Early Introduction of Environmental Engineering and Sustainable Design Philosophies in the K-12 Classroom

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Introduction

The United States of America is one of the most technologically advanced nations in the world. It therefore has not only the opportunity, but also the obligation, to lead the way in the development of environmentally sustainable design concepts. What do we mean when we refer to designs in this way? An excellent definition of environmental sustainability has been given by Peter Raven and Linda Berg who refer to is as "the ability to meet humanity's current needs without compromising the ability of future generations to meet their needs."[1] They go on to say that sustainability is based on considering the effects of our actions on the health and well being of all around us, recognizing that we must live within the limits of our finite resources, recognizing all the costs of the products we consume, and sharing individual responsibility for environmental sustainability. Sustainable designs are ones that take into account these environmental attributes as a part of the basic design criteria.

Generally speaking, Americans have a very low environmental awareness and a very large environmental impact. The American philosophy that everything is readily disposable tends to steer design engineers away from using sustainable design practices and more towards convenience and accessibility. As William McDonough says, "Our culture has adopted a design stratagem that essentially says that if brute force or massive amounts of energy don't work, you're not using enough."[2]

How can the U.S. philosophy catch up to the more advanced sustainable approaches and environmental awareness as seen in Europe, Australia, or even in their North American neighbor, Canada? It seems that the American mindset of "use and dispose" must change in order for significant progress in this area to be made. Nowhere is it more important to begin this mindset change than in young people beginning careers in Science, Engineering, and Technology. And nowhere is the mindset of "disposability" more deeply engrained than in inner city households.

It was therefore a unique opportunity when the authors, one a Mechanical Engineering Technology professor, and the other a middle school Mathematics teacher, were given the chance to teach a summer enrichment class for secondary school students in the Purdue University Science Bound Program. These students come from the urban Indianapolis Public Schools (IPS) system, the largest school system in the State of Indiana, and one where over 80% of the students are from low socio-economic status homes that qualify them for free or reduced cost school lunches. The students are typical lower economic status adolescents with myopic world views and a narrow experience base. They strongly reflect the "use and dispose" outlook toward both products and resources. Such students are the best possible subgroup with which to begin the philosophy change just discussed.

The three week long summer course will involve two topics associated with the environment and sustainability. The first topic is development of an environmental footprint for use in understanding personal (and subsequently larger group) impacts on the environment. This is similar to the concept of an ecological footprint, as introduced by William Rees and Mathis Wackernagel.[3,4] However, Rees and Wackernagel's model calculates the resource acreage required to support a community's, or nation's, lifestyle. Even Rees recognizes that it is difficult to correctly include all the factors that are involved in the ecological footprint of a small group or an individual.[5] The objective of the project described here is to help students to evaluate the impact on the environment of a particular activity or product. This is a more manageable task for students to actually become personally involved with during a short-time classroom experience. The second objective of this project is to perform an investigation and evaluation of the effects of a potential new industry (and its associated byproducts) into a local environment, and examine how an individual can become involved in the decision making process of their community.

Developing an Environmental Footprint

The authors decided to examine the environmental footprint of something that today's youth, even in the inner city, take for granted as being easily accessible, and even more easily disposable. That is; the cell phone. A surprising number of cell phones are present in a typical high school classroom each day. If the base number of cell phones is expanded to include those carried by the members of the students' immediate family members, then the quantity of phones begins to be significant.

While most of these students have access to a cell phone, virtually none of them have any knowledge of how one works, so it is necessary to disassemble one so they can see its major components, with particular attention given to the printed circuit boards and batteries. Since it is not obvious what a printed circuit board is or does, a demonstration is helpful, whereby pairs of students use copper wire, a 9 volt radio battery, and a small light bulb, to create a simple electrical circuit capable of lighting the bulb. They then can understand that the copper imbedded in the circuit board serves the same purpose of carrying the cell phone's electric power from the batteries to the various components.

The process for manufacturing a circuit board is investigated along with a discussion of the creation of a major byproduct of the process; copper chloride. Production of a printed circuit board of this size can create as much as a gallon of used copper chloride solution which must be disposed of. However, copper is what is termed a "heavy metal" and ingesting it can cause cancer, kidney failure, impaired mental abilities, and even death. For this reason, the copper chloride residue cannot simply be poured down the drain. US Regulations require that in order for a copper solution to be released into the wastewater system, it must be at a concentration of no more than 1 part per million. The students then conduct an experiment involving dilutions and testing of the copper chloride concentration in the dilutions until an acceptably small level of copper chloride remains. The students can then extrapolate the amount of water that would be required to adequately dilute all the waste fluids created in the manufacture of the base number of cell phones connected with the class. They will most likely be shocked at how much water is required and may need to compare the volume to something in their paradigm, such as a large swimming pool or small lake, in order to make sense of the numbers.

Having shown the environmental impact of trying to dilute the circuit board waste water, the students are then led on an examination of extraction techniques to remove the copper from the wastewater. This is followed by a study of evaporation and incineration techniques. All approaches have costs and problems associated with them and these issues are examined. At this point, students begin to realize the impacts of the wastes created by the manufacture of their cell phones.

So far only the manufacturing side of the footprint has been examined. What happens when a cell phone stops working? Most urban students will simply see it as disposable. This leads to an examination of what happens if a cell phone ends up in the landfill. The possibility exists that acidic solutions can be formed by rainwater and compounds in the landfill. Some of these acidic solutions, even though weak, can begin to slowly dissolve metals which can then enter into the ground water system. Additionally, the result of batteries leaking with time and allowing mercury or other potentially toxic compounds to leech into the water system must be discussed as a potential problem. The small amount of these elements that can turn a large body of water toxic will be used to impress upon the students the impact of a "use and dispose" philosophy.

The students now have the knowledge necessary to chart the basic life cycle of a cell phone and to construct a simple environmental footprint description for their use of cell phones. Using population statistics from the local city, it is possible to estimate how many households there are, and extrapolate how many cell phones are in use in the whole city. The magnitude of dealing with the by products and waste products of cell phone ownership can be seen, and the results should be quite surprising to the students. This can be used as an intro to discussing the appropriate way of handling wastes, from both manufacturing and end-of-life disposal. Students should be urged to discuss how purchasing decisions should be made. The effect of an individual's decision should be examined relative to the decisions of an entire community, or a small business. A good way to develop this larger picture for the students is to construct a simple role-playing scenario in which they are placed in the position of being a corporate manager evaluating the purchase of a quantity of cell phones. This exercise should enlighten the students on the magnitude of the impacts that they make as individuals, and how the philosophical approaches that they and their society make need to take into account environmental impact.

Civic Engagement

The second activity designed for the course is to present a scenario in which the students are all citizens of a small town. A company has proposed to move its operations to this hypothetical town, however, there are important issues regarding the impact of the new plant on both the local environment and local economy. The students will study the chemical processes that the new facility would be involved in, and then evaluate the byproducts of the these processes with regards to wastewater treatment, air pollution, and possible other environmental effects. A hypothetical chemical process is evaluated to determine the environmental footprint of the new plant. However, students will be told that the influx of new jobs to the depressed local economy is another consideration. Socio-economic issues would be introduced, such as new jobs opportunities opening up and new local tax income to help the town and the local school system. The students will have to deal with the conundrum of jobs versus environmental impact, and will be asked to choose sides in order to debate the decision. A simulated town council meeting will be called, with school administrators filing the roles of the council members. Students from both sides will be allowed to present their case, explaining why, or why not, the company should be given approval to locate its new facility in town.

Not only will students have to evaluate the chemical processes associated with the plant operations, but they will have to make tough, real world, evaluations of what is best for their community. They will then get a taste of how the political process works. They should come away with a better understanding of the importance of being a part of that process, as well as how they can play an effective role in that process.

Conclusions

The scenarios described herein are initially designed for secondary school students, and will be evaluated during classroom exposures during the summer of 2005. However, with appropriate changes, the topics could be presented at lower levels within the K-12 academic world. With high school or middle school students, the actual chemical reactions could be performed in the classroom. With students from lower grades, the concepts would have to be simplified, and while the experiments could be done as demonstrations, they could no longer be hands-on lab experiences for the students. However, the general concepts of developing an environmental footprint and understanding civic involvement, could be communicated to students in lower grades.

By the time of the conference, the first evaluation of this plan of study into a real classroom will have occurred. The authors will present the results of these activities along with observations about how they can be most effectively integrated into the K-12 environment. Materials from the course will be available at the conference, or through the Portal Resources for Indiana Science and Mathematics (PRISM) website at www.rose-prism.org. PRISM is a free website providing collections of online resources for educators in science, mathematics, and technology, indexed according to Indiana Academic Standards for grades six through eight.

The necessity of today's pre-college students understanding the effect of their actions and decisions on the environment cannot be understated. It is critically important that the next generation be prepared to use sustainable practices and create designs that minimize their impact on the environment. In order to do this, these concepts must be introduced in the K-12 world, so that today's youth recognize the importance of pursuing environmentally sound and responsible approaches when developing tomorrow's solutions.

References

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Biographies

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