E-waste: An Industrial Designer's Perspective
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Introduction: The Traditional Role of the Industrial Designer

Industrial designers have always been responsible for the design of product aesthetics, the shape, form, and feel of products. I grew up in the back of my Dad's electronic store in the 1950s and was amazed at the complexity of TVs with their polished furniture cabinets, yards of wiring, dazzling vacuum tubes, hundreds of mechanical parts and metal fasteners, and Bakelite knobs and dials. Repairs typically included replacement of bad tubes, new electrical components and a new picture tube. There were large boxes of disassembled electrical components and maybe a million machine screws of every shape and size imaginable, and shelves and cubby holes of scavenged electrical parts. I spent a lot of time disassembling old electronics for reuse later. As things were designed to be repaired repeatedly, surprisingly little was thrown away, i.e., an occasional chassis carcass or small burnt-out, broken, and un-repairable electrical components. A refrigerator in the front of the repair shop worked fine for three decades.

So electronics (and other things) in that paradigm were designed to be repaired. They were beautifully crafted, and built to last; they were sustainable. From the scrap pile of old metal parts and other electrical gizmos I used to make robots and high school science projects. My Dad frequently crafted special tools or designed new uses for these scrap leftovers. Surprisingly little was actually discarded. I think you get the picture; this was a sustainable period when families saved all year to purchase a quality Maytag washer for Christmas.

A New Role for Industrial Design

Fast forward half a century to today. With the advent of transistors, the miniaturization of components and the transition from the use of buttons, switches, knobs, and housings to sleek flat touch screens, physical design opportunities have decreased and our roles as form meisters, i.e., form givers, has changed. One only has to visit a modern electronics store, sans repair shop, and look at the rows of similar-looking monitors to see that the major difference from one to another are slight styling changes and the branding logo. Emphasis is increasingly on what our modern electronic entertainment and work tools "do" as opposed to what they "are." "Less is more" has taken on an entirely new meaning. Less physical components and materials are being used for each product, meaning less physical design opportunity while what these products do and the experience they provide through their knowledge-based technology has skyrocketed. The opportunity for industrial designers to "shape" a positive user experience, delivered increasingly virtually, has expanded. We have an explosive growth of knowledge and more and more designers influence the use of this newfound knowledge in innovative ways by an expanding global middle class.

With increasing technological parity worldwide, companies can no longer compete on the basis of technology alone. Simply stuffing more and more technology into the product is not the answer, except for perhaps the early adopter technophiles willing to have the newest gizmo on the block at the expense of having to memorize the user's manual. For those of us among the average consumer masses in the middle of the technology adoption cycle, companies must produce innovative products that delight customers. They must increasingly deliver a user-friendly or user-centered experience. User-centered design now is *the* design, according to Dr. Rafik Goubran, Dean of the Faculty of Engineering and Design at Carleton University. The features on the iPhone were available on early adopter electronics years before their release by Apple. Dean Goubran

demonstrated one of these competing devices to me recently and observed that “this device does much more than the iPhone… the problem is it is so complex that you need to get out the instruction booklet every time you want to use it.”

Who is Responsible for the E-Waste Problem?

Our profession, industrial design (product design), is responsible for much of the electronic waste generated by the developed nations of the world. True, other professions like engineering and marketing share culpability as well, but it is industrial designers in particular who stimulate sales and improve the bottom line by creating attractive new products that customer’s desire. By using advanced mass production methods and flexible manufacturing techniques and by not paying full price when considering the damage to the planet and its ecosystem, we have undervalued these wonderful devices and made them available to the many worldwide. We have been hugely successful judging by stupendous market successes like the iPod and iPhone. These sleek new gadgets and effective advertising campaigns, coupled perhaps with a sense of our own entitlement, have helped create the current wasteful paradigm. This plethora of riches and planned, unplanned, or imagined obsolescence, along with designs that make cost-effective repair and recycling or reuse improbable, are hastening discarded electronics (e-waste) to landfills at an alarming rate.

According to the U.S. Environmental Protection Agency, Americans own almost 3 billion electronic products. When new products are purchased, about two-thirds of the electronic devices removed from service were still in working order at the time. Only 15%-20% of this material is recycled; the rest is land filled or incinerated, where the embedded energy and tremendous material value is lost (U.S. Environmental Protection Agency, 2005). By some estimates, as much as 80% of the electronic waste collected for recycling in the U.S. is sent to countries such as China, India, Pakistan, Vietnam, and the Philippines, where unregulated rudimentary recycling methods foul the air, water, and soil and endanger the workers involved. If we consider the not-too-distant view ahead, the current paradigm is simply not cost-effective and is increasingly unsustainable. It is also plain wrong-- ethically and morally. Additionally, pathways to the cheap dumping of e-waste in developing nations such as China, India, and Africa are likely to increasingly be restricted or stop all together for a simple reason: the amount of e-waste generated by these countries is expected to exceed that generated by Western nations in a few years. These countries will increasingly have their own e-waste problems to deal with. A recent report by United Nations Environment Programmed (UNEP) stated that China in 2010 produced about 2.3 million metric tons of e-waste, second only to the U.S. with 3 million metric tons, while e-waste from computers in India is expected to increase by percent by 2020 (United Nations, 2011). Except for CRTs, it is completely legal under current U.S. law to ship electronic waste overseas, even in some cases when it is against the laws of the country (such as China) receiving this material. The e-waste problem is one that we will increasingly have to solve ourselves.

Another major problem is the poisonous electronic (and other) products we design; yes, poisonous. The culprit is the tens of thousands of synthetic materials such as benzene and biphenyl A (BPA), the chemical building block of polycarbonate created from the hydrocarbon byproducts of fuel refining. This a key ingredient in flame retardants in electronics as well as epoxy resins. These substances are found nowhere in nature and once they navigate there, persist for decades. Many are hazardous to human health and the environment. Many others have never been tested to see if they are harmful. These chemicals are actually changing the world’s chemistry and scientists confirm that these synthetic chemicals are migrating from finished products into us. It is a sobering fact that these chemicals are in all of us, and in our children, who enter the world with hazardous chemicals already in their blood (Grossman, 2009). We must learn about hazardous materials and embrace the new field of “Green Chemistry” and specifying safe alternatives.

New Paradigm Needed

The existing paradigm is increasingly not sustainable for a number of reasons, among them increasing population, our rising standards of living, increased consumption, etc. Demographers at the United Nations recently announced that the number of people on the planet is set to reach 7 billion on Halloween (Engleman, 2011) and is predicted to be 10 billion forty years from now. (B.K. Fishbein, 2000). All those people will want access to information and the electronics that deliver it so there will be plenty for designers to do. The challenge will increasingly be to design technology products to generate less waste, close the manufacturing loops, and reduce adverse impacts on the environment. Our current system is a linear one, where primary raw materials and nonrenewable energy fuel manufacturing processes that produce products along with landfill pollutants and ecosystem disruption. It's designed to manufacture products and get them to the customer as cheaply as possible, without considering much else (McDonough, 2002). The marketplace demand for electronics is satisfied but the true full price of these products, i.e., environmental impact cost, is not paid. The increasing risk of doing business as usual is a depletion of material and energy, expanding landfill needs or increased dumping in lesser developed countries, along with pollution and resulting health problems and continuing risk to the ecosystem.

We need an efficiency revolution in materials and technology to sustain technology and economic development without unacceptable environmental, health, and social consequences. Fundamentally, this will require changing the way we think about the design of electronics and the system that delivers them to the user...the product life cycle. Can industrial designers alone change the system? Maybe not, but as Ray Anderson states in *Mid-Course Correction* states, someone has to lead (Anderson, 1998). We have to partner with engineers, other scientists, business visionaries and others with specific knowledge. As cloud computing and the delivery of services with it increase, the emphasis on user-centered experiences continues to increase. We must ask ourselves, can these products be designed for a closed loop system? It is exciting to imagine what such a system would look like. Realistically, this will involve closed loop recycling but that offers both holistic and lateral design opportunity as well. Just imagine if a product never goes away, and is perpetuated ad infinitum, how that impacts design and our role as responsible designers. "Away" now means being incinerated or ground back into silica where the manufacturing process of delivering these fantastic machines started. This "end" to our sweat, toil, and innovative thinking does not make sense on so many levels and is simply terrible. We must use our talents as designers and teachers to change this mind set.

What can industrial designers do? The e-waste problem is getting worse by the minute, so we must begin to act now. Not only are new methods needed to collect, sort, test, refurbish, repair, and remanufacture this potentially valuable material, we need better systems for designing, producing and managing the life cycle of discarded electronics. Due to the complexity of the problem a multidisciplinary problem-solving approach is needed in order to implement effective systems to recycle and reuse these materials.

Education

The first course of action is a commitment to learning about the problem. The Internet provides much general information as well as some specific sites with extensive databases. Our Sustainable Electronics Initiative (SEI) at the Illinois Sustainable Technology Center at the University of Illinois, under the guidance of Emerging Technologies Information Specialist Joy Scrogum and Librarian Laura Barnes, has developed an extensive RefWorks Database and additional information to facilitate access to the many aspects of electronic products and their interactions with the environment (http://www.sustainelectronics.illinois.edu/research/refworks.cfm). In addition to links to business

practices, education, and policy and statistics, engineering/design information is sourced. Given the magnitude and complexity of the problem along with the rapid development of new knowledge, be prepared that this is an ongoing challenge.

Although this paper is not about the now trendy topic of sustainable design, knowledge of sustainable design is now essential and provides a philosophy to sustain and embrace. Though we are not generally in the new knowledge business, at least to the extent of research scientists and other knowledge brokers, use of sustainable manufacturing methods, decreased energy use, and nontoxic recyclable materials are not only good for the environment but for the bottom line as well. It is good to remember that most environmental impacts associated with products are determined during the design phase. So by being better informed you can make better choices. One strategy is to develop a cadre of specialists that can be drawn upon as needed. I heard of one particularly innovative colleague who regularly reads a seminal book in a new area and this provides a basis of understanding for learning more from experts. Many of you likely work at companies with chemists, materials, and other experts. A number of our colleagues are involved in conducting research in relevant areas and those experts can be tapped as well. And of course there is a plethora of short courses and webinars.

Understanding Standards and Life Cycles

To contribute meaningfully to solving this problem, industrial designers are going to need to develop proficiencies in standards and life cycles that were previously the province of engineers. The good news is that several of the CAD software programs now offer assistance to the designer with life cycle analysis and sustainable materials and manufacturing choices. Understanding current legislation and standards Governing E-Waste is also helpful. The U.S. government website, http://www.fedcenter.gov/programs/electronics/#regs, provides much useful information. Links are provided to regulations, guidance and policy concerning electronic waste. The site contains a useful Electronics Waste Resource Locator with links to regulatory agencies and rules covering electronic waste and recycling. Our SEI website http://www.sustainelectronics.illinois.edu/policy/ is also a good place to start..
The recently released National Strategy for Electronic Stewardship includes recommendations to promote the design of greener electronics. The federal government wants to lead by example in "acquiring, managing, reusing and recycling its electronics, increasing domestic recycling efforts, and reducing harm from U.S. exports of electronic waste and improving safe handling of used electronics to developing countries" (National Strategy for Electronics Stewardship, July 20, 2011).

Sadly the U.S., although among the largest producers of electronic waste, lags behind the rest of the world in regulating electronic waste. We have recommendations but no federal laws restricting use of materials in electronic devices and should be discarded. The federal government has largely delegated regulation to the states. While half the states have laws regulating electronic waste, they are all very different from one another. The implication for designers is that with so many different regulations, it is very difficult to know how to design products to facilitate all the different state regulations.

There are two main models: Extended Producer Responsibility (EPR) and Advanced Recycling Fee (ARF) laws. With EPR, e-waste recycling and collection of is the responsibility of the producers (Fishbein, B.K.; Ehrenfeld, J.R, 2011). Producers register with the state. If they are unwilling to comply they are not allowed to sell their products in the state. They must meet a specific quota based on sales of electronics. Further variability in the laws is shown based on the definition of "electronics." What constitutes "electronics" varies by state, with some states restricting this only to computers. ARF is only used in California where consumers pay a fee when they purchase electronics that is applied to end-of-life management once discarded. As you can imagine this form of "green tax" has generated some controversy (Nixon, H.; Saphores, J-D.M., 2011). With e-waste collection, management, and export legislation varying from state to state and with half the states having no significant legislation in place, interest in national e-waste

legislation is increasing. An e-waste export bill to stop global e-waste dumping was introduced in June 2011. The Responsible Electronics Recycling Act (http://www.electronicstakeback.com/wp-content/uploads/GREETX_028_June-6-2011.pdf) was designed to stop U.S. recyclers from dumping electronic waste on developing countries and to promote recycling jobs at home. This bill has wide support from environmental groups and major electronics players such as Dell, HP, Samsung, Apple, and Best Buy) (Basel Action Network, 2011).

European Union member states, on the other hand, have taken the lead in passing regulations to manage the e-waste problem. In the EU, legislation governing e-waste includes the Waste Electrical and Electronic Equipment Directive (WEEE), created to reduce electronic waste and to promote its reuse and recycling by making producers responsible for recycling products at the end of its useful life. These laws are designed to encourage electronics producers, distributors, and consumers to make environmentally sound decisions. Closely linked to WEEE is the Restriction of Hazardous Substances Directive (RoHS), which restricts the use of hazardous materials in the manufacture of electronic and electrical equipment (http://www.sustainelectronics.illinois.edu/policy/international.cfm).

Sustainable Electronic Design

The next approach, of course, is to use our design talents to help solve the problem. Using our creative design talents, there are two basic and perhaps obvious approaches to consider. One is the challenge of dealing with the immediate problem at hand, the low-hanging fruit, specifically, the tons and tons of e-waste that have been generated. Designing for reuse or creating entirely new and improved uses for e-waste offer challenging opportunities where we can help. There are many laudable examples of innovative designs that a quick online search will reveal.

So dealing with the immediate problem at hand is a pressing opportunity for designers. However, this does nothing to stem the ever increasing amounts of discarded electronics.

Blending Theory and Practice

An example of steps we are taking at the University of Illinois is the Sustainable Electronics Initiative (SEI; http://www.sustainelectronics.illinois.edu/). SEI is an industry and education partnership that conducts collaborative research and facilitates networking and information sharing. This partnership is dedicated to the creation of more sustainable systems for designing, producing, remanufacturing, and recycling electronic products.

In our view, the complexity of the e-waste problem demanded an interdisciplinary approach, whether it was creative lobbying for seed money during a state budget crisis; assembling a multidisciplinary team from academia and industry to develop courses designed to tackle the problem; or launching a competition designed both to promote the issue on campus and internationally as well as serve as a venue for students class projects.

Educational components of this multiyear pilot program are a new team-taught class on e-waste that educates students on the local through global e-waste issues, and a collaborative design research and development laboratory, Design for Energy and Environment (DEE Lab) where top students from engineering, design and business (marketing) work on industry sponsored research alongside faculty and industry experts. These activities are generating new knowledge, and along with our international e-waste design competition (http://www.ewaste.illinois.edu/), offer students the opportunity to work in interdisciplinary teams to develop creative design solutions that demonstrate the e-opportunity inherent in e-waste.

Reaching the Next Generation: E-waste Class

The newly created class, “Introduction to E-waste…and What Can Be Done About It,” offered by

the University's industrial design program, challenges students and faculty researchers to learn more about this growing problem. This class introduces students to relevant national and international issues and offers proactive experiential learning experiences to demonstrate what can be done to contribute to solutions. Content is delivered through a variety of methods including lectures, seminars, discussions, workshops, field trips and multidisciplinary teamwork to develop innovative design concepts of useful products that can be made with e-waste. This course was the first of its kind, according to Bob Tonetti, Senior Scientist from the U.S. EPA's Office of Solid Waste (unpublished communication).

This seminar class of graduate and upper-level undergraduates debuted in fall semester 2008. Guided by faculty researchers with regular participation from an industry expert in recycling, students with backgrounds in industrial design, urban and regional planning, computer science, international studies, and engineering were assigned the task of studying the e-waste problem from a local campus perspective, as well as state, national, and international standpoints.

Over the course of the semester students in the e-waste class perform as a highly effective research team and transitioned into a project steering committee. Four main areas of the e-waste problem were studied: the University's recycling system, the national recycling and refurbishing movement, various state laws, and international laws and treaties. Interviews were conducted with a number of department heads, managers, and workers involved in overseeing and implementing state policy concerning recycling the campus' electronic waste. In addition, a sample survey of five buildings on campus was conducted to determine the scope of the problem. Study results were compiled in a final report at end of the semester. The results of the survey were compiled in a separate report.

The second semester of the debut class, "Introduction to E-waste and What to do about the Growing Problem," built on knowledge gained during the first seminar research course. Thirty-five students from a broad array of disciplines, including design, engineering, computer science, enrolled with a similar number who audited the class. The lecture-lab class began with the research team from the first semester presenting their findings. The class also featured weekly lectures by industry experts. The first half of the semester consisted of working in multidisciplinary teams to create innovative new uses for e-waste, what we dubbed "turning e-waste into e-opportunity." In addition, students organized an on-campus event to collect old e-waste from the community for recycling, which yielded more than five tons of material. (Because of complex state regulations concerning information security and surplus property disposal, electronic waste from the University itself could not be accepted.)

Putting Classroom Activities to Practical Use: E-waste Design Competition

Later in the semester, students were also charged with submitting their class projects to a competition set up for that purpose. The inaugural E-Waste Design Competition (http://www.sustainelectronics.illinois.edu/) was held on campus, with judges from companies such as Dell Computer, Wallmart, Motorola, and funded by corporate donations raised by the primary author. In its second year, the competition expanded to the international level, with at least six entries from overseas design teams. The results of our third year are just in and can be viewed at www.ewaste.illinois.edu. Entries were received from design teams from seven different countries in two competition categories: E-waste Prevention and E-waste Reuse. We are looking to expand the competition to more countries during 2012.

Ongoing Research: Sustainable Electronics Initiative

Currently we have funding proposals pending from our university Student Sustainability Committee and from ISTC waste tipping fees, and a Fortune 500 computer manufacturer. The *Repurposing Campus E-Waste* grant will support a pilot program to study the feasibility of refurbishing surplus computers from our academic unit in order to prolong their useful life and to

prevent them from becoming e-waste. Students will have the opportunity to learn refurbishing repair skills and knowledge. We are optimistic that this will lead to the establishment of a sustainable student repurposing operation on campus. Other universities such as Temple University (http://www.temple.edu/cs/crc/) have similar student-led programs. To their credit, our student body recently voted to increase their sustainability fee to $14. These funds are used to support this and other student and faculty research initiatives to aid in developing a more sustainable campus.

The second proposal we expect to be funded through state trash tipping fees and an industry grant is a survey of staff in the parent academic unit of ISTC to characterize factors involved in computer disposal and purchase decisions. The process by which various University departments acquire, use, replace, refurbish, and reuse computing equipment is not well understood. The SEI will examine these factors in a pilot study of the Prairie Research Institute (PRI). Specifically, SEI will hold focus groups for each of the five divisions of PRI (or targeted staff interviews depending on the size of the division). The purpose will be to gauge which groups of individuals are involved with computer equipment purchasing and disposal decisions within each division and to determine some of the factors that might be involved in making those decisions. The results of focus group discussions will inform the creation of a web-based survey open to all PRI staff members to determine how decisions are made regarding the disposal of computer equipment, the need for new equipment and choice of such equipment; differences that may exist in those procedures between PRI divisions; and reasons for any such differences.

We hope to learn what the tipping points are as to when and why computers are discarded. For instance, when is it cost-effective to surplus an old energy-inefficient computer and purchase an energy-efficient model? The goal is to provide new knowledge that would inform development of a more environmentally and economically sustainable system for computer use and disposal within PRI, and hopefully campus wide. We expect to identify opportunities to extend the lifecycle of computer equipment through consumer education; adoption of Institute-wide policies and guidelines; and defining barriers to reuse and redistribution. Our findings will include recommendations for ways to prolong the life expectancy of computer equipment and avoid unnecessary discarding of equipment that may be tied to user misconceptions.

We expect this information to be of value in guiding future decisions regarding use, disposal, and acquisition of new equipment. We also hope this will contribute to the growing body of knowledge about user needs relative to computers that will inform the design process.

We have also launched a new Design for Energy and Environment Laboratory (DEE) Lab to conduct collaborative product design and development research focusing on sustainable energy-efficient products and product systems. DEE lab offers teams of students from the sciences (engineering), design, business, and other disciplines the opportunity to work under the guidance of research faculty on sustainable product development problems for industry. The lab is housed at the Illinois Sustainable Technology Center (ISTC), under the Center's Sustainable Electronics Initiative program

Conclusion

The e-waste legacy is not one that a profession such as ours, one that characterizes itself as a user friendly broker and purports to represent betterment of the human condition through design should be proud of. We must act now to change the way we do business. Together we can begin to usher in a new paradigm. In conclusion, as responsible members of our profession, I hope you will take the challenge. We must begin now to use our talent and ability to help solve this growing problem. We can use the power of design to change things for the better if we care and get involved.

I have begun my own journey to try and do something constructive about this terrible problem. My involvement these past two years in the Sustainable Electronics Initiative education and

research activity at the Illinois Sustainable Technology Center has been rewarding. I owe much to my university and especially the Office of the Vice Chancellor for Research for seed funding of this effort; Tim Lindsey, former associate director of ISTC; Manohar Kulkarni, ISTC director; the School of Art and Design; and especially to my friends, faculty, and industry professionals such as Willie Cade, CEO of PC Rebuilders and Recyclers, who have lent their support to the SEI (www.sustainelectronics.illinois.edu). Our initial plans when we began in 2008 with the first e-waste classes and our pilot research program were to establish a research and education center here at the university. Although the economy and political ideology have temporarily intervened, we are optimistic that we will ultimately be successful. We are refocusing our SEI efforts on education and knowledge to inform better inform the design of sustainable electronics. This and our other activities continue to gain momentum and we look forward to discussion, collaborations, and partnerships with schools and corporations.

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