Plastic Explorations

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Abstract

This paper will review the issue of transforming "waste" plastics into the beautiful, useful, and meaningful through sculptural and architectural works in multiple contexts, such as design studios, installations, and educational tools. Crafts and design strategies reviewed in this paper will serve as references for future explorations by artists, engineers, and researchers at large.

1. Related Work

Our society has developed a love-hate relationship with plastics. They are relatively inexpensive to produce and versatile to use, permeating our everyday lives. However, most plastics maintain chemical stability and become resistant to degradation in natural processes. This usefulness of plastics co-exists with the possibly large amount of waste as plastics.

In the past fifteen years or so, artists, designers, and engineers have been making efforts to raise the public's awareness of disposable plastics and find strategies to recycle them. The field of plastic recycling intersects across creative disciplines. Numerous artworks focus on transforming disposable plastics. For example, Tara Donovan's works, such as *Logical Conclusions* (2005), *Untitled (Plastic Cup)* (2006), and *Untitled (Mylar)* (2007), resemble topological landscapes and biomorphic processes, composed of everyday objects [Kino 2008, Baume 2009]. Jean Shin's *Sound Waves* (2007) literally presents a wave of vinyl records [Shin 2018]. Chris Jordan's *Gyre* (2009), a plastic reinterpretation of "Great Wave off Kanagawa" creates a blunt link between our everyday plastic waste and the sea [Ragona 2012, Jordan 2009]. Sayaka Ganz's *Material Afterlife* (2009) turns household plastic into a frozen moment of moving animal bodies.

In the area of portable engineering, Dave Hakkens' *Precious Plastic Project* aims "to provide people the tools to start working with plastic waste locally." [Rognoli 2015, Hakkens 2018]. Hakkens has been taking on an intense journey since the beginning of 2013. He developed and launched two versions of a modular plastic recycling system, made the recycling system an online open source for a wider audience to access, and traveled to under-developed areas, such as Kenya, Mexico, India and Bali, to help local people build their own recycling systems. Further, Hakkens made small-scale objects, such as lampshades and vases, from the recycling system. These objects become sample designs for people to envision the end products of plastic recycling.

Lionel Taito-Matamua et al. contextualized plastic recycling in the local indigenous culture [Taito-Matamua 2015]. Inspired by the world's first RecycleBot, which recycles 3D printing waste into reusable filament for the printers, by Victoria University in Wellington, Taito-Matamua engineered ways to combine plastic water bottles and coconut fibers in 3D printing filament to print souvenirs for tourists. The project addressed multiple issues from the negative impact of tourism to Samoa (Taito-Matamua's own heritage has strong ties to Samoa), such as disposal of plastic water bottles, damage to rare species resulting from the demand of souvenirs, and the stagnant economy of the local indigenous population [Taito-Matamua 2018].

Trussfab integrated computer software development and 3D printing to design and construct truss structures with plastic soda bottles [Kovacs 2018]. Truss-Fab's "converter" software transforms a three-dimensional digital model into a honeycomb structure and edits it to a desired form. Based on the form, *Truss-Fab*'s "hub generator" software creates connectors for 3D printing and laser cutting. These connectors combine soda bottles into a large truss structure. Integrating structural calculations, the truss structure can hold human weight so that they can be parts of furniture, such as chairs and tables. The most recently constructed large-scale structure derived was 5 meters tall and consisted of 1280 bottles and 191 3D printed hubs [Kovacs 2017].

2. Exploration 1: Design Pedagogy

The author's earlier experiments with recycled plastics were in architectural design studios. Materiality, modular design, and scale were the design pedagogy embedded in the choice of material. The issue of recycling remained as an unspoken undertone.

Hat/Mask (2011) was a 24-hour design competition among undergraduate architecture students at Texas A&M University (Figure 1). Students were charged to transform water bottles into a hat/mask. They went through experiments to understand the plastic material of water bottles and developed methods, such as cutting, heating, and threading, to manipulate the material. The result appeared more decorative than structural due to the scale of the project.

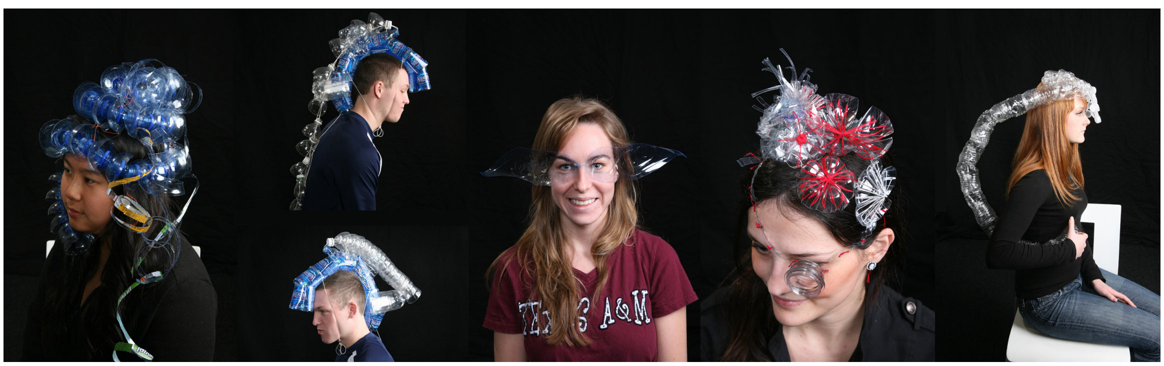

Figure 1. *Hat/Mask*

Fashion Theater (2011) invited students to use recycled plastic objects as modules to make a wearable kinetic piece (Figure 2). The project emphasized the geometry of the plastic objects and their accumulated material effects. To achieve the kinetic feature, students carefully designed joints. For example, one student arranged plastic straws to form layered surfaces, creating varied translucency. These surfaces were connected with pins to allow open and close movements around the body. The overall zigzag geometry of the design derived from the tectonics of straws and pins. At the performance, the students turned into dancers and their work transformed in lights, music, and digital projections.

Figure 2. *Fashion Theater*

Para-site (2013) set the design and the construction with recycled plastics in an overlooked interstitial space between buildings (Figure 3). The design needed to negotiate not only within the spatial contexts defined by walls, stairs, and columns, but also with loads, such as wind and weight, whose effects are more noticeable in an architectural scale than in an object scale. The concept of a module was interpreted in gradual deformation, construction efficiency, and structural strength of the joints. Materiality presented itself in natural phenomena, such as sunlight, shades, and shadow.

Figure 3. *Para-site*

Para-site investigated materiality. Mundane plastic objects were examined in terms of their material properties: convexity, flexibility, perforation, and transparency. But, they were separated from the original context of their conventional functions, such as a water-container or a shopping bag. The designs were not representative of things in nature, a fish or flower, for example, but rather an aggregate of physical properties and material phenomena, such as shades and shadows, translucency, and even minute sound. Such dissociation from a materials' existing and potential figurative meanings allowed their formal and physical properties to become more apparent and freed the students to manipulate materials in their immediacy.

To express materiality, it is critical to identify tectonic strategies and construction methods. The pieces are composed mostly of repeating modules assembled into a surface. The geometry of the surface is a basic grid that allows gravity to deform it and become curvilinear and complex. Therefore, the engineering of structures needs to provide semi-flexible connectors, which allow the deformation, and an anchoring system that sustains gravity and natural forces. Students used cable ties as connectors for their low cost, strength, structural flexibility, and construction efficiency. Some students even integrated cable ties as a way of visual expression in their design.

Because materials demanded specific transformations, details were added and variations appeared.

3. Exploration 2: Architectural Impact

Architectural scale installations with recycled plastics influence our living environment and compel us to think. Spatially, these projects actively address the notion of a site. Interventions of existing spaces, from the scale of an interior hallway to the scale of interstitial spaces between buildings, create a new dynamic on and with the site. A neglected space becomes appealing; a sterile space transforms to inviting enclosures. Eventually, these interventions merge into the background architecture to stimulate and house human bodies and events.

Plastic Poetry (2013) was a winning project at the *Curtains* competition called by the American Center for Architecture and Design, University of Austin, US. It was constructed on the campus of University of Texas in Austin, US, in 2013. Hanging between two buildings and hovering over a campus pathway, it was 50 feet tall and 55 feet wide, made of 14,000 plastic shopping bags (Figure 4). The author worked with structural engineer, John Nichols, and graduate students Ganesh Rao, Miaomiao Xiao, and Shyam K., and over 200 volunteers to design and construct the piece that only requires a simple tying method to make. *Plastic Poetry* was an intrusion to the peaceful campus, creating a "shock" in the first impression. People stared at it and asked: "what is that?"

Figure 4. *Plastic Poetry*

The structure of the piece relied on plastic bags tied in simple knots and an underlying rope structure tied in figure-eight knots. The piece was anchored on the existing hooks embedded in adjacent buildings. The intended pre-hung geometry of the "curtain" was a rectangular profile with a recessed arc on the bottom. The author intentionally anchored the corners of the curtain to not only create a slanted gesture but also utilize gravity to further define the geometry of the piece. Thanks to gravity and wind, the curtain also resulted in a billowed appearance. Curves were not defined as pre-determined geometry but as a result of a deforming process.

Cloud Igloo (2014) was part of the *Comfort Zone* project curated by Peter Lang in the architecture building of the Royal Academy of Arts (KKH) in Stockholm, Sweden (Figure 5). The purpose of the project was to transform the sterile interior of the entry hallway into a gathering space. Due to the tight three-day period from conceptual design to completion of construction, the author and 10 volunteers used 2,000 water bottles and nylon ropes to create the project. Clusters of white opaque volumes and voids filled in the space that was originally only of straight lines. Collaborating artists incorporated music and digital projection, which accentuated the liveliness of the space.

Figure 5. *Cloud-Igloo*

Cloud Igloo may be the most improvised piece presented in this paper. The only control of the geometry was a tying process; that is to string bottles together and loop the string to create a cluster. Among the two available bottle sizes, the selection is random; the number of bottles in each cluster is random. As the clusters were anchored to building structures, additional clusters were added. The construction process was literally "filling" the space with plastic bottles while creating voids for users to gather and stay.

Milky Way (2015) was a collaborative project for the Brazos Valley African American Museum in Bryan, Texas, US (Figure 6) curated by Cecilia Giusti and Wayne Sadberry. The site of the installation was a trapezoid-shaped space at the museum. The installation was an outdoor shading/lighting piece from 3,000 milk jugs. On top of the piece, solar-powered lights were evenly distributed. A parasitic structure, *Milky Way* made an ambivalent statement: at once invading the space with plastic waste and bringing ethereal qualities to the space by the varying degrees of translucency in the layering of the material. After two years of effort together with some 100 volunteers, including collecting milk jugs, washing and cutting them, making modules from the cut pieces, design and assemblage, and final installation, *Milky Way* was finally ready for the holiday season in December 2015 —through transformation, allowing a mundane waste to assume a pleasing role in the life of a community.

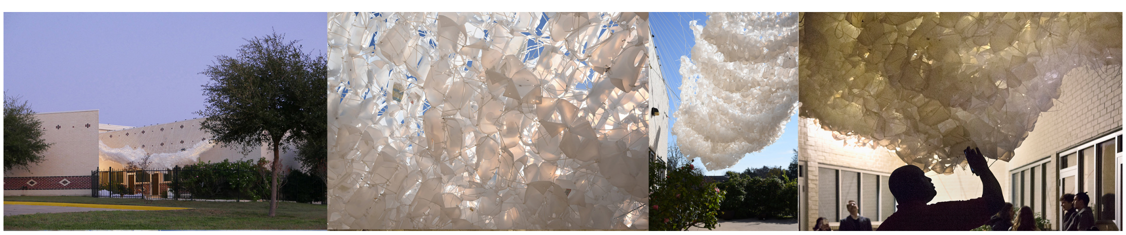

Figure 6. *Milky Way*

The module of *Milky Way* was carefully manipulated. The jugs were cut vertically along the two diagonal axes, revealing its interior space and creating visual depth. Each module was connected from three slices of the cut piece, creating an approximation of an equal-lateral top projection. Modules were connected into strips, and strips into a surface of two gentle convex curves that contracts at the ends and expands in the middle. Additional strips were twisted first and then added to the middle section of the surface to create a layering effect and adding weight to the middle. With the added weight, the middle section curved down, achieving the curvature along the Z axis. Overall, the overlapping of the identical modules contributed to the changing translucency in the changing light of the day.

These installations as the fundamental question "What is beauty?" They oscillated between the beautiful and the ugly. From a distance, a plastic bag curtain draped, swung, and billowed, as elegant as trains flowing behind elegant dresses in a cherry blossom color. The plastic bottle clouds and igloos glowed in light and seem innocently dreamy. But looked at closely, these plastic materials were still waste, ugly and dispensable. They screamed the monstrous truth: a single plastic bag can take up to 1,000 years to degrade; plastic bags remain toxic even after they break down; and every square mile of ocean has about 46,000 pieces of plastic floating in it. The surface of these projects brought the uncanny anticipation of the grotesque.

4. Exploration 3: Interactive Elements

Digital sensors enable art installations of recycled plastics to respond to the viewer. They initiate a constantly changing interface with the viewer and engage him/her for further and prolonged interaction. Triggered by the sensors, light and sound amplify material and spatial effects, transform the works, and highlight their time dimension.

Light Echo I & II (2016) reused the materials from *Milky Way* but reorganized the modules. In this sense, these two projects were doubly recycled. The author collaborated with digital artists, Hwaryoung Seo, and Morgan Jenks, to create immediate livelihood. *Light Echo I* was an interactive screen that responds to viewers' proximity (Figure 7). Made from recycled milk jugs and embedded sensors and LED lights, the piece intended more than a static object of decoration. Instead, a viewer's relative distance and his/her duration of stay would trigger the colors in which LED lights shone. Such engagement seems to propose that only when recycled art reintegrates in our everyday life is it truly recycled. With its playfulness, *Light Echo I* attracted numerous children at the *Dallas Earth Day 2016*. Children's interaction with the piece brought out an unexpected gentleness to the piece made from "trash."

Figure 7. *Light Echo I*

Light Echo II was a backdrop at the green carpet of the *6th Austin Trash Makeover Fashion Show 2016* organized by the Texas Campaign for the Environment (Figure 8). In this project, the author collaborated with Hwaryoung Seo, Morgan Jenks, Daniel Eynon, Stephanie Maddamma, Samuel Mortiz, and Charley Tyeskie. With further designs of sensors and programming, the piece gradually changed its colors when no one was close and instantaneously warmed up when a viewer stopped in front. The colors of LED lights interpreted the plastic material in various ways – a corner of an iceberg or a gigantic gemstone. Eventually, the ephemeral quality of the changing lights and their interaction with the viewer took the place of the actual form of the installation.

Figure 8. *Light Echo II*

Kusama Re-iteration (2017) was exhibited at the *7th Austin Trash Makeover Fashion Show 2017* curated by Cecilia Guevara. Inspired by Yayoi Kusama's work, the project is a collection of

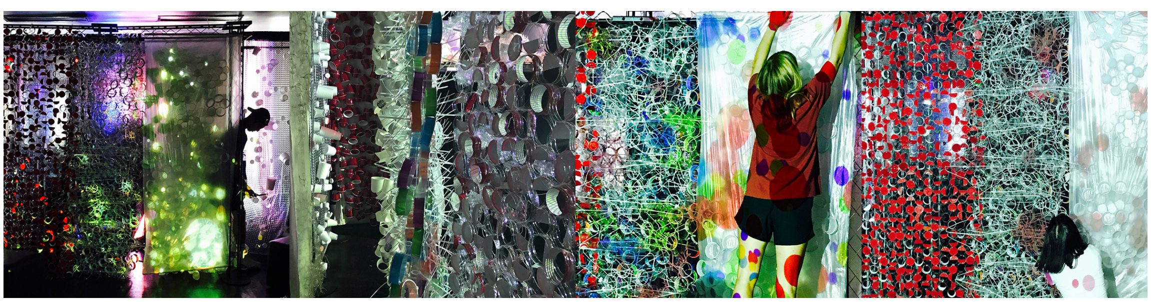

Figure 9. *Kusama Wall*

panels made by students from circular and spherical disposable plastic objects. Animations of circular compositions were projected onto the *Wall*. The author collaborated with artist Hwaryoung Seo to iterate the interactive feature of this project as an event in the future. To activate the animation projection, the viewer will be given a chip to insert into a "card reader," a reminiscence of a credit card reader. The colorful and fleeting projections are an analogy of the illusionary luxury that consumers experience (Figure 9).

5. Exploration 4: Middle School STEM Pedagogy

Most recently, the author collaborated with Ergun Akleman, Liang Hong, and Mary M. Capraro, two engineers and one educator, to explore the possibility of using recycled plastics as a source in middle school science, technology, engineering, and mathematics (STEM) education. In an initial study, the team investigated how to teach children both recycling and geometry in an integrated process by constructing deltahedra from recycled plastic bottles [He 2017]. The work demonstrates that the two-bottle modules can potentially represent all possible 2-manifold meshes. To make the process as ``easy and safe" as possible for children, we avoided cutting the bottles. To ensure structural stability, we used triangular faces. As an implication of the theoretical foundations, all possible deltahedra, i.e. polyhedra whose faces are all equilateral triangles, can be constructed by assembling these two-bottle modular units (Figure 10).

Figure 10. Initial Study: Constructing Polyhedra with Water Bottles

Departing from the initial study, future work will examine how to engage middle-school students in a real-world STEM project–based learning activity that utilizes a portable recycling lab to transform disposable plastic packaging, such as water bottles, cups, and jugs, into educational models and structures. This project will involve a variety of STEM concepts using the engineering design model. The objective of this research is to generate and provide data reflecting on the effectiveness of stimulating young minds' intellectual curiosity and discovery mindset by linking familiar recycled plastic packaging into unique items of discovery; demonstrating the power of creativity in transforming "waste" into educational models and structures; establishing the connection between fabrication and abstract mathematics; and integrating new technology into learning, such as computer 3D modeling and 3D printing.

This future work will integrate learning and making through a tangible process, bringing the real-world grand engineering challenge to the middle-school STEM classroom. Students will learn STEM concepts in an interdisciplinary approach: the *science* of recycling plastics, the *technology* of 3D printing, the *engineering* of mechanical systems and connectors, and the *mathematics* of geometric structures. The project will empower young minds to creatively use their acquired STEM knowledge to realize the social responsibility of recycling.

6. Conclusion

From design to construction, from art to engineering, and from consumerism to aesthetics, the inquiries and discoveries of recycled plastics extend in multiple dimensions. Some efforts aim at finding a solution. Others target at raising a question. Regardless if they solve a problem the purpose, perhaps, is to reflect on our own creativity – the contradictions and complexity in the everchanging world – as Hakkens described on his blog, "plastic is made to last forever but designed to threw away." [Hakkens 2018].

Ultimately, these projects ask philosophical questions of value in the context of the prevalent consumerism of the modern society. Is value inherent in material itself or the object that material is made to be? What is the critical point when waste becomes valuable? Is recycling an economic solution of cost and efficiency or is it an ethical position?

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how these were designed and fabricated as well as which were the challenges in modelling such shapes at a large scale. Given the focus of the event on generating shapes and the interplay of theory and practice, it will be useful for the author to describe in more details the processes for building such shapes from the moment that they are conceptualized to their actual fabrication. Conclusions could also point out the challenges for these processes.

“the practical problems of generating shapes and specifically…the interplay of theory and practice,’ or for that matter, its connection to the “crafts to digital” phrase in its title.

sharing more of the geometrical/technical details behind these works

One simple improvement would be to use fewer and larger images, favoring those that best reveal the techniques used to realize these works. If space must be cleared for technical details, the descriptions of other artist’s work could reasonably be trimmed.