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Article

Integrating Emotional Attachment and Sustainability in Electronic Product Design

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Abstract: Current models for Information and Communication Technology (ICT) products encourage frequent product replacement with newer versions that offer only minor incremental improvements. This pattern, named planned obsolescence, diminishes user experience and shortens product lifespan. This paper presents the conceptual basis for a two-part integrated approach to combating planned obsolescence in ICT devices. First, design for emotional attachment, which creates products that users enjoy, value, and use for longer. Second, technological adaptability, which anticipates product upgrades and repairs as new technologies emerge. A model interdisciplinary design course in industrial design and sustainability, also described herein, trains students to apply this approach to create innovative ICT products with smaller environmental footprints.

Keywords: sustainability; industrial design; emotional attachment; design education

1. Introduction

Current product consumption is based on short product life cycles that reduce the quality of connection with users and lead to serious environmental impacts. The notion of planned obsolescence, which deliberately promotes product replacement regardless of functionality [1], is embraced by many companies and by users who are only interested in the latest and newest products. In the case of Information and Communication Technology (ICT) products [2], this problem is even more severe, given the fast pace in which new devices like computers and laptops are introduced to the market. This accelerated cycle diminishes perceived value of products and limits effective strategies for product end-of-life management through reuse or recycling.

As sustainability tries to address many of these issues, the notion of integrating emotional attachment into design offers a viable solution for the problem. Emotional design addresses connections between products and users that transcend form and function and can often lead to prolonged product lifespan, due to increased levels of pleasure and user experience [3]. By extending the useful life of a product, many of the environmental issues currently faced by society could be reduced. In the case of electronic products such as ICTs, offering a stronger emotional connection is not enough. Technological obsolescence is an inevitable state in most products, regardless of business-based plans. ICTs and other similar products need to offer not only a stronger emotional connection with users, but also a technological adaptability that prevents technological obsolescence. This combination of emotional attachment and technological adaptability is a more comprehensive approach for addressing some of the environmental issues created by new products.

The integration of these strategies is being explored at Rochester Institute of Technology, in a course on sustainable product design that integrates industrial design and sustainability. Both disciplines are growing interest for environmental advances, but with different approaches. Design tends to have a more qualitative approach focused on user needs and experience. Engineering focuses on material extraction, manufacturing and end-of-life. The integration of these two disciplines offers a more comprehensive approach that looks at a product's life cycle as one big, integrated system. Student projects in this course offer interesting and exciting examples of integration of sustainability strategies in engineering and design.

2. Current State of Product Consumption

Economical models in modern societies are significantly dependent on consumption. A common measure of economical improvement is manufacturing growth. The United States focused on stimulating consumption after the end of World War II, encouraging people to not only consume as many goods as possible to stimulate manufacturing and generate jobs, but more importantly to turn consumption into a way of life.

Today, people face increasing pressure to keep consuming at a rapid pace. Societies have modernized, lives have become more complex, and technology has advanced, so it is easier for industries to develop products and goods that are more efficient, less expensive and, in many cases, disposable. These attributes make for an easier, more convenient lifestyle. As this cycle progresses, people become less attached to their products, assuming in most cases that they are good only for a short amount of time and can be disposed of and replaced easily [4]. By replacing products, consumers have access to newer technologies, functionality and appearance, and industries flourish due to high demand. Abundance of incremental minor improvements, addition of irrelevant product features, portfolio diversification, and market segmentation increases constantly, as brands try to stay competitive. Products, on the other hand, are becoming less durable and dependable. Demand for cheaper production often results in lower quality.

2.1. Evolution of Planned Obsolescence

The pattern of cyclical, frequent product disposal and replacement is a result of planned obsolescence, a deliberate action of making products obsolete before their technical functional obsolescence is reached. Designers are essential in achieving planned obsolescence, as they are able to create and manipulate product appearance and experience in a way that makes other products feel outdated and passé.

The notion of planned obsolescence has been around for a long time. Although its relevance became noticeable after World War II, Bernard London first introduced this strategy in 1932. In his essay "Ending Depression Through Planned Obsolescence," London notes how consumption patterns in the United States had changed around the Great Depression:

> *"In a word, people generally, in a frightened and hysterical mood, are using everything that they own longer than was their custom before the depression. In the earlier period of prosperity, the American people did not wait until the last possible bit of use had been extracted from every commodity. They replaced old articles with new for reasons of fashion and up-to-dateness [5]."*

After the Industrial Revolution led to new generations of products and devices, it was evident that many of these artifacts were manufactured in a way that extended well beyond their planned useful life. You could find, for example, shoes that people used only for a couple of years, but that contained materials that could last for decades. Artifacts that most people disposed of after a few years were manufactured out of durable metals and other materials that outlasted the functional life of the products. London's analysis on consumer behavior proposed a government-based leasing plan where consumers would pay to use products for a number of years and then would return them to government-run collecting offices. These offices would issue deposit credits for the returned goods, which could be used for leasing newer products. Although London's plan doesn't offer much insight into the benefits of collecting used products, current efforts in sustainability reflect a similar approach with efforts on recycling and repurposing. London's utopian plan was never implemented in its entirety but the notion of planned product lifespan became embedded in new product development. Marketers eventually modified the concept, focusing more on the idea of encouraging people to dispose of their products on a regular basis. Designers around this time became catalysts for creating product iterations that encouraged this behavior. Brook Stevens, important figure in early Industrial Design in the United States, acknowledged the importance of planned obsolescence, stating that "our whole economy is based on planned obsolescence, and everybody who can read without moving his lips should know it by now. We make good products, we induce people to buy them, and then next year we deliberately introduce something that will make those products old fashioned, out of date, obsolete [1]." Stevens goes on to describe this strategy as "a sound contribution to the American economy." Although design has evolved significantly since this time and vision, it is clear that the influence of marketing-driven design is still widely prevalent in design education and professional practice.

2.1.1. Environmental Effects of Planned Obsolescence

From an environmental standpoint, the implications of accelerated consumption behavior are critical [6]. The large amounts of waste that are created because of frequent product replacement are increasing at a rate that cannot be managed effectively with current waste management systems. This problem is expected to increase as global production keeps growing in scale. Traditionally, the notion of increased population has been considered a huge challenge in the environmental aspect, but population density alone is not necessarily a problem. According to Jonathan Chapman, there are a number of examples of natural ecosystems that thrive despite their high density [7]. The problem does not lie in population density, but rather in how the resources that ecosystems consume are handled. Resource management implies two stages: on one hand, there are the resources needed to create input (e.g., food, goods and services) and on the other hand, the output created by the consumption of these resources (e.g., manufacturing by-products, waste and used goods).

In the production of goods and services, natural resources are often abused and overused by most industries. Little attention has been given to maintaining resources and setting up systems that make them renewable and consistently available. Many modern processes, which involve complex chemical-based operations, not only deplete resources but also contaminate peripheral ecosystems [8]. As for waste and discarded goods, the scale at which they are produced exceeds the capacity of current waste management and recycling systems. The most common solution has been using landfills, which do not transform waste and redirect it back into the cycle, but rather collect and hide it. Recent challenges associated with climate change, resource scarcity, and ecosystem damage show the effects of this irresponsible cycle and underscore the need for developing sustainable solutions.

2.2. Additional Complications Specific to ICT Products

When looking at issues on resource management and disposal, ICT products require special attention. This product category involves high-tech devices ranging from computers to smart-phones to other similar products and peripherals. Two important factors make ICT products particularly critical when looking at their environmental impact. First, the complex functionality of these products requires the creation of complex plastics, semiconductors, and other materials, requiring large amounts of energy and infrastructure to develop. While many appliances such as major home appliances show most of their energy demand during their use stage, ICTs can use up to 80% of their total invested energy in their manufacturing alone [9]. Along with energy-intensive manufacturing, ICTs require a large mix of plastics and base and precious metals leading to depletion of potentially scarce natural materials. Microchips are excellent examples of extreme use of materials for ICTs. A DRAM chip, needed for memory management of every computer, weighs only 2 grams but the amount of secondary fossil fuels and chemical inputs for its production add up to 1600g and 72g, respectively [10]. These devices are not only resource intense to fabricate, but also hard to dispose of. Because of their complexity, most of these products are hard to disassemble in ways that allow for material separation for recycling, or recovery of precious metals. The U.S. Environmental Protection Agency estimates that from electronics discarded in 2007 only about 19% were collected for recycling [11].

The second factor that makes ICT products so detrimental to this cycle is the high pace of technological evolution. Scientist Gordon E. Moore realized in the 1960s that performance in ICTs doubled in ability about every eighteen months [12]. This projection, known as Moore's Law, has proven to be fairly accurate since its conception and shows no sign of slowing down. Given this accelerated technological improvement, people replace products on a regular basis, even when the products they own still work, and in most cases, offer all the necessary functionality to fulfill the needs of their users, even after the time they are replaced.

This pattern goes back to the issue of planned obsolescence. For example, current service structures for mobile phones are based on contract plans between users and carriers. Many users replace their mobile phones every eighteen months, not because these devices begin failing around that time, but because carriers offer new free or heavily discounted phones when the contract reaches that length and is renewed for another term. Even in other product categories not linked to contracts such as computers, users replace them an average of every three years. EPA projected sales in the United States of 440 million new electronic products in 2010 [11], doubling the number of electronic products sold in 1997. Out of the 440 million products, about 53% are mobile phones (in 1998 mobile phones accounted for only 12% of total sales). Victor Papanek, design visionary and strong advocate of design for social impact, highlights how "much driven design has satisfied only evanescent wants and desires, while the genuine needs of man have often been neglected [13]."

3. Two-Part Integrated Approach

In response to the growing challenges associated with consumption and waste generation, policies aimed at curbing ICTs environmental impact have been rapidly emerging at local, state, national, and international levels over the past several years. Many extended producer responsibility (EPR) policies, like the European Union's WEEE (Waste Electrical and Electronic Equipment) Directive, aim to ensure that manufacturers share in the responsibility for their products to be reused, recycled, or disposed of in an environmentally benign way [14]. Ideally, this mechanism would incentivize manufacturers to design and produce greener ICTs that could be upgraded easily for reuse or dismantled quickly for recycling. These goals are shared by policies and initiatives focusing on product labeling and procurement tools, notably the Electronic Product Environmental Assessment Tool (EPEAT) in the U.S. EPEAT, an incentive based system by which original equipment manufacturers (OEMs) declare their products' performance in specified environmental criteria, built up significant momentum when the U.S. President signed Executive Order 13514, "Federal Leadership in Environmental, Energy and Economic Performance" in October 2009, mandating that all federal agencies purchase EPEAT-registered electronic products. Other entities, including universities and corporations, have followed suit, all with the intention of selecting ICT products designed for sustainability across their life cycle. In the European Union, similar efforts have been underway, in the preparatory studies for Eco-design requirements of Energy Using Products (EuP), culminating in several broad analyses and recommendations for general product design [15,16].

While policy-driven solutions often focus heavily on manufacturers, institutions, and recycling systems, the ICT consumer also shares in the responsibility for preventing environmental impact due to the products manufacture, use, or disposition. Reuse, for example, is an important strategy that focuses on extending the lifespan of a product to minimize waste production and offset the energy and material input to the manufacturing stage. Reusability depends on both the producer to design a durable product that can be easily maintained and upgraded and the consumer to be willing to invest time and money in the product upkeep or refurbishment. In practice, however, lifespan extension through reuse faces two challenges: first, users tend to lose interest in their products quickly because of change in taste, market trends, or other similar factors. Second, even if users want to keep using products for longer, this will be impossible if such products become outdated. Therefore, an approach that addresses desirability and functionality simultaneously is necessary in order to create products that have extended lifespan.

3.1. Emotional Attachment

An innovative tool that designers have identified as conducive to sustainable behavior in consumers is Emotional Design. This strategy enables strong connections between users and products, which go beyond form and function, and promotes longer product lifespan due to the enjoyable experience that products offer [17]. Although the connection between emotional attachment and sustainability sounds evident, it is important to mention that when reviewing earlier literature on Emotional Design from influential authors like Donald Norman [18] and Patrick Jordan [19], sustainability was not a factor considered in their discourse. Most of their analyses revolved around pleasurable experience, user satisfaction, product’s reflective character, prolonged lifespan, and brand loyalty.

Nevertheless, designers have been able to apply these product attributes into a behavior that promotes a more responsible use of products, extending their useful life. The result is environmental advantage by means of superior user experience. Emotional attachment can occur at multiple levels such as sentimental relevance, dependability, timelessness, usability, and graceful ageing. In most cases, this connection doesn’t come from a single level or attribute but rather from a combination of several ones, and users tend to see products as valuable for as long as they connect emotionally to them [20]. When applying the potential of emotional design to environmental issues, products that achieve this emotional connection are more likely to have a longer lifespan. Willie Cade, CEO of PC Rebuilders and Recyclers, a PC refurbishing company based in Chicago, noticed that the length of time that users keep their computers is significantly longer for Apple users versus PC users [21]. It is expected that the reasons for this difference include perceived product dependability, cost of investment, and satisfaction and pleasure when using the product.

3.2. Technological Adaptability

For ICT products, achieving emotional attachment is not enough to ensure longer lifespan. As technologies advance and improve, certain products become truly obsolete. Examples of this pattern are found in everything from home appliances to typewriters, telephones, and sewing machines. Although some of these products are still functional as stand-alone products, the product category they are part of is no longer current, making them inevitably obsolete. A good example of this pattern is Braun’s SK5 turntable (Figure 1). Designed by Dieter Rams in the early 1960s, this product is considered a design classic because of its beautiful lines and proportions, high quality construction and superior usability.

Figure 1. Braun SK-5 turntable. Photo by xavax (Own work) [Public domain], via Wikimedia Commons.

But the fact of the matter is that turntables are no longer prevalent in mainstream market and many owners of the SK5 model keep them more as memorabilia than usable every-day products. Obsolescence, whether planned by marketing strategies or caused by legitimate technological advances is unavoidable, and good design needs to account for it through creation of products whose functionality can be evolved and adapted over time to meet current technological needs.

3.3. Integrating Emotional Attachment and Technological Adaptability

In order for modern ICT products to have a potentially long lifespan, they must be intentionally designed to allow for emotional attachment as well as for technological adaptability. In the case of personal computers, many models are designed in a way that allows them to be upgraded and repaired. However, most users won't consider doing this, since they don't feel attached to their computer and will prefer to replace it. Even if users are not interested in replacing their products, legitimate technological obsolescence will eventually force people to upgrade. There are certain mobile phone users who reach a point where they are forced to upgrade their devices, because the ones they have are no longer compatible with the carrier's network.

In order for assure a successful, long lifespan in electronic products, it is necessary to address both emotional attachment and technological adaptability. There are a number of examples of this combination from other product sectors. One example is the Fender Telecaster electric guitar (Figure 2).

Figure 2. Fender Telecaster electric Guitar. Photo by Danny Burage (Own work) [Public domain], via Wikimedia Commons.

Designed by Leo Fender in 1948, this guitar is still in production to this day. Many guitar players develop a strong connection with their instrument, viewing signs of wear as a hallmark of the guitar's history. As a guitar is used, it has the potential to develop a distinctive sound, a result of how its ageing materials and components affect its tonal quality [22]. These instruments also lend themselves to be repaired, customized, or upgraded with a wide range of electronic components.

Another example is the Maglite flashlight (Figure 3). This durable, rugged flashlight made out of solid aluminum is used in many extreme situations and is very good at accumulating character as it is used and wear marks appear.

Figure 3. Maglite flashlight. Photo by kaʁstn Disk/Cat (Own work) [Public domain], via Wikimedia Commons.

Maglite flashlights were first developed in 1979, featuring incandescent bulbs. Although the overall design hasn't changed significantly to this date, in 2006, Maglite transitioned to LED bulbs, which offer a number of benefits, including lower energy consumption and improved luminosity. Even when the opportunity of technological obsolescence knocked on Maglite's door, the company decided to acknowledge the durability of their products by designing an LED fixture compatible with older products. Owners of older models can keep the flashlight they have grown to trust and depend on, and simply upgrade to LED bulbs using the simple retrofit kits.

4. Sustainable Design in Higher Education

The ability to implement successfully the integrated approach described above depends on the development of practitioners who have both design acumen and sustainability awareness. Sustainability is gradually being incorporated into many disciplines in higher education, two of the most common being engineering and design. Engineering offers an approach based on systematic analysis and quantitative data assessment, which offers good understanding on environmental impacts at multiple stages of a product's life cycle. However, this approach may not be explicitly connected to user needs, ignoring impacts that environmentally driven decisions have on product behavior and experience. The field of design is very effective at understanding user needs and translating them into specific features, using qualitative measures of product behavior, which may apply better to factors like user experience and emotional connection. Given the different approaches that these disciplines have towards sustainability, there are significant opportunities for integrating them in cross-disciplinary environments, so that each can inform the other and lead to creation of comprehensive and compelling solutions. Important learning outcomes from this integration are to familiarize students in both disciplines with each other and to provide students with a clear idea of how sustainability applies to their professional practice, which is a topic that has not been integrated into design curricula at a broad scale [6].

Engineering and design integrate sustainability in different ways into their processes, often focusing on different areas of the product life cycle. Engineering tends to focus in the development and manufacturing stage, offering significant benefits to areas such as low-energy production and appropriate material selection. Industrial design navigates intuitively to the "use" stage, understanding user needs, wants, and expectations. Both disciplines also focus greatly on end-of-life, whether in encouraging reusing and recycling practices, or in improving systems for responsible disposal of products. Integrating the benefits of both disciplines can lead to products that are more sustainable, while also promoting more sustainable behaviors in their users, manufacturers, and recyclers. The principles mentioned earlier of emotional attachment and technological adaptability can be achieved only through collaboration between these disciplines. Focusing on only one of these two areas, without addressing the other, will most likely result in products that cannot be used over an extended lifespan, whether because users are not interested in using them for a long time, or because they are not able to meet user needs and wants over time.

4.1. Model Interdisciplinary Course

To this end, an inter-disciplinary course on sustainable product design at Rochester Institute of Technology has been developed to demonstrate a curriculum that can successfully integrate sustainability and industrial design through team- and project- based learning. The main goal of this course is for students to develop projects under an inter-disciplinary model, in which they can integrate the eco-design tools commonly developed by sustainability engineers into design process. This collaboration hopes to create design professionals familiar with eco-tools as well as sustainability practitioners that understand how their tools impact designers and end users. This academic model is an emerging focus that builds on techno-centric analysis and elevates results to ecologically and socially responsible solutions [23].

The course assembles teams of senior level Industrial Design and graduate-level Sustainability students who, together, develop innovative conceptual design of sustainable ICT products. The course follows a knowledge-based studio format, in which content is delivered through readings, lectures, and discussions and then applied to as assigned project. Lectures cover core content in sustainability, challenges in ICT products, and sustainable design strategies. Students then create small teams (on average 3 members per team) and start defining the problem areas that they want to address. A key element in this process is the peer-peer mediated interactions across graduate-undergraduate and sustainability-design divisions. To achieve this interaction, at least one graduate sustainability student is represented on each team, or, when enrollment of graduate students is lower than needed, the sustainability students act as "consultants" across multiple teams. In this role, the graduate students meet with each design team and providing them with analysis, insights and strategies that could benefit their projects. It is important to mention that in the course evaluations for this course, industrial design students highlight the benefits of collaborating with sustainability students as one of the most valuable components of the course.

4.2. Student Projects

While student projects vary in specific product category and sustainability strategies applied, a key requirement for every team is to address the problem as a system that includes the whole life cycle, rather than focusing on the product as an independent unit. An important realization that students have throughout the course is that most of the environmental opportunities don't come from the "use" stage, but rather from manufacturing or end-of-life considerations. Students are encouraged to integrate all of these stages in their solutions, so that the end results are comprehensive and compelling. In terms of emotional attachment, while the strategy is not specifically required to be integrated into the project, most teams include it as part of their solution, given its ability to define a consistent sustainable behavior throughout the solution's lifecycle.

A first example is "revOlve" (Figure 4), developed in 2009 by Chandra Baker, Dada Deng, Christopher Platt, and Jason Schuller, involving a smart-phone designed for easy upgrading and disassembly and for stronger user attachment.

Figure 4. Revolve phone concept by Chandra Baker, Dada Deng, Christopher Platt, and Jason Schuller, allows for emotional attachment and for easy repair and upgrading. Photo by Lobos.

Given that mobile phones often go beyond being just communication devices and act as signifiers of lifestyle, status and other social traits [24], emotional attachment is an emerging strategy to prevent users from replace their phones often and to enable longer lifecycles for the product. The elements used for achieving emotional attachment include the use of an interchangeable outer shell that provides the right balance of weight, texture, and strength. The team proposed the shell to be made out of aluminum as well as plastic. While some users appreciate the feel and durability of metal, the team realized that some users prefer the variety in finishes and colors that plastic can offer. The internal components of the phone slide out easily. This allows for accessing and replacing internal components, minimizing situations where the phone needs to be thrown away because it cannot be opened easily. This feature also acknowledges that newer technologies will always be offered, so users can upgrade components such as a brighter screen or a faster processor. Another important element of revOlve is a magnetic charging mechanism activated by kinetic motion. As the phone is spun, the magnetic coils are charged by kinetic energy, eliminating the need for adapter, cables, etc., while maximizing the interaction between user and product. Additionally, alternate charging methods for electronic devices such as solar, wind, or in this case, kinetic energy, empower users to generate energy that doesn't rely on large-scale, centralized systems [25].

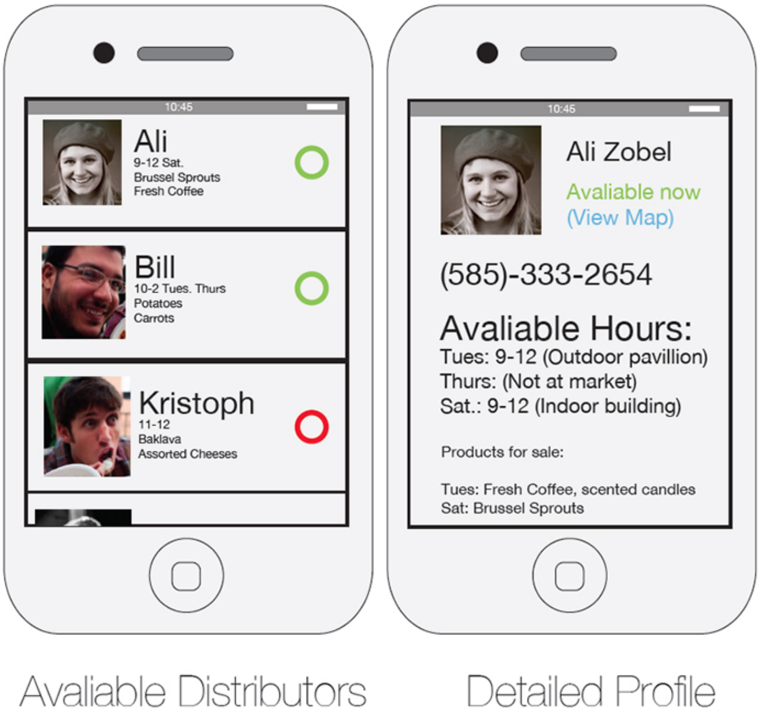
A second example, Dismantle (Figure 5), is a laptop created in 2010 by Isaac Alves and Joseph Lapke that addresses design for disassembly. A typical laptop takes about fifteen minutes to be disassembled fully, which presents too high a labor and operating cost burden to recycling facilities. Therefore, typical practice is for only large components to be removed by a technician at a recycling plant, with the remainder of the product shredded for bulk recycling at significantly lower recovery rates. This process not only eliminates any potential benefit coming from disassembly techniques, but it also reduces the efficiency with which precious metals contained in the circuit board can be recovered for reuse.

Figure 5. Dismantle laptop by Isaac Alves and Joseph Lapke can be fully disassembled in about ninety seconds. Photo by Lobos.

Dismantle offers an innovative disassembly system, based on sliding and snapping actions. Inspired by easy methods used in building toys like LEGO, Dismantle can be easily opened and fully disassembled in about ninety seconds. This solution an interesting example of a "persuasive technology [26]" that encourages change in behavior and promotes a more sustainable behavior because of the enhanced convenience and efficacy offered when accessing the laptop. Dismantle's basic disassembly method not only benefits recyclers dealing with disposed products, but it also encourages users to repair and upgrade their devices, instead of simply throwing them away.

A third example of student projects from 2011 shows an alternative approach to the assignment. Julian Del Campo, Alexander Freeman, Benjamin Hudson and Anton Siekmann were interested in creating a system that would support local businesses. After deciding to focus on local farming and local markets, they suggested that the most sustainable approach for ICTs was not to create a new device, but rather to use existing ones to address community-based issues and to improve user behavior. This strategy aligns with similar approaches that don't focus on manufacturing or materials efficiency but rather on improving the "use" stage of products [27]. Their solution is "farmLOCAL," an online system that works as a website, blog, mobile app, and social network interface (Figure 6).

Figure 6. FarmLOCAL by Julian Del Campo, Alexander Freeman, Benjamin Hudson and Anton Siekmann connects farmers, costumers and related businesses by using a multi-level social networking service. Photo by Lobos.



farmLOCAL allows local farmers to publicize the produce that they will be offering, in this case, at the Rochester Farmer Market. By doing this, consumers are encouraged to reach out to vendors and find ingredients that they want. farmLOCAL also allows local businesses to connect to the farmers and to promote local ingredients in their menus, achieving a solution that addresses not only environmental issues but also social and economical ones, which is the ultimate goal of sustainability [28]. The social network-based community interface facilitates activities such as "ride-shares," allowing visitors to the market to carpool or to assign a designated purchaser, reducing energy usage in transportation. farmLOCAL could also serve as a hub for exchanging recipes and promoting local events and other activities. farmLOCAL was developed so that it could be adopted by farmers markets throughout the country in an easy way, maintained by local business organizations or farmers cooperatives.

A final example from 2012 is a phone designed for repair, by Fahmi Dereinda, Patrick McKernan and Gregory Townsend (Figure 7). The team was interested in developing a phone that was solid and durable, in order to minimize damage during use. At the same time, their research showed that most phones that suffer physical damage are result of broken screens.

Figure 7. Design for Repair phone by Fahmi Dereinda, Patrick McKernan and Gregory Townsend allows for easy access to internal parts while providing additional protection if dropped. Photo by Lobos.

The team's final solution addresses both issues, using rugged caps that protect the phone's screen while enclosing internal components. The phone is attached with a screw that is highly visible, making it a clear "entry point [29]." This strategy results in a phone that is durable and dependable with a bold appearance and an internal architecture optimized for access and repair. An additional benefit of the phone is that users feel more connected to the phone after repairing it and are more likely to keep the product for a longer time.

5. Conclusions

As technology keeps evolving and new products are introduced, it is important to develop them in a way that allows for responsible manufacturing, use, and end-of-life considerations. Strategies such as planned obsolescence are accelerating the frequency at which products are replaced. Although this cycle appears to offer benefits to manufacturers and users interested in having the latest technology, it is generating critical environmental issues as well as making functional products to be perceived as obsolete.

To address the issue of planned obsolescence, design and engineering approaches must be integrated so that new generations of products are designed for longer lifespans. This can be achieved by creating products with strong emotional attachment, so that users are interested in keeping them for longer, and by designing the products so that they are able to adapt to newer technologies and functionality.

The role of higher education is key to this approach, in providing the creative and collaborative environment in which design and engineering students can learn to work with each other and generate models that address environmental issues with a comprehensive point of view that takes into account all stages in a product's life cycle.

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