poverty (World Toilet, 2014).

Ask students to research and summarize some of the problems associated with poor sanitation in developing countries. What are some of the technological issues in toilet and sanitation design? What are some of the technological solutions being tried? Discuss the types of applications for two of the technologies, and analyze the pros and cons of the two technologies.

Are Fisheries Sustainable?

Water quality, sanitation and food are also tied together through the fish that provide a major source of protein in the human diet. The topic was added to our class activities as the result of a newspaper article questioning the sustainability of fisheries. The students had to come up with a group consensus position summarizing the issue, the evidence, and potential interventions. They also had to examine the roles of the food industry, consumers and non-governmental organizations (NGOs) in sustainability (Hannesson, 2008; Tilman, 2011). The issue has been well researched, with many concluding that deep sea fisheries are unsustainable. An article by Norse and colleagues is particularly suitable for educational use (Norse, 2012).

Effects of Ramping up Ethanol in Gasoline

The largest user of water in the US is agriculture. A significant portion of that water is used to grow corn. Over a third of the corn grown in the US is used to make ethanol for fuels, with an expectation that the proportion will increase as a federal law has mandated an increase ethanol in gasoline from 10 to 15% (although partial waivers have been granted) (EPA, n.d.). Water usage has increased at a much greater rate than corn for ethanol production. Each liter of bioethanol requires from 5 to over 2100 L of water (Chiu, 2009), with 70% of the corn used for ethanol requiring 10-15 L of water (Wu 2009). Students were asked to analyze the environmental impacts of this policy. Biofuels can be a polarizing issue, so the students were asked to ignore the politics for this assignment and just focus on the environmental impacts of the policy calling for increasing ethanol usage.

Environmental Inputs and Impacts of Daily Caffeine Usage

Many people stop for morning caffeine, typically coffee or cola. Some try to minimize the environmental impact by bringing a reusable cup. Just that one aspect of daily activities produces a significant environmental impact. Students were challenged to consider one thing eaten or used on a daily basis (for example, a coffee cup, a cell phone or an automobile). Discuss what is required to get the product to the end user and the impact on the environment.

What does it really take to make a soda at a fast food restaurant? Consider just the basics: cup, water, carbon dioxide, straw, lid, electricity for the ice maker and soda dispenser, gas to drive to the restaurant. But where did each of these come from? Water: underground wells, pumped up, treated, pumped up into water tower, travels by metal pipes to the restaurants, and travels via plastic pipes to the cooler. Carbon dioxide is produced in industrial facilities via combustion, or as a by-product of other chemical production. The carbon dioxide is cleaned and then compressed using electricity, shipped via truck to a storage facility, then shipped via a smaller truck to the restaurant. And one can continue the exercise by considering everything (including sugar, artificial sweeteners, and coloring!) embodied in the cup of soda handed over the counter (Agriculture and Agrifood Canada, 2014).

Paper, Plastic or e coli?

Banning plastic bags seems like a good idea. But is it really a solution to an environmental problem or just something that makes one feel good about her/his impact on the environment? What are some potential unintended consequences of a ban? For example, there is some research that suggests reusable bags can build up bacterial contamination (Williams, 2011). How much plastic is really used to make all the bags, and how much is that in comparison to the overall consumption of petroleum and natural gas? To put plastic bag usage in perspective, students can be challenged to calculate their "plastic bag miles," which is the gasoline equivalent in plastic bags that it would take to drive a car back and forth to the store to pick up whatever they are going to buy.

Leadership in Energy and Environmental Design (LEED) Certification

Energy efficiency of buildings is a critical element in reducing the increase in energy demand. Our university and many others have degree programs in energy and the environment. Some states regulate energy efficiency. The State of California has had building energy efficiency standards since 1975 that have had significant environmental and financial benefits. Aroonruengsawat and colleagues (2012) found that "states that adopted building codes followed by a significant amount `of new construction have experienced detectable decreases in per capita residential electricity consumption - ranging from 3-5% in the year 2006" (p. 31). The voluntary US Green Building Council LEED program is one attempt to reduce energy usage and environmental demands of new buildings (U.S. Green Building Council, 2014). The LEED program addresses energy and other environmental impacts. While the LEED program has had demonstrable impacts on energy reduction in some commercial buildings, the certification process for homes allows for many ways to get the necessary "points" to achieve certification. Students in an introductory environment and sustainability course were challenged to examine the LEED rating system for homes and to identify as many items as possible that may have little energy use impact. Students were surprised by the ease of accumulating points with no apparent energy reduction in the building design and operation--for example, plant drought-resistant landscaping. However, the LEED rating system should not be examined on the metric of energy efficiency and CO_2 reduction alone, as drought-resistant plants are an important way to reduce water, if not necessarily energy, usage. Instead, LEED for homes can provide a readily understood example of a holistic approach to a wide range of environmental impacts and mitigation steps.

From Eco-Anxiety to Eco-Action

There is little point in teaching the complexity of sustainability if all one does is discourage students about the futility of small actions, possibly leading to “eco-anxiety.” A 2011 Denver Post article by O’Conner entitled “For Those With Eco-Anxiety, It’s Not Easy Being Green,” found that nearly 50 percent of Americans said the more they know about how to live a sustainable lifestyle, the more guilty they feel. “Super greens,” the subset of Americans who cultivate the greenest lifestyles, feel twice as guilty as average Americans (O’Connor, 2011). Parents may be particularly susceptible to environmentalism anxiety due to concerns about possible failures of governmental systems to protect children from such things as plasticizers in bottles and other environmental toxins (Cossman, 2013).

A way to reframe this anxiety is to help someone focus her/his actions on short, medium, and long term goals. Ask students to make a list of what concerns them about the “environment.” Rank them on a scale of 1-5 in overall importance (5 most important). Rank them on a scale from 1-5 for ability to directly influence or change (5-most ability to change or influence) Ask students, “Is there a difference between which are most important to you and which you can most influence or change? Explain.”

Further, we ask students, “Which are related to: Personal choices (e.g., recycling plastic bottles); Community-scale issues (e.g., recycling options); Regional-scale issues (e.g., water quality); National-scale issues (e.g., energy policy); or Global-scale issues (e.g., climate change)? Choose one that you think you could influence or change in each of these time frames: Tomorrow; This month; This semester; This year; Within the next 10 years; Within the next 20 years; Within a lifetime; Not likely to be able to influence or change in a lifetime.”

Working Together on a Real-World Scale: Engagement with Industry

One of the best approaches to teaching complexity is to become a partner with local industrial facilities and build engaged learning activities around specific sustainability needs of the companies. This is more than field trips to the plant. It is getting involved in sustainability projects with the company. Hazardous waste minimization learning changes from an exercise about reviewing pollution prevention recommendations to real problem solving when a student is confronted with the question: How should this company handle this contaminated rag? The students had to determine the intersection of sustainability, productivity and practicality, just like they will do at their first job after graduation.

In one course on sustainability, students visited an industrial facility to conduct assessments directed toward pollution prevention and regulatory compliance. Students were asked to identify and develop pollution prevention solutions for a fifty employee manufacturing facility. They were challenged to:

- Visit the company to identify opportunities for greening production;
- Research to develop an understanding of the industry and specific operations;
- Document current practices;
- Research regulatory requirements;
- Review pollution prevention case studies and apply the lessons to specific operations;
- Develop interim alternatives for evaluation by the company;
- Fully develop best alternatives;
- Prepare a report for the company with analysis and recommendations.

The students conducted five site visits to the facility. There were many sustainability opportunities, so the students had to perform informal feasibility analyses in order to focus on projects that could be effectively evaluated in a semester.

The company was using new scrap rags (industrial wipers) that were usually disposed of as non-hazardous wastes, while some of the used wipers were classified as hazardous waste. The students conducted worker interviews and determined the uses of wipers in the various processes, along with learning about the importance of proper wiper selection and use. This revealed the subtlety of the very complex problems of wiper selection, use, and disposal. Different types and qualities of rags were required in preparation, casting, and finishing areas. Students learned of the concerns about cross-contamination, as rags containing silicone-based mold releases could create production problems in preparation operations. Students developed a program that took into consideration the workers needs for convenience and practicality. They recommended color-coded wipers to minimize cross contamination, and recommended the use of an industrial wiper service company to provide wipers and to clean the used rags.

This approach has been used at a number of other local industries. Students have developed storm water pollution prevention plans for a metals recycling company, evaluated recycling options for production wastes, and performed energy audits and relighting studies for a small car wash. The feedback from recent graduates is that they felt comfortable from the beginning of their employment confronting challenges that cannot be easily answered, just as in their school experience.

Students participating in industrial engagement have responded positively when surveyed about the educational experience. Example comments include:

- "Being able to identify issues, evaluate them, and come up with possible solutions or be able to reduce problem areas and report our opinions and thoughts were important skills that we practiced in class that would be important to specific jobs."
- "Several of the skills and activities that we have learned or studied in class both theoretically and in our field trips to local and lesser local area businesses have directly led to me receiving jobs over other students who did not have the skills."

Not all learning can be engaged learning. Students also need some context to conduct their analyses. One student stated:

- "…I believe a combination of traditional in conjunction with engaged learning may be more beneficial for core material. An initial lecture or teaching on what the material should consist of, how it should be presented and where the information can be found followed by the practical application, may be more helpful for the basic/core material."

Such comments are a helpful correction and a reminder that different teaching and learning styles need to be incorporated in the classroom environment (Felder, 2005).

Summary of The Exercise Section

Students need to understand that choices that make them feel good, such as eating locally grown food, may not lead to real sustainability. For example, in Exercise A, we showed that while "food miles" is a concept readily grasped, with some research and discussion, students can determine that there are not enough farms within 100 miles of an urban center such as Chicago to feed the entire population of the city a balanced variety of foods year-round. Locally grown food does not significantly enhance overall sustainability, although it might enhance a feeling of goodness in those who can afford this lifestyle choice. Similar considerations characterize the other exercises. Early efforts at sustainability such as putting a brick in the toilet to minimize water usage were superseded by regulations that changed the toilet specifications. With proper understanding, students can learn how to make decisions that will have a real impact, instead of putting another brick in the toilet.

Students' Perceptions of the Work

During the Fall 2013 semester, 16 survey respondents were enrolled in one or more of seven technology courses in the College of Engineering and Engineering Technology's (CEET) Department of Technology at NIU with the goal of earning a degree in engineering, most often industrial engineering or engineering technology. All seven courses are part of the Environmental Safety and Health program, and use teaching protocols and exercises similar to those described in this paper. The respondents included 43.8% females and 56.3% males. Twelve students took TECH 245 - Pollution, Pestilence, Prevention, and the Cost of Doing Business, and eight took TECH 437 - Fundamentals of Industrial Hygiene. (Students can take several program courses at once.) Here are the responses to the survey questions.

- 93.8% of the students agreed (62.5%) or strongly agreed (31.3%) that, "Inquiry and engaged learning experiences in the course(s) taught me the core knowledge content needed for a career in environmental, health, and safety."
  - Eight of the respondents added comments. Those that related to the content and method (rather than the teacher) include: "By doing individual assignments instead of listening to the professor talk, I was able to do my own research and come to my own conclusions to the problems that were given;" "Several field trips to area industries. Several real-life examples. Daily group work with students. Group work always involve doing research on industry topics with both regulatory and non-regulatory websites. Strong focus on work ready students and work applicable knowledge and skills;" "Definitely helpful for understanding concepts and being able to identify and describe issues."
- 87.5% of the students agreed (37.5%) or strongly agreed (50.0%) that, "Inquiry and engaged learning experiences in the course(s) taught me how to evaluate actual environmental, health and safety issues."
  - Seven of the respondents added comments. Those that related to the content and method include: "I was able to use the individual devices that we would be using in the field and get hands on experience with them;" "Coursework mainly included actual problem-solving skills. Whether they be environmental industrial hygiene safety - any of the above. Total approach was taken from the preliminary investigative stages all the way to recommendations and conclusions with explanation examples and coursework on individual steps alone and with other students;" "Definitely helpful."
- 75.1% of the students agreed (43.8%) or strongly agreed (31.3%) that, "Inquiry and engaged learning experiences in the course(s) were helpful in obtaining an internship, job interview, and/or employment. The same percentage and distribution agreed that, "Inquiry and engaged learning experiences in the course(s) were helpful in obtaining an internship, job interview, and/or employment."
  - Seven of the respondents added comments. Those that related to the content and method include: "Several of

the skills and activities that we have learned or studied in (this) class both theoretically and in our field trips to local and lesser local area businesses have directly led to me receiving jobs over other students who did not have the skills. I cannot emphasize enough how much real-world experience we received in addition to our theoretical education which is the main goal of (the) approach;" "Being able to identify issues, evaluate them, and come up with possible solutions or be able to reduce problem areas and report our opinions and thoughts were important skills that we practiced in class that would be important to specific jobs."

Especially important to our students was the improvement in their job outlook as a result of learning about environmental health and safety in this way. They wrote: "I think that this experience will definitely help in obtaining a job or internship. I got an interview with a company solely from a project that I did in TECH 411;" "(The) coursework and the skills...as well as the networking experiences...have directly lead to me getting two internships;" "The hands on work we did on location was a really big help during interviews just being able to tell the person interviewing me that I did more than just learn the theory;" "I think that this style of learning was the most beneficial out of all the learning styles that I have encountered." Engineering students are used to lecture-style classes, and the teaching model described in this paper represents a paradigm based on practices that science educators have been using for years, but with current examples related to the vital issues of our time. Our students embraced and valued this model.

Discussion

Some difficulties with this teaching approach are dealing with student expectations of a (traditional) fact-based learning model, with defined problems and answers. Engaged learning is intellectually demanding, putting students at the top of Krathwohl's modification of Bloom's taxonomy, with its focus on evaluation and creativity rather than merely finding the "correct" answer (Krathwohl 2002). But students did learn that it may be best to develop a selection of alternative approaches that can achieve equivalent goals.

Students experienced frustration due to the uncertainty of assignments and the lack of a precise endpoint. The corrective action was to provide more detailed instructions on the processes to follow, and providing more initial reliable resources for the students to begin this exploration. This is particularly important for semester-long projects.

A useful model is available from the US Forestry Service, entitled "Investigating Your Environment." This public domain resource (which includes detailed lesson plans and activities) was developed for grades 6-12 (U.S. Forest Service, n.d). Originally developed in the 1960's, it is a remarkable early example of engaged learning, with an emphasis on the exploration and analysis of an environmental issue. Complexity is also taught (but within a structured format) as students are challenged to analyze an issue from the perspectives of many stakeholders. Adapting information from this public domain resource provided the basis for structured week-by-week milestones in open-ended projects. Student groups were formed very early in the semester. The groups picked among a selection of topics to explore, including: vermiculite insulation in home attics (which can contain asbestos), hormonal influences of plasticizers (which are in many consumer products), global environmental impacts of cell phone due to rare earth metals used, and radioactive contamination of a local community due to wastes from a rare earth metals processing facility. Time and computer access were provided during class for the groups to work on their projects. Individual effort could be evaluated (which can be difficult and a cause of group dissension) through the use of Blackboard, where each individual's effort was documented. The adapted detailed analysis process of issues and options resulted in final student presentations that were both tightly structured and creative. The bottom line is that environmental issues can serve as a framework for high-level student analysis of critical scientific and social concerns, and the activities and discussions described here successfully motivated students to engage in such analysis.

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