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Educating Students on Sustainability and Recyclability in a World with Underdeveloped Recycling Systems

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Educating students on designing for disassembly and recyclability is challenging in a world with underdeveloped or non-existent recycling facilities and systems. In many countries and regions, recycling systems are well established, mainly because land costs are at a premium due to high population density, rendering recycling and composting necessary because of the limited amount of land. Other countries in the developing world have inadequate recycling systems. The United States is challenged with this conundrum, where much of the land is less densely populated; therefore, conditions for recycling and composting are not encouraged because the cost to dump garbage in landfills is more economically viable—regulations and funding are needed to encourage these areas to implement more sustainable systems. However, government consensus on this topic is lacking. New approaches are needed.

When educating students on these topics, they rise above limitations and invent innovative solutions for products incorporating circular and sustainable imperatives that align with recycling and disassembly systems. In this paper, case studies and design research projects that highlight these novelties are presented. Excellent visuals that communicate the potential of these more sustainable concepts will be shared.

As students become more engaged in sustainable practices, change is inevitable. We will also highlight examples of how students have become leaders in society, community, and corporate realms as they develop environmentally friendly ideas beyond the academic environment.

This paper also introduces non-profit organizations that local community members created. These establishments are disruptors in locations where recycling and composting processes are challenged or nonexistent. They aim to divert waste from the landfill by establishing community-led systems for recycling and disassembly. These facilities inspire students as they see first-hand the grit needed to make a stand for sustainability.

Furthermore, this paper will elaborate on the partnership established with these facilities and academic educators, enabling professors to introduce students to the complexities of recycling and inspire them to design products from recycled materials while applying principles relating to designing for disassembly. This advances the conversation about the broader aspects of designing with sustainability as a priority. Students become positive influencers within the business and public sectors as they progress through their careers.

We recognize the challenges of making a stand for better practices and establishing healthier and more sustainable systems for the environment. Repeatedly, we are confronted with a lack of funds and limited time. However, we understand the urgent need for this type of work, research, education, and community engagement. Educators and community leaders must unite and share this knowledge with students as we prepare them to become guardians for a better world.

Finally, we will introduce some of the health and well-being benefits that accompany community engagement projects as like-minded people come together to make a difference.

***Keywords**: Sustainable Design; Design for Disassembly; Recycling; Waste Systems; Circular Design*

The Problem

Educating students on designing for disassembly and recyclability has many challenges. As they begin to develop new product visions, it is our job as responsible professors to teach them how to design products with the end-of-life in mind. Here, in a world with underdeveloped or non-existent recycling facilities and systems, the challenges begin, and solutions are developed. Equipped with this new-found knowledge and methodologies, these students become leaders and visionaries in sustainable design within industries that largely focus on stakeholders and profitability.

In many countries, recycling systems are well established, mainly because land is expensive with high population density. With limited land, recycling and composting are essential. Other countries, including the developing world, have inadequate recycling systems. In the United States (US), where much of the land is less densely populated, conditions for recycling and composting are not as prevalent since dumping waste in landfills is economically viable. Also, a well-established car culture within the US allows low population density to exist in many parts of the country.

Recycling and composting are ideal end-of-life solutions for materials and products that are no longer used. Recycling takes the pressure off manufacturers to produce virgin materials extracted from the natural environment, reducing current and future ecological impacts. Composting food waste is essential for growing food and revitalizing soil for the next generation of grown materials and resources.

Educating students about the economics of recycling and composting is important because finances don't always lead to the best or most logical solutions. Also, recycling systems are underfunded and underdeveloped, with a poor capacity to effectively recycle (Young, Sullivan, Schwartz, & Kramer, 2020). The cost of reclaiming materials is more expensive than the process of burying waste in a landfill, incinerating it, or open waste burning (OWB). These practices come at a cost to the environment. 'OWB practices are strongly related to the mismanagement of municipal waste systems in an area. Bibliographical analysis shows that researchers are concerned about the environmental and health risks of open burning due to their potential hazardous emissions' (Ramadan, 2022).

Metals have large energy footprints to extract from the Earth and are economically competitive to recycle. Aluminum can be recycled infinitely without degradation and has a high energy footprint to extract from ore, rendering reclamation economically competitive. Many materials, such as plastic, have reduced costs due to lower extraction and refinement expenses, making them less economically competitive in the traditional recycling scenario. However, this scenario changes when land costs are more expensive due to supply and demand, rendering the costs of dumping materials in landfills higher than the cost of recycling them.

Figure 1. Photographs demonstrating waste challenges in Haiti. Source: Professor Trauth

In poorer countries, such as Haiti, where economies are less developed, the added costs of recycling or waste collection are unaffordable. Recycling infrastructure in Haiti is limited compared to many developed countries, and recycling rates may be relatively low (Figure 1). In these scenarios, required regulations are needed to make recycling and composting competitive both at the beginning and end of the material life, which will artificially inflate the costs of materials to create economically desirable conditions to allow for recycling or composting systems to develop. However, this can be politically

undesirable and a difficult process to implement. Because of this, new approaches are needed to find solutions to these challenges.

Design for Disassembly (DfD) allows products to be dismantled into recyclable and reparable parts. If materials are glued, blended, or mixed together, it is difficult or impossible to disassemble and prevents customers from being able to repair or recycle these products. Strategies for DfD are screws and snaps, which make it easier to recycle or repair. When learning about different methodologies for DfD students typically develop innovative solutions that can be cost effective.

One of the greatest challenges with education is helping students understand the many complex scenarios that relate to the multitude of materials used to create complicated consumer products. Each material has its own recycling requirements, which are often location-specific. How and where the material is recycled, transported, processed, or reused are basic questions students start with. Ultimately, there is a buyer who will transform these processed materials into products. Having enough buyers for the material is critical because the system could break down if the materials cannot be fully processed.

When teaching sustainable design practices within the academic environment, students learn the multifaceted aspects of this growing area of study. However, because this topic is complicated, it can be challenging to teach. Nonetheless, designs that create innovative products and enhance society ecologically can be inspiring. These approaches, practices and methodologies taught within the educational environment encourage students to emphasize the importance of minimizing environmental impact, promoting resource efficiency, fostering resilience to climate change, enhancing human health and well-being, and creating products that harmonize with natural systems.

Methodologies in Education and Sustainable Design

When educating students about sustainable design, there are several foundational methodologies to teach that create a strong platform from which they can expand. Designing for disassembly, materiality, economics, and understanding recycling systems is a good beginning. Furthermore, there are numerous resources available to assist in the educational process.

Students need to understand and apply systems thinking methodologies in the design process. ‘The Story of Stuff,’ a book (Leonard, 2010) and online video, discusses the materials economy and introduces systems thinking while exposing threats of overconsumption. ‘Cradle to Cradle: Remaking the Way We Make Things‘ (McDonough, 2002) educates us on designing products and systems to mimic natural cycles, introducing the idea that waste from one process becomes a resource for another. This is a concept of eliminating waste altogether and promoting a regenerative approach to manufacturing and consumption. Manuals such as the ‘Okala Practitioner, Integrating Ecological Design’ (White, St. Pierre, & Belletire, 2013) are useful in providing guidance, techniques, and case studies for professionals interested in ecological considerations.

Software for life cycle analysis (LCA) is designed to assess the environmental impacts of products, processes, and systems throughout the entire life cycle of an artifact, beginning with raw material extraction to end-of-life disposal or recycling. When accessing which LCA software to use, students and professionals should consider factors such as the software's features, capabilities, user interface, database quality, and compatibility with the designer’s specific needs.

Helping students navigate these resources is convoluted. The most comprehensive educational systems incorporate concepts for DfD, cradle-to-cradle, and LCA. Circular Design focuses on creating products that can be easily disassembled, recycled, or repurposed and aims to emulate natural systems where materials are continually reused and regenerated. The Ellen MacArthur Foundation (Foundation, 2024) (Figure 2) expands the scope of this concept and is dedicated to promoting the transition to a circular economy.

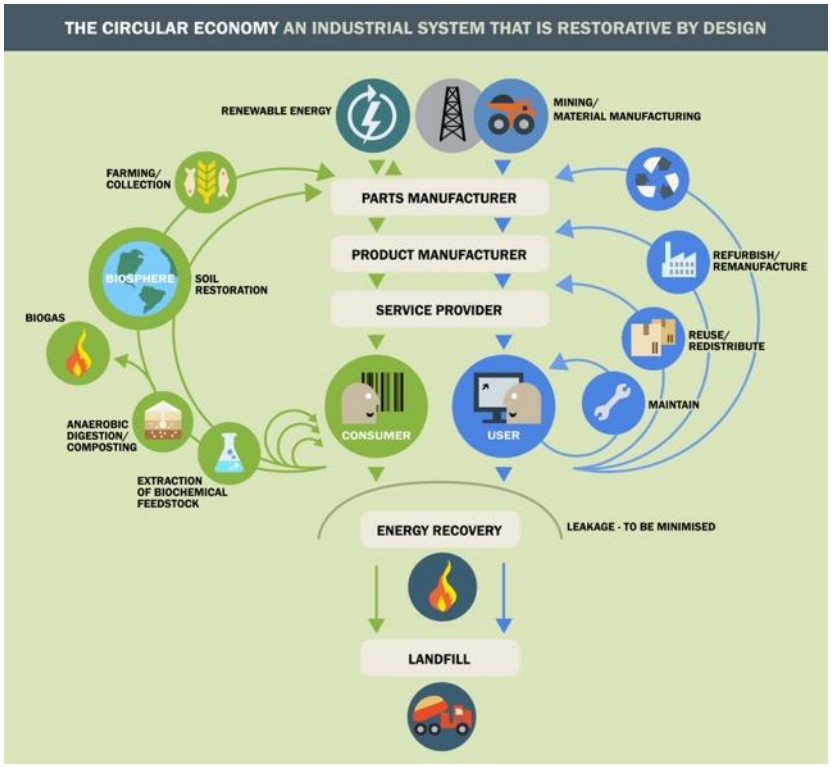

Figure 2. Source: Circular Economy diagram created from The Ellen MacArthur Foundation website.

Mutualistic (Symbiotic) Design (Trauth B. , 2017) expands this even further by questioning the economic system that the West has built. It also integrates permaculture concepts incorporating energy theory, economics, green building, urban planning, and Regenerative Agriculture.

Each one of these broad-scope design systems has strengths, weaknesses, and appropriate design applications. They assist students in navigating these possible transitions as they seek to earn a living through design while also building a world that moves towards a sustainable future. It also takes broad community, government, and business support and engagement to build out this vision.

Helping students understand how to investigate waste collection and its challenges is important because of the diverse source points, each with its own challenges. Much of how these materials are managed before they enter the collection system can define its success, such as cleaning recyclables before collection can make or break a system (Hub, 2024). This is difficult because it is a social or cultural construct that is often beyond most product designers, such as educating the public about the proper separation of or cleaning of materials before placing them in a collection receptacle. Beyond those complexities of pre-collection, students employ their understanding of systems thinking to comprehend how to manage, process, and direct those materials into new products. Books such as 'Thinking in Systems, A Primer' (Meadows, 2008) provide introductions to systems thinking, emphasizing the interconnectedness and dynamics of complex systems. It encourages readers to analyze systems as a whole, rather than focusing on individual components or events. When students understand waste flow systems, they are better informed to design products that employ circular design concepts.

Addressing the topic of Municipal Solid Waste (MSW) by the size of the waste category helps effectively frame the problem. 'The breakdown of the 292.4 million tons of MSW generated in 2018 by product category is as follows: Containers and packaging comprised the largest portion of MSW generated at 28.1 percent, or over 82 million tons (USEPA, Facts and Figures about Materials, Waste and Recycling, 2023). Packaging is diverse, and each category has its own challenges. For example, food containers must be cleaned and dried to avoid contamination (Hub, 2024), which dovetails into the second category: 'Food made up 21.6 percent' (63.1 million tons). Durable goods, such as furniture and electronics, and non-durable goods, such as paper products and footwear, are also major contributors to the waste stream. 'Durable goods made up over 19.5 percent (over 57 million tons) while nondurable goods made up about 17.3 percent (over 50 million tons)' (USEPA, Facts and Figures about Materials,

Waste and Recycling, 2023). These are impactful statistics to share with students so they can ponder the effects of the design profession, connecting design with environmental studies.

It is important to recognize both the waste and capture sides as they present challenges and opportunities. Most American recycling systems focus on food packaging, yet still don't capture it all. Most urban waste systems collect yard waste, while some have started collecting food scraps; both are compostable with different challenges. Most, if not all, recycling systems don't touch durable goods, leaving the work of DfD and end-of-life recycling for durable goods up to sporadic government-led, citizen-led, business-led, or small institutional-led recycling campaigns. This includes electronic recycling programs or business-led programs such as Nike's shoe recycling and Patagonia's Worn Wear programs. Nike's program will accept shoes mailed back and recycle them into running tracks (Nike Inc., 2024). Patagonia will buy and resell its old clothing through the Worn Wear program and repair or recycle old clothing for free through its Iron Clad Guarantee (Patagonia, 2024).

Large volumes of clean single-source materials can create their own markets if they're price competitive with virgin materials. Metals and cardboard are examples of this. Metal recycling is common because of its energy footprint, as previously mentioned. This leaves a competitive second-hand market that has commonly incentivized metal collectors who live near these sites. Despite these strong networks, especially in urban areas, this patchwork has left many gaps in moving towards a circular economy. Rural areas are more challenging due to higher transportation costs from longer distances traveled to recycling centers. This requires creative thinking in understanding the flows, economics, viability, and acquisition of recycling second-hand materials, which should begin at the product design process.

As students work through these challenges, they begin to see possibilities with customers dedicated to environmental responsibility who are willing to pay a premium and/or dedicate time to the end-of-life of a product. If this customer doesn't exist, then one could create the market by informing customers. Designing with commonly recycled materials expands that potential market and its ultimate success. To get to that point, it starts with the Designer.

The Right-to-Repair movement has grown recently as customers are increasingly frustrated with planned obsolescence; warranties are void if casings are opened to repair the product. If a consumer brings the product to a place for repair, the warranty is not voided. This system prohibits do-it-yourself care, and therefore, The Repair Association has come about (The Repair Association, 2024). Their '…objective is to shape pro-repair policies, guidelines, and regulations across federal, state, and local governance structures.' Currently, Right-to-Repair legislation has been passed as law in four states and requires manufacturers to sell parts and tools so anyone can repair their electronics at home or in repair shops.

The lack of repairability is a business model to sell additional products for profitability. Corporate dominance in these repair networks adds unnecessary costs for the consumer and additional waste when products are beyond repair after limited use. The added costs from a repair shop often make buying a new product more economically desirable.

Students must also know concepts such as perceived obsolescence, timeless design, and heirloom design. Perceived obsolescence is when products appear to be out of date when, in fact, they function just fine. Electronics, furniture, fashion, and the automotive industries count on customer misperceptions to sell more products. These sensitivities make people feel insecure about their older products and purchase new products to improve their image. Timeless design creates products that do not go out of style, assuming society will accept timeless design years from now. It is an attempt to make products last longer from an aesthetic point of view. Heirloom design refers to products handed down from generation to generation. Each concept is embedded into the industrial design process and challenges students to ponder their actions from an ethical perspective.

When students transition into the working environment, they become design leaders and sustainability champions within the industry. They can influence other decision-makers within the business realm to understand how to implement better product life cycle (PLC) practices through the numerous methodologies, systems, and processes discussed in this paper. Training students to thoughtfully design products that address a broad spectrum of layered issues relating to a product's end-of-life is both rewarding and complicated. Industrial design students continue to develop products from toasters to cars, to wearable technology to shoes, and ideally, are advancing towards a sustainable future.

Non-Profit Organizations and Partnerships with Academia

In the 2020 PBS Documentary 'Plastic Wars' (Young, Sullivan, Schwartz, & Kramer, 2020), in response to societal concerns over plastic pollution in the oceans, citizens have stepped up to solve the problem with creative solutions along with the support of the US Environmental Protection Agency (US EPA). These range from non-profit organizations seeking to expand the impact of recycling to Zero Waste stores returning from their last incarnation with the Natural Food Grocery store movement, which consolidated into Whole Foods and its various competitors. The Bipartisan Infrastructure Bill in 2021 created a map, the Recycling Infrastructure and Market Opportunities Map (USEPA, Recycling Infrastructure and Market Opportunities Map, 2021), to support the National Recycling Strategy and 'to meet the National Recycling Goal of increasing the US Recycling rate of materials generated in MSW to 50% by 2030' (USEPA, Recycling Infrastructure and Market Opportunities Map, 2021). MSW is commonly known as trash or garbage that consists of everyday items consumers use and then throw away. This can be a very helpful tool in building out the circular economy, but it will take more engagement to make it successful. This is where citizens, government, and business can play a critical role.

One example of local citizen-led and government-supported recycling efforts is the Cincinnati Recycling and Reuse Hub (CRRH) (Figure 3) located in a middle-sized American city, public and private grants support it. CRRH diverted 188-tons of materials in 2023 to recycling that the local municipal recycling system won't accept. The municipal recycling system collects easily recycled and sold materials. However, CRRH collects plastic bags, eyeglasses, footwear, jeans, oral care, rigid plastics #1-7, Styrofoam, metal, office supplies, pak-techs, plastic cutlery and straws, Teracycle branded materials, and x-rays for free. For a fee, they collect light bulbs, smoke detectors, batteries, tires, car seats, electronic media, ink & toner cartridges, electronics, appliances, bike helmets, string lights & cables (Hub, 2024).

Figure 3. Students touring the CRRH Source: Professor O'Kane

The multitude of different products and materials each have unique challenges for recycling, including cleanliness, purity of the materials, value, ease of disassembly, time to disassemble to pure materials, labor, and distance to a recycling center. The more difficult it is, the less likely recycling will happen. Each step can add costs, making it less economically competitive with virgin materials. Bringing students to CRRH helps them to understand the challenges and how designers can play a role at the start of a product's life by designing for the end-of-life.

Another system that was created as a non-profit by local citizens and a graduate is Precious Plastic Cincinnati (PPC) (Plastic, 2024). This organization takes plastics from CRRH and shreds them into meltable plastic to create new saleable products. PPC struggled with multiple roles: collection, cleaning, shredding, and making new products. The recycled plastic has low value, so selling to other manufacturers on a small scale wasn't feasible. They started to consult on designing products for clients, but eventually closed and pursued another model with less processing of different materials which also proved to be challenging. Educating students about these failures has helped them design other solutions, such as re-visualizing new recycling non-profits or products that work off smaller loop cycles to reclaim packaging and other materials.

One example of this was a business created by a graduate that collected local compost and transformed it into soil (Riders, 2024). Rust Belt Riders was successful and helped other graduates replicate their model in a nearby city. Rust Belt Riders employs the model of hot compost, accelerating the processing time and mitigating compost challenges such as smell and turnover time. Composting requires steady streams of green compost (nitrogen-based materials-N) and brown compost (carbon-based materials-C) combined with water and air. This accelerates the process to 18 days when proper parts of N & C are present.

Students and professionals are educated when visiting these facilities. Within the academic environment, these local businesses make it possible for students to experiment with developing local circular economies. Many challenges are overcome, such as cost competition with globally developed products that are cheaper than locally made products. However, with the right mindset, these challenges can be motivating.

Student Examples

When working with students in the educational environment, there are many different methodologies and approaches to sustainability that incorporate end-of-life solutions. Some studios have focused topics, and others are broad. Focused topic studios have unique challenges when teaching since student projects are similar. Open-ended studio projects are tricky to teach because the professor needs to be familiar with a broad range of sustainability-related topics. However, student concepts produce a wide variety of innovative solutions that are unpredictable and can highlight their unique interests in the field. The following are examples of student projects that incorporate sustainable design methodologies taught relating to the challenges presented in this paper.

Elimination and Paring Down

Responsible designers must think through ideas to reduce excess materials. Thinning material thicknesses and eliminating parts such as unneeded screws and fasteners is essential. The method of elimination and pairing down extends into the concept development phase, leading to entirely new products. To achieve this, students are given ample time within the studio to research and are encouraged to imagine ideas that don't exist. They must be allowed to freely take risks and abruptly change direction at any phase of the design process.

Several product examples of elimination came from a studio called 'The Future of Food.' Teams of Industrial Design and Graphic Communication students collaborated to develop sustainable solutions linked to this theme. One product concept titled 'milkmade.' (Figure 4) involved making plant-based milk powders more accessible and desirable to customers while reducing agricultural emissions and increasing biodiversity. Five students worked together and created a comprehensive website for ordering almond, hazelnut, oat, and soy powdered milk with unique recyclable branding and packaging. Customers can easily order a starter kit and samples, along with a large or small container for mixing the powdered milk with water. This 'one-time purchase' container is made of glass with a wide mouth for easy scooping. It also had an optional silicon grip, making it easy to hold while shaking. This grip can be disassembled and recycled. Different-sized tins with removable paper branding labels were designed to hold the powder. Networks of approved farms that focus on ethical practices, such as crop rotation and polyculture farming methods, would be sourced to provide ethically produced powders. Shipping powder eliminates liquids and is more energy efficient due to weight reduction. Powder would be shipped in tins or in lightweight bags and then poured into the tin containers. If the attractive tins are no longer needed, they can be reused, recycled, or returned to the manufacturer as a loop system.

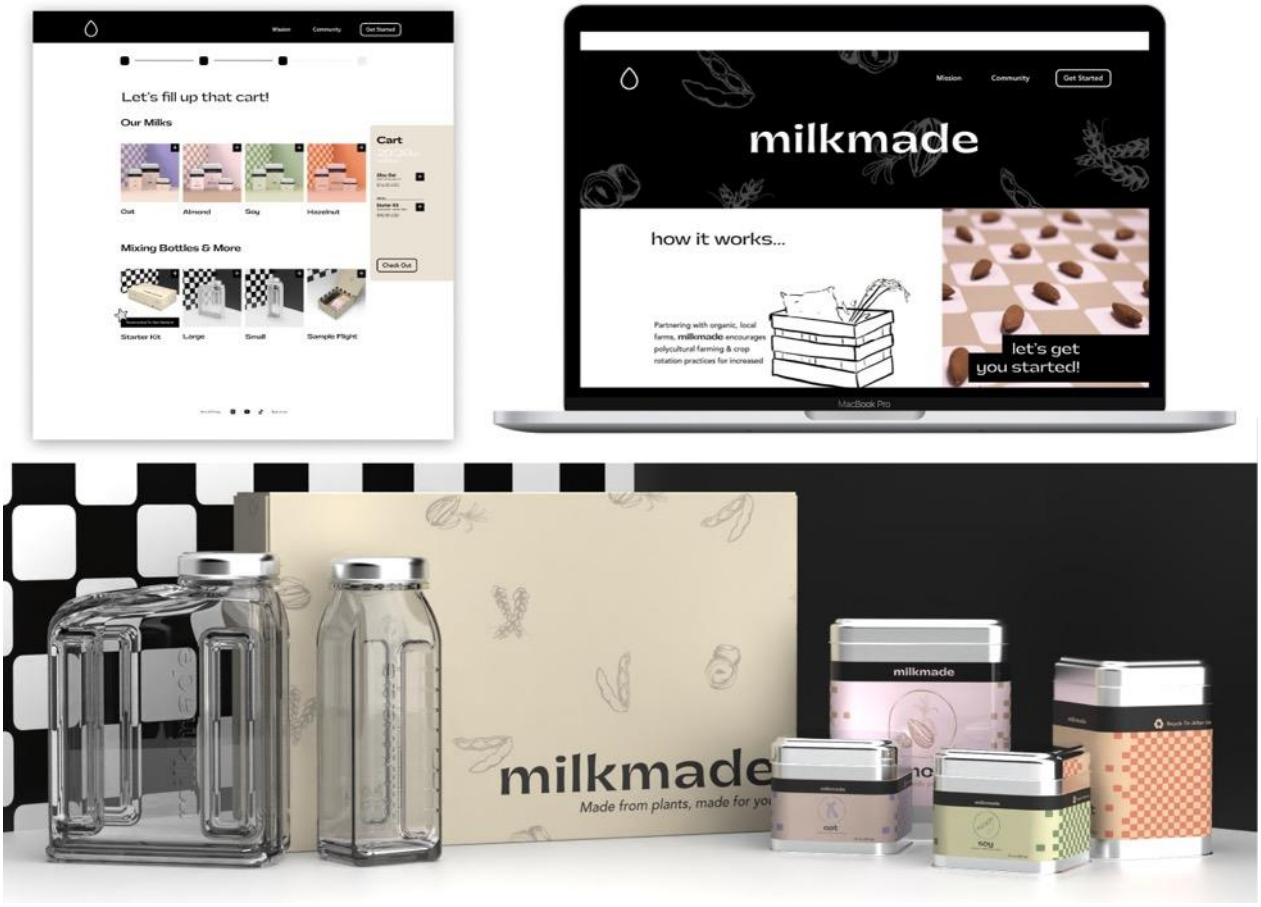

Figure 4. The 'milkmade' concept with large and small glass bottles for mixing milk powders with water. Source: Professor O'Kane

In another sustainability studio students were challenged to develop concepts with reverence towards nature. Students were required to spend time in nature contemplating the value and benefits we all receive from the natural environment. Ultimately, all materials used to make all consumer products come from nature. This insight motivates students to develop sustainable solutions for all types of product niches. One student project involved elimination and paring down by using tablet toiletries instead of liquid soaps, shampoos, conditioners, and other such products. She designed a container called 'Soaplet' (Figure 5) that held tablets to be mixed with water. This project eliminates packaging and reduces the energy used for shipping liquids. Packing and hauling liquids when traveling can be challenging, especially for air travel. This compact multi-chamber container would hold soap, shampoo, conditioner, or other tablets in one chamber. At the destination, water can be added to the other chamber and mixed with the tablets, which would dissolve in the water. She also designed a case for the tablets made from recycled paper.

Figure 5. The 'Soaplet' concept encourages consumers to use tablets instead of liquid products, which are ideal for air travel. Source: Professor O'Kane

Pioneering New Product Concepts

In studios focusing on sustainability, students are introduced to sustainable methodologies, fundamentals, principles, and product examples to develop pioneering new concepts. To achieve this, experimentation and failures are celebrated. This can be hard for students who are often focused on successful outcomes for excellent grades. Giving students A's for failure flips the grading system, allowing them to experiment in ways they wouldn't be able to in other strict educational settings.

'Bioma' (Figure 6) was a concept developed in a studio collaborating with a Fortune 500 company that explored sustainability. One student took the failures of the recycling system head-on by looking for new compostable materials that could replace plastic. This was inspired by simply working with natural materials. Resources that are regeneratively grown (Trauth, Synthesizing Humans with the Planet: Regenerative Agriculture and its relevence and application to Industrial Design, 2023) can reverse ecological destruction and climate change through carbon sequestration and minimize impacts if they are distributed through more sustainable transportation modalities. The student began individual research to make new natural and compostable materials with accessible materials that he could experiment with, including Agar-agar, Cornstarch, Cellulose, Chitosan, recycled Cotton Fibers, Bamboo, and Glycerin to make bioplastics. He also experimented with natural glues. He selected Agar Bioplastic packaging. One product incorporated bamboo fiber to make a box for packaging, while another used pure Agar to make bags. He also made a cellulose 'leather' bag. All the materials and packaging come close to matching plastics' versatility while easily composting at the end of the product's use. Materials development may seem beyond the scope of a designer, yet research shows (Poblete, 2023) that designers are very involved with new materials development due to their knowledge of product needs.

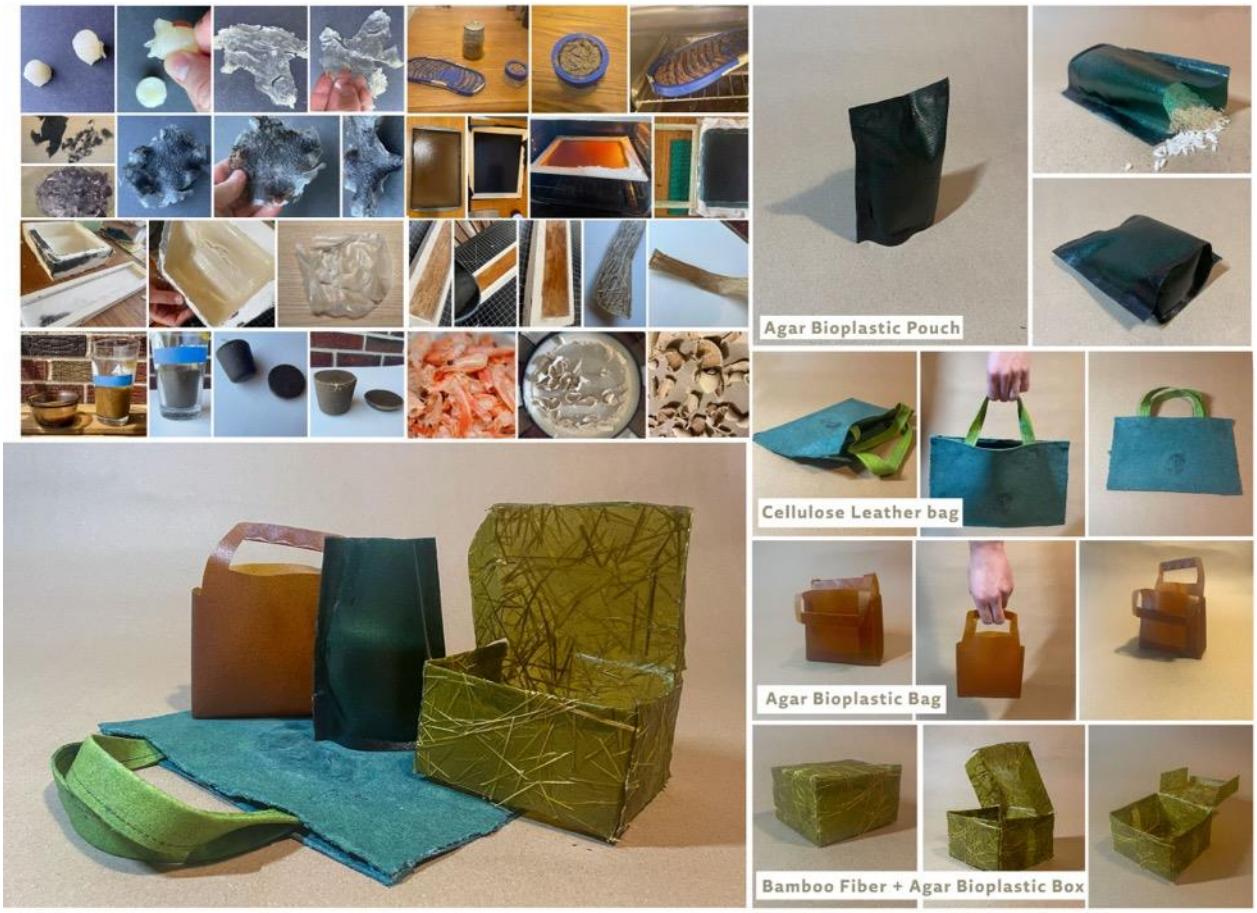

Figure 6. 'Bioma' product concepts explore the use of compostable materials that replace plastic. Source: Professor Trauth

In another studio working in collaboration with an industry sponsor dealt with sustainability, one student focused on consumer electronics, which are very complex and challenging regarding recycling. He brought forth a novel idea combining Right-to-Repair with an accessible design for disassembly that relates to a centralized repair network for sending out new parts, returning broken parts, and then remanufacturing those parts for sale again. His concept, the 'Mindful Blender' (Figure 7), is like the company UpFix, which repairs automobile electronics through a shipping network and Apple's network for remanufacture and sale. The unique aspect of his project includes Right-to-Repair, minimizing costs for the consumer for products that can often be cheaper to buy new than the labor costs involved with the repair. This extends product lifespan in products that are made from non-renewable materials, reducing their ecological footprint.

Figure 7. The 'Mindful Blender' is a fix-it-yourself product that explores the Right-to-Repair through Design for Disassembly. Source: Professor Trauth

Upcycling – Taking Waste and Turning it into Something New

Upcycling is a methodology where one product of lower quality, be it a single-use or disposable product, is recycled into a more durable, long-lasting product. This increases its economic and social value and ideally slows its movement towards final disposal.

Students for this studio had free reign over what they wanted to design, and they self-organized into groups of four based on topics. One student group was involved with Precious Plastic and networked with CRRH, which defined this project. The students used medicine bottles collected at CRRH, which were made of polypropylene, a plastic that is easier to recycle. Through their experiments, they developed a design that worked with their manufacturing capacities, which included making new sheets out of shredded plastic bottles through ovens and then using vacuum forming to shape the final product. This project, called 'Enlighten' (Figure 8), was a great connection between these two non-profits, using waste resources that were not recyclable by the municipality into new products.

Figure 8. 'Enlighten' is a light made from recycled medication bottles, claimed at the CRRH. Source: Professor Trauth

Another upcycling student concept involved designing a medical wrist product for patients with carpal tunnel called 'Carpal Flex' (Figure 9). He created this product from recycled pharmaceutical polypropylene plastics. Through research, he discovered an alternative way to design these wrist products that included three key trigger points, which are more effective than current devices. He then consulted with experts to realize this concept. He mocked up several different form studies and received feedback through user testing. The final design incorporates the most optimal aesthetic and size chosen during the validation process.

Figure 9. The 'Carpal Flex' concept is a medical wrist brace to correct carpel tunnel made from recycled pharmaceutical polypropylene plastics. Source: Professor O'Kane

Systems and Project Management

Methods of systems and project management are elaborated on within this paper and taught within the studios. Inspired by these ideas, another student created a product to eliminate food waste. She designed a smart grocery shopping device to scan produce that is being purchased. The device would, in theory, keep track of all items being purchased, which would eliminate the checkout line. The device is designed to connect to an app with virtual pantry features, meal planning, recipe searching, and expiration notifications. She created a branding system for 'Pantry Pal' (Figure 10) and designed a compact scanning device to attach to a keyring. The app has many different features for easy meal planning and shopping. As food neared the expiration date, the app would alert the customer and suggest meal plans for using the food before it expired.

Figure 10. The 'Pantry Pal' concept is a smart grocery shopping device with a companion app to help reduce food waste. Source: Professor O'Kane

In a studio that was sponsored by an industry sponsor, one student was interested in UI/UX and saw an opportunity within the Amazon business model to employ the app platform and build out a support system for customers to keep their products out of landfills called 'Amazon Loop.' (Figure 11) She employed many strategies, including diverse resources for repair and end-of-life recycling, as well as in-house second-hand sales. The end-of-life recycling feature facilitates connection to resources outside of municipal systems. This is a skillful use of technology to navigate the complexities of recycling and life extension in a world flooded with cheap, disposable products. Since the development of such an app proposal, a new program has been launched called Recycle Check which relates to SmartLabel and How2Recycle (Kingston, 2023). These apps and organizations are linked through a QR code on the product or packaging, and link consumers to local recycling sources to recycle it.

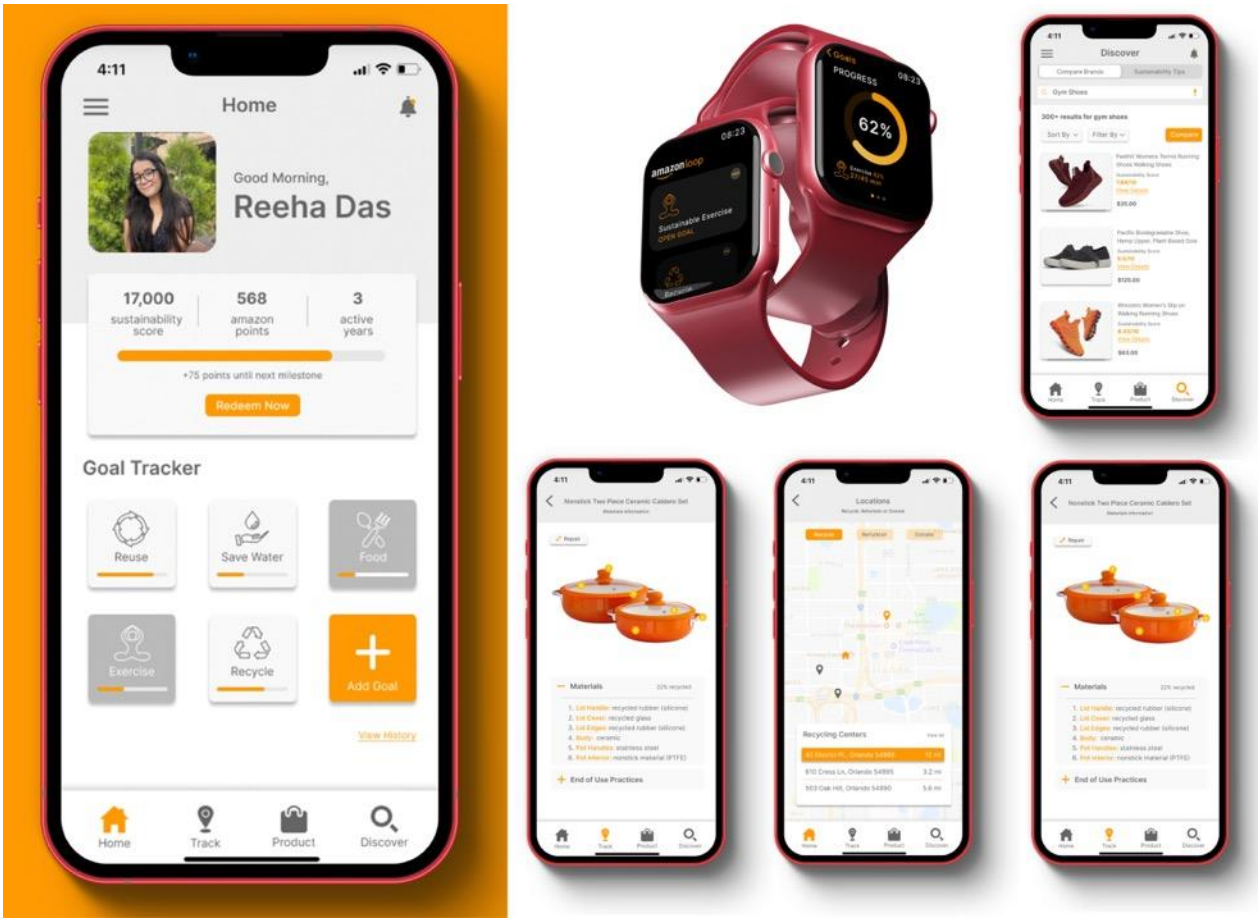

Figure 11. The 'Amazon Loop' concept explores an in-house circular economy and informs users of external resources to help recycle products. Source: Professor Trauth

Health, Well-Being, and Conclusion

Preparing students to understand sustainability complexities is critical in preparing them for the world they inherited. Many students come into our program aware and overwhelmed by the environmental challenges, experiencing climate anxiety. Design can play a critical role in helping current systems transition to models that work within Earth's limitations and restore ecological processes. This is encouraging for students and can be achieved through applying the processes and methodologies presented in this paper.

Humans have been the Keystone species of Earth for around 10,000 years in a destructive way. This can change if we mimic how the Earth works. Extractive cultures have come to dominate the world over the last several centuries, resulting in growing populations from that extractive process. These systems have brought global connectivity, which can accelerate the worldwide transition to a circular economy at an accelerated rate. Teaching students about this empowers them to navigate complex challenges and move from a disposable economy to a circular and mutualistic culture. Many of these students have gone on to make impacts working for Fortune 500 Companies, pioneering Regenerative Agriculture developing plant-based materials, leaning towards circular packaging and products, and working in communities to build sustainable connections that move toward mutualism and circularity.

We have no choice but to heal the Earth by employing the strategies mentioned in this paper and by participating in the transition. To restore the planet and increase its productivity, we inevitably need to transition to renewable resources created through regenerative farming and ecological restoration methods.

Connecting students to these concepts and community resources helps them understand the complex network it takes to build this future: one product, one project, and one organization at a time. Community

engagement projects have many health and well-being benefits as like-minded people come together to make a difference. Also, being part of the solution improves the students' outlook on the future.

Hopefully, this stair-stepping process will allow governments worldwide to centralize and simplify these collection processes. If that is not achieved, alternative collection systems can arise to support communities that don't have the resources to support those collection systems. Design and creativity are critical for this vision, and the more students understand these systems, the better they can help clients find solutions to build a world where non-renewable resources are maximized for their greatest positive impact while minimizing their negative impacts. This establishes healthier and more sustainable systems for the environment. Educators and community leaders must unite and share this knowledge as we prepare students to become guardians for our beloved Earth.

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