Session 3560

Teaching the Engineering Students of Today to Sustain the Resources of Tomorrow

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Abstract

The actions of the past are beginning to take their toll on the environment, the economy, and society. The consequence resulting from the carelessness of industries is beginning to show its ugly face in the form of rising health care costs and other costs associated with air pollution, lack of space for solid wastes, and diminishing sources of clean water. There is no doubt that steps need to be taken to ensure that there are sufficient recourses to sustain an exponentially growing world population.

This paper will address the most critical points affecting environmental issues such as resource conservation, sustainability, and national and international corporate responsibility, and the reasons they need to be addressed in engineering curriculums. Additionally, it will discuss creative methods that environmentally friendly practices can be integrated into the engineering curriculum through partnering with industries.

Introduction

A key phrase among many of today's environmentalists, economists, and engineers is "sustainable development". For this paper, sustainable development will be defined as, "The acting out of cultural and economic programs that would allow the current population to live off of the resource interest provided by environmental, economic, and social plans, concepts, projects, and innovations without lowering the value of resources for the following generations."

It is obvious that the clear goal of business is to make money, but responsibility should be spread among international and national businesses that are contributing to the problem of pollution and anti-sustainability. Too many penalties for pollution are less than the cost for cleaning the problem, so often that the option of paying penalties is chosen over fixing the problem. For some companies, money now is more important than a future later. Nevertheless, there are industries that go above and beyond to ensure that the

environment is not harmed as well as ensure that the resources they consume now can be available to later generations. For example, just last year, IBM was given an award from the Environmental Protection Agency (EPA) for their contribution to environmentally safe commuting practices [1]. The Mobile Air Conditioning Society (MACS) Worldwide recently accepted a Stratospheric Ozone Protection Award on Earth Day from the EPA for contributions and innovations in protecting the Ozone Layer [2]. In recent years, the Saturn Corporation teamed with the EPA to study car recycling [3].

One of the best ways to ensure that future industry will be environmentally friendly is to teach the principles and importance of sustaining the environment to today's engineering students. As demonstrated by such companies as IBM and Saturn, there are industries working hard to preserve the environment. One way to help future engineers learn sustainability is for universities to partner with such industries.

Few fields of study can have a more dramatic impact on sustainable development than that of engineering. Engineers provide designs for everything humanity uses, from motor vehicles and refrigerators, to parks and city sidewalks, and all of these have the potential to impact the environment. However, it is up to the engineering educators of today to help ensure that engineers of tomorrow will impact the environment in a positive manner. Through integrating exciting methods of learning sustainability in engineering curriculums, engineering students can learn how to design and produce in an environmentally friendly manner.

Sustainable designing and sustainable products

In the market place today, advertisements overwhelm the consumers with terms such as longer lasting, improved, or lighter weight. One term rarely used in commercials is sustainable. That is because many products are not designed to be environmentally or economically sustainable. In order for products to be sustainable, they should have a relatively short lifespan, a definite biodegradable catalyst, and be re-usable in multiple forms. Finally, these designs should focus on the total life of the product, from the first removal or harvest of a resource to the time it spends after its original intended use.

The relatively short lifespan of a product expects that a better and more efficient version will be produced in a within a few years. To keep all of these products from flooding landfills, all products should be easily recycled, reused, or biodegradable. Components from one product could be used to replace or repair components in other similar products. All materials should be easily recycled, hopefully in such a way that the cost and recovery of recycled materials is better than or equal to that of harvesting resources to begin again. A good example of this is that many car companies offer rebuilt equipment such as engines and transmissions that function like new.

However, should parts end up in a landfill, which will inevitably occur, products should be equipped with a breakdown system, allowing for quick degradation of materials in the presence of water, sunlight, or other natural incidents.

When blueprinting products, designers should look at the total life of the product from beginning to end. Questions to be asked should include the following:

1. Where do the raw materials come from?
2. How they are collected?
3. What are the effects of producing such a product on the environment?
4. Where is it most likely to end up?
5. How long it will stay in its produced form are all questions to be asked during design?

Thinking in this way, sustainability would be easily achieved by abandoning those options which do not support sustainable design as a whole. The study of how human beings can live well for thousands of more years should be incorporated into every field, especially that of mechanical and design engineers.

Engineers should also be well trained in resource efficient planning. The latest technology and materials must be available in the planning stage to properly blueprint a sustainable product. Take for example a residential apartment complex. The architect or civil engineer must develop a building in which the materials do not change, but the design provides for less energy consumption and an overall sustainable design. Exchanges in ideas over pump systems, which the total energy requirement can be cut by more than eighty percent by installing larger diameter pipes and straightening them rather than having turns (both reduce friction); using wire with an increased diameter to reduce electrical resistance; and using passive solar techniques to reduce heating and cooling bills, all can help to decrease both the energy consumption and the bills of the tenant [4]. When apartment leasers search for a place to live, they will find the less expensive unit more attractive knowing that they will save money in the long run.

Arguments have been brought up that increasing cost to increase savings is not justified. But this is slowly changing. Greater savings always help to pay for themselves when compared to less costly but also less conserving methods. A better heating system that saves the consumer money is a better alternative than spending a little less on a heater that creates larger bills. The Energy Star program sponsored by the Department of Energy is actually helping consumers to find the most efficient products and it has made a difference in the purchases of economically and environmentally friendly equipment.

Programs such as these are a good step in the right direction, and engineering educators should be sure to teach students some of the fundamental concepts of sustainability in order to ensure they continue and advance. In order for students to one day become responsible engineers they should first understand the value of resources, be taught concepts of sustainability, and have a grasp of responsible resource consumption. They should also have a basic understanding of the role of government and international problems in sustainability. These concepts will now be discussed as well as ways to effectively integrate them into the engineering curriculum.

Helping students understand resource value

The goal should not be for engineers to design a cost structure with equations, but to incorporate a cost limits into their thinking. Cost limit in this sense refers to the point at which the ecosystem can no longer repair itself from human consumption in a relatively short amount of time. This type of cost limit can be difficult to quantify, so it must be thought of in somewhat abstract terms. For example, an ecosystem can deal fairly well with a small number of dirt roads leading to the logging site, despite erosion and other concerns. Asphalt on the other hand, can create breaks in the water table, disrupt normal water shed routes, and provide for any number of problems, many of which cannot be quantitatively measured. When the cost of production and replenishment are greater than the environmental limit, the ecosystem will deteriorate and not be able to provide the necessary materials for production at the same level as before, thereby increasing the costs of both production and replenishment. As a result, that system of production can no longer be sustainable.

When developing products, the costs of manufacturing cover a variety of topics, but there is not a set dollar amount for the environment. Take for example a coal-fired electric plant. The obvious costs are the price of the coal, including mining and transport, the costs of the plant itself, and the costs of electricity being provided. Some astute observer might also add in the price of air pollution control technology and/or fines administered for non-compliance of environmental regulations. However, there are many costs to consider when looking at the big picture. For example, when the coal is mined, how is the health of the miners and of the land surrounding the mine affected? When the effluent from the plant is discharged, how does that affect the surrounding ecosystem? What is the worth of another person's health, or having a thriving ecosystem? These are the questions that should be addressed in engineering curriculums.

Nevertheless, all of the answers to these questions are not usually found in a textbook alone. One way to help students explore these concepts is by exposing them to various field trips that help them to realize the big picture. For example, in the upper division class entitled, Pollution Control Technology, at Middle Tennessee State University (MTSU), engineering students attend a variety of excursions that include trips to the local waste water treatment facilities and landfills. The tour guides are experienced experts who lecture to the students about the importance of both consumer and industrial responsibility. The students are required to apply what they learn in the textbook and lectures to what is discussed on the trip by writing reports and giving presentations. In addition, they are required to raise questions and explore better ways to sustain resources. The manager at the BFI landfill is currently seeking to collaborate with some students on methods to improve odor control. These experiences help students apply the knowledge that they have learned in class. In addition, it allows students to see how difficult it is to remedy existing problems of overcrowded landfills and water pollution.

These field trips allow students to gain a better understanding of the cost limits of resource values that are often difficult to quantify. By applying the knowledge they have

learned in class to real world problems, the interest of the students in the class is heightened. This is evident in the fact that students have done better on examinations since the field trips were introduced. This is particularly true in the case of the waste water treatment plant. After exploring the facility, the students have a much better understanding of the waste water treatment process and perform better on the tests in that subject area. Their excitement about the subject matter is also apparent in listening to the heated class discussions about topics dealing with sustainability.

Teaching students sustainability

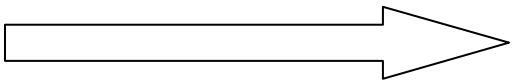
Of course not all resources are sustainable. People around the world use cars that run on fossil fuels, which have a definite amount on the Earth. Nevertheless, there are sustainable alternatives. Alternatively fueled cars are already being driven in many countries including the United States. As fossil fuel resources deplete, it is wise to train future engineers in the area of alternatively fueled transportation.

Professors in the Engineering Technology and Industrial Studies Department at MTSU use exciting projects to help teach students the concepts of alternative fuel. One such project is the Solarbike Rayce competition. In this competition, students are required to design and build a solar vehicle. They are responsible for all aspects of the project including the cost analysis, design, safety, and fabrication. They apply the concepts they learned in Fundamentals of Engineering, Pollution Control Technology, and other classes in order to make responsible decisions. The project has four major benefits. The first two benefits are that the students must learn to work responsibly, while simultaneously striving to win the race. Third, the students practice their technological skills in designing transportation that is environmentally sound. Finally, students remain in constant communication with industrial leaders while working on this project. If they need advice on any aspect of the design, fabrication, or safety components they are able to call those professionals who are currently working in the field. This type of project encourages students to think creatively about ways to design and fabricate products that minimize the consumption of resources.

Teaching students resource conservation

Needless to say, all production consumes resources, no matter what product is being made. Typically, industry is thought of as a pyramid, where the resources, time, and effort construct the bottom, and at the peak is the product. That product will eventually turn into waste at some point, which ends up for the most part in one of the thousands of trash sites around the world to decompose. This is very inefficient when considered as a whole. New approaches need to be considered to develop the concept of circular industry into reality. The current industrial plan looks like figure three, while the ideal industry could appear something like figure four, where the product can be used as a material for another when it has completed its usefulness.

Fig 3



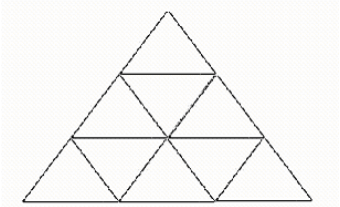


Fig 4

This represents industrial sustainability, which is an idea that can only be completed by the engineers of the world. The wastes of one process must be valuable to another as is demonstrated in various processes including everything from electricity production using methane gas from landfills and livestock farms to multiple miniature industrial ecosystems that make money while reducing waste with little capital overlay. Encouragement of this mode of thinking will not only be profitable to participating companies and the environment, but also to the engineers who design these steps.

One way that engineering professors at MTSU are helping students learn about resource conservation is through the use of specialized projects. As mentioned previously, students at MTSU are involved in the solar vehicle project. In addition to this project, they are involved in several others simultaneously, which include The Great Moonbuggy Race, The SAE Formula One Collegiate Competition, and The Mini-Baja Race. Projects such as these are worked on every year. With budget crunches, one might reasonably wonder how the students are able to successfully work on various projects year after year. The answer is through resource conservation. Students are responsible for all aspects of these projects, including the budget. They are given a set limit to spend and often must make do with recycled parts. Nevertheless, the students have been quite successful in doing so, as they have placed in several national competitions, including one first place win. They learn to salvage and recycle, which will help them become more environmentally and economically responsible engineers.

Importance of teaching international concepts of sustainability to students.

The economic system in some countries relies on shipping out the material wealth of its people. Wealth cannot be spread in such a way today. It is obvious that the richest nations are slowly getting richer, while the poorer countries are becoming more and more destitute [5]. Local resources have a greater economic value when harvested and used in the home country. By keeping the resources of a nation within its borders several bonuses occur. Citizens have a greater product wealth, responsibility is kept close to home making it more likely for sustainable use, and the nation does not lose its capability to produce goods and services.

In the competitive world of economic expansion, people tend to forget exactly where their goods are coming from. While America is rich in natural resources and labor, the United States still imports the vast majority of its goods. Imports and exports shift the responsibility of sustainability to others not involved in the consumption of the good.

The transfer of burden does not provide for maintaining the environment and the continuous use of that environment's resources. Very similar to landfill and trash site arguments, with people saying "Not in my backyard," the liability of keeping a sustainable world is much easier when it is passed to someone else.

It is frightening to think about the over flooding of landfills and the overuse of natural resources. Yet, since the great advent of the industrial revolution, increased productivity has been the goal of almost any industry. Nevertheless industries should be directed to operate and use resources responsibly; for the idea that new reserves will constantly appear in the environment after a few months or years of waiting is not realistic.

In fact certain statistics have already shown that human consumption of resources is leading to the extinction of species around the world. Though many estimates are available, a middle ground number is between fourteen and seventeen species of life will go extinct every day until 2050 [6]. All industries in every country need to practice responsible means of production in order to achieve a solution to this problem. This is why it is imperative that businesses across the world be on the same page in terms of environmental responsibility. The following is an excerpt written by Jill Stoffers, a professor of Economics at the University of Washington Seattle that demonstrates this need:

> Sea turtles are an endangered species. One cause of death for turtles is drowning in nets used by commercial shrimpers. In an effort to save sea turtles, Congress passed a law requiring US shrimpers to use nets equipped with "turtle excluder devices," or devices that allow turtles to swim out if they are accidentally caught. US shrimpers felt this put them at a disadvantage compared to their foreign competitors. So, Congress passed another law requiring all foreign shrimpers who export shrimp to the US market to use them too. Essentially, the US passed a law and expected the rest of the world to follow it. Because this law affected trade, foreign nations took the US to the WTO (World Trade Organization) for a ruling. The WTO ruled that the US could not apply law extra-territorially, or in other countries. Environmentalists were outraged by the WTO's decision [7].

In order to prevent the unnecessary deaths of sea turtles and other species, more effective international legislation needs to be investigated. It is extremely important that engineers be educated in the concepts of international industry and sustainability. Engineering educators have the capability to make a major impact in this area, especially since there are often many international students enrolled in engineering programs. Upon graduation, these students will take back knowledge learned in the United States if they choose to return to their home countries.

The role of international and large national corporations has always been near to that of government, though without much of the social responsibility. They are both accountable to those who invest in them, be it taxpayers, stockholders, or consumers and both carry a

great weight when it comes to becoming sustainable. The only problem lies in the avoidance of sustainable actions by some international and national corporations.

Role of government

Since 1965, the American Department of State has taken a major role in securing the earthly assets required to make the economy move in a positive direction. It directly motivates other countries to exploit resources in developing nations by using subsidized loans to help these nations mature. In order to repay these loans, poor governments must rely on the material wealth of its location, sacrificing long term sustainability for the short term gain. Other world authorities act in the same manner. Such authorities include the World Trade Organization and the International Monetary Fund, both supported by the U.S., allowing re-compensation to occur without any regard to the environmental drawbacks of such actions [8].

The American government did start to back off of investments into foreign development in the early 1990's, where 57% of international capitol flowing into the developing world was governmental. However, by 1997 the total amount injected into poor countries did not decline, rather it was shifted to the private sector to the tune of 85% where environmental controls are few and far between for small nations [9]. It may be easier to leave an area a wasteland, depleted of resources and generally unable to produce more, but the brunt of unsustainable industry will be born upon the shoulders of everyone, not just the poor and underdeveloped.

The methods currently employed by government are not productive enough to sustain the environment. For example, governments keep the prices of raw materials artificially low by not factoring in the environmental costs. Raising the prices of virgin resources would allow for a shift in the market towards reused and recycled resources, creating even more jobs and a wealth of resources. A recycling program installed in America has untold amounts of possible wealth. Recycling sixty percent of the United States solid waste would result in a savings equivalent to 315 million barrels of oil every year [10].

Students' roles in creativity and the sharing of ideas

Pairing young engineers with professors and industrial leaders on real world projects may lead to answers to questions that have bothered engineers for years. Often times, professionals say it is helpful to have a set of "new eyes" to find something that has not yet been seen. For example, another way that professors at MTSU teach resource conservation is through teaming up with industries to help them prepare for ISO 14000 inspections. One professor divides his Occupational and Environmental Hygiene class into teams and has each team conduct an inspection in various areas of a facility. The managers than use the information gathered and presented by the teams to help prepare for the real thing.

In this way, students gain real world experience by actually working on something concrete rather than simply memorizing what was said in lectures. While what is said in

class lectures is important, this information can be incorporated into a real life situation in order to develop skills. Experience is often a greater teacher than any classroom situation can hope to be. Students learn more efficiently from the "do" of an experience than the "see" of a lecture. They can also contribute a brand new development towards what they are studying.

In many cases, new ideas are already out there. They just have to be found and instituted. A small amount of research by an educator can lead to a wealth of new ideas from his or her pupils. Students are, for the most part, ready to learn and excited when what they are doing can have an effect on how things are engineered. The cutting edge of science should include those who are new to the field and they should be challenged with projects that bring light to many of the problems in sustainability.

The progress of spreading new ideas should be encompassed by all institutes of higher learning. This should not be a privilege given to just a few. Universities and colleges should be made aware of new technology and processes. Many universities have been set up to encourage the sharing of sustainable methods. Groups at major schools, such as the Massachusetts Institute of Technology, Harvard, and Cambridge have all set up sustainable engineering think tanks, where students and professors from around the world solve real problems dealing with the sustainability of certain operations. Non-profit groups have been set up as forums to discuss problems involved in localized engineering encountered around the globe. The idea of "two heads being better than one" is beginning to reach a whole new level [11].

Conclusion

The key to overcoming the hurdles in reaching sustainability can only be reached with efforts in various fields, but most of all sustainable development will rely on the engineers of tomorrow. The need for engineering instructors to develop key skills in their pupils and encourage the active participation of students in sustainability is now more important than ever. A good way for educators to accomplish this is through partnering with environmentally responsible industries. Developing momentum in economic, environmental, and social sustainability, the young engineers of today will surely make great leaps and bounds in the world of tomorrow.

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Biographies

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Saeed Foroudastan is an Associate Professor in the Engineering Technology and Industrial Studies Department. He received his B.S. in Civil Engineering (1980), his M.S. in Civil Engineering (1982), and his Ph.D. in Mechanical Engineering (1987) from Tennessee Technological University. Professor Foroudastan's employment vitae includes: Graduate Instructor for Tennessee Technological University (1983-86), Instructor of Mechanical Engineering for Tennessee Technological University (1987-88), Assistant Professor of Mechanical Engineering for Tennessee Technological University, Senior Engineer, Advanced Development Department, Textron Aerostructures (1990), and Middle Tennessee State University. Professor Foroudastan is involved with several professional organizations and honor societies, and has many publications to his name. He also holds U.S. and European patents.