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Incorporating Environmental Ethics into the Undergraduate Engineering Curriculum*

Katherine Rowden and Bradley Striebig
School of Engineering, Gonzaga University, Spokane, WA

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ABSTRACT: *The design and economic realities associated with Personal Computers (PCs) was used as a model for implementing ethical issues into the core-engineering curriculum. Historically, products have not been designed to be recycled easily. By incorporating environmental ethics into our classrooms and industries, valuable materials can be recovered and harmful materials can be eliminated from our waste stream. Future engineers must consider the economic cost-benefit analysis of designing a product for easy material recovery and recycling versus the true cost of the disposal and continued use of virgin materials. A three hour unit on the economic and environmental impacts of product design is proposed for inclusion in the ABET accredited engineering program.*

Introduction

In the National Society of Professional Engineer's code of ethics, to hold paramount the safety, health, and welfare of the public is the first fundamental canon as well as the number one rule of practice.[1] In nearly every aspect of engineering this is upheld, yet there is a very subtle and insidious problem as we learn more about the long-term environmental impact of our traditional economic consumer models.

For example, a computer engineer consults books, equations, and codes to design a new computer. However, only recently have some of them begun to consider where the materials come from for these objects or where they will end up when the product becomes obsolete. The impact of current computer design and waste disposal practices was evaluated as a potential case study in environmental ethics.

While many countries and some individual companies here in the United States have begun to address environmental issues in the design phase of products, it is important to educate the engineers that are involved with nearly every new product,

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Address for correspondence: Katherine Rowden, School of Engineering, Gonzaga University, Spokane, WA 99258, USA: email: katheriner@qoa.com.

building, and operation, to look seriously at these issues. The ideal time to introduce environmental ethics is when engineers are learning all the fundamentals needed to be proficient in their chosen field. An ethics course would be a convenient place to broach this topic, but few universities require one for undergraduate engineers.

Most universities however, do require engineering economics or principles of design. A three-hour unit on the economic and environmental impacts of product design is proposed for inclusion in such a course. To strictly treat the subject as an ethical issue would give students a platform to work from when dealing with new designs, but not necessarily the tools or ideas to make them work. Under our current economic model, in which profitability is one of the main considerations in product design, students should be presented with the knowledge to accomplish sustainable product design while maintaining profitability in the marketplace. This paper focuses on the design and economic realities associated with Personal Computers (PCs) as a model, chosen because of their familiarity, for implementing ethical issues into the core engineering curriculum.

The case for environmental ethics

Currently there are few federal or state regulations in our country to encourage responsible material use or planned recycling at the end of a product's life. In our country the citizens subsidize disposal through local government-run landfills and incineration. As time goes on, more of the citizens' dollars will go to remediate contaminated landfills that have leached toxins and heavy metals into the communities' air, soil, and water. Waste incinerators may also emit heavy metals, dioxins, and furans as well as other harmful substances into surrounding communities. To date, only a few states or counties have begun to legislate what may or may not be disposed of in municipal garbage systems.

Spokane City and County in the state of Washington exemplify the waste problem. The population of the city and county combined is 427,000 people. Over the last twenty years, the City and County collectively have spent over $40,000,000 to close four contaminated landfills, and will spend millions more before they are done.[2] These costs included buying contaminated homes adjacent to the landfills and piping water to homes whose wells had become contaminated from intrusion of pollutants from these landfills. The City of Spokane currently pays nearly half a million dollars every year to monitor and maintain two of these closed landfills.

For the past decade, the waste disposal practice in the City of Spokane has been primarily incineration. The City of Spokane made this choice in part because incineration has been heralded as a way to dispose of garbage cheaply in return for inexpensive energy. For a citizen of Spokane it costs only 98 dollars per ton to dispose of garbage. The current law says that anything coming from a household is "garbage" and therefore able to be picked up at the curb and sent straight to the incinerator. This includes all recyclable materials, hazardous waste, appliances, and electronic products.

The current programs in place do not adequately encourage consumers to properly dispose of or recycle potentially hazardous products. According to the Environmental Protection Agency (EPA), over 3.2 million tons of electronic waste are deposited in landfills every year.[3] In 2001 only 11% of retired PC's were recycled. Furthermore, the EPA estimated that 75% of obsolete computers are being stored in people's homes, with no idea of how they will eventually be disposed. The costs of disposal and possible subsequent treatment of leachate and contaminated sites from computer and electronic wastes are considerable. Neither the EPA nor local governments have devised a feasible system for dealing with these electronic wastes.

Consider that in any given computer you may have four pounds of lead, along with mercury, nickel, cadmium, zinc, and chromium, and other potentially toxic substances. Improper disposal may lead to the release of these potential toxins into the environment with serious environmental, health, and economic consequences. For example, elevated levels of lead detected in blood samples have been associated with learning disabilities and lowered intelligence, and exposure to lead continues to affect over a quarter of a million children in this country .[4]

Mercury emissions associated with the improper disposal of computers and electronics may also present a hazard. Mercury poisoning in children often occurs by contamination *in utero*. The EPA reports that while there is no safe level of mercury in the body, 8% of women of childbearing age have 5.8 ppb or higher, the current benchmark used by the EPA. Above this number, and sometimes below it, there is an increased risk of detrimental health effects that cause neurodevelopment, cardiovascular, immune, and reproductive problems. [4] Municipal incineration is one of the top sources for mercury contamination, responsible for nearly 20% of mercury emissions into the environment.[5] Dioxin, a known carcinogen, is another potential pollutant associated incineration.[6]

Current design issues related to environmental ethics

Figure A. Woman about to smash a cathode ray tube from a computer monitor in order to remove the copper laden yoke. Guiyu, China. December 2001. Copyright Basel Action Network.

Currently, a popular practice among computer recyclers is to ship retired PCs over-seas to Asia.[7] Labor costs to dismantle the computers here in the States would be exceedingly high by virtue of their design. The resulting situation for Asia has turned into an environmental and public health catastrophe. There, they are "recycled," but with little or no protection to the workers, and no safe disposal alternatives for the remaining waste which often ends up in unregulated stockpiles or dumped into unlined ditches. The resulting waste products contain lead, mercury and other toxins that have polluted the local water supplies. Subsequently, clean drinking water must now be purchased and trucked into the contaminated areas.

Historically, products have not been designed to be recycled easily. Engineers expect a product to be discarded and there is no motivation to design something that can easily be disassembled. In American society, products are designed to become obsolete to increase profit margins. Consider a computer, full of potentially toxic but recoverable and reusable resources; only recently have some companies begun designing computers that can be easily disassembled to recover these valuable materials.

In comparison to the European Union (EU), the United States has barely begun to address these potential hazards associated with household items and improper disposal practices. The EU has instituted a mandated producer take-back policy of most appliances and electronics, from toasters to PCs, which contain hazardous materials.[8] In the United States, there are several groups, including the EPA, attempting to get companies to voluntarily take part in Extended Producer Responsibility, which is working its way into some larger corporations such as Dell.[3] However, there is a common complaint that mandatory recycling of products is too costly to be feasible. This is not surprising since public tax dollars and not the corporations are currently paying for the problems created by improper disposal.

Incorporating ethics into the economics curriculum

In an economic analysis, when the true cost of disposal is considered as part of the cost of the product, it begins to make financial sense to design a product that can be easily recycled. Not only can the company then regain and reuse valuable materials, recycling eliminates harmful materials from our waste stream and prevents pollution.

Currently there are many companies and government agencies that are beginning to require environmentally responsible design for their new purchases, including PCs. These companies and agencies look for various environmental labels, which include the EPA's Energy Star label, the German Blue Angel Certification, and the Swedish TCO label. The certifications, along with the companies that are looking for these certifications, require computer manufacturers or designers to limit or eliminate the amount of hazardous materials such as mercury and cadmium, meet low energy-use requirements, and include information on electronics recycling. Plastics must consist of no more than two types, be free of coatings, metals, or toxic brominated flame retardants, and be labeled for ease of recycling,

These issues are important due to the costs associated with recycling PCs in the past. While there may be $50 in recoverable materials for a recycler, it may cost nearly that much for the labor involved with dismantling, purification, and smelting the raw materials. The recycler is also responsible for disposing of the remaining material, much of which is hazardous waste. Labor costs are increased by the time required to dismantle a unit due to the high number of screws used. Another problem is the large variety of unlabeled plastics used that require a much greater amount of time for identification and sorting. In addition, the plastics are often coated with hard to remove metals or toxins such that "even a small amount of incompatible plastic can contaminate an entire load of otherwise pure material and render it nearly worthless."[9]

One current example of how a company is addressing these issues is Apple Computers under their Design for the Environment program (DFE).[10] On their Power Mac G4 model they were able to:

- Reduce the stand-by electricity from 30 to 5 watts, 70% less than Energy Star compliance requires.
- Reduce the number of screws used to connect the motherboard from eleven to two.
- Provide easy access to the components to make replacement and upgrading easier in order to extend the lifetime of the product.
- Eliminate halogenated flame-retardants from the plastics.
- Use a lithium battery free of heavy metals.
- Label plastics with ISO codes for easy identification for recycling.

In a previous model, the Power Mac 7200, they were able to:[11]

- Reduce the overall resources resulting in a 12% weight reduction.
- Reduce the cost of production by 15-20%.

It is important to consider the energy efficiency in a computer design. Consider that "every kilowatt-hour of electricity not used prevents the emission of 680 grams of CO2, 5.8 grams of SO_2 and 2.5 grams of NO_x. This translates into several tons of reduced emissions over the lifetime of an Energy Star-Compliant computer." [11] As the effects of energy consumption and prevalent design practices become more widely understood, having the approval of the EPA's Energy Star label, or any similar certification, can be used as a powerful marketing tool for companies

Implications of addressing environmental ethics

The ethical issues previously discussed become more egregious as traditionally low-consuming, developing nations have begun to follow the lead of the United States. In China for instance, capitalism is on the rise along with an enormous spike in consumption of the same types of the products consumed here, such as computers, televisions, refrigerators, automobiles, and small appliances.

Engineers must be aware of the implications of the products they design on human health and the environment. Children in China are regularly exposed to toxic materials from the disassembly of computers and communities are saddled with the costs of environmental remediation and medical costs. A lack of insight on the part of engineers and business professionals has resulted in the victimization of marginalized populations that may unknowingly accept high-risk labor due for subsistence living.

While this is just one topic that can be brought into the student engineer's awareness, it is easy to take this information, expand on it, and present it in a three-hour unit. The first hour should introduce the potential damage to the environment and health that is unaccounted for in our current economic models, which do not include disposal costs. The second hour should focus on the ethical responsibility of engineers and the sustainable design alternatives utilized in Europe and among progressive companies in the United States. The second hour may also include the cost analysis and environmental costs described within this paper. The third hour should be utilized to discuss an economic cost-benefit analysis of designing a product for easy material recovery and recycling versus the true cost of the disposal and the continued use of virgin materials.

The need for a paradigm shift on the part of engineers is apparent. Engineering students must be exposed to environmental and ethical issues along with the fundamentals of chemistry, mathematics and physics. Future engineers will need a deeper understanding of their ethical responsibilities to sustain industry and social peace.

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