How Can Rapid Product Development Support Sustainable Product Design Research

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ABSTRACT

The consequences of the continually increasing impact of human development are confronting many people on a daily basis. Now more than ever there is a need to confront and challenge the way we live, one that is currently based around unsustainable production and consumption. Consequently, the design community has responded by recognising the potential opportunities associated with supporting sustainability, and well-informed designers are in a powerful position to help address some of the issues facing us. For many designers, reframing their practices and processes presents a great challenge.

For new product designers to enter and engage in this new design era requires that sustainable design is deeply embedded into the curriculum of product design programmes. While many design programmes have embraced principle of sustainability, many have developed projects around the need for social responsibility, and have orientated teaching and studio projects around designing products to help those communities in greater need. Alongside is a rise in the number of sustainable design frameworks, all of which propose potential solutions to the world ecological crisis. However these frameworks may not always be founded on a good, or realistic understanding of the underlying ecological principles, or are over simplified by designers who do not have sufficient understanding of the ecological processes that underpin them.

This paper describes some recent activities of the newly formed Sustainable Product Design Research Group at AUT, and presents a recently initiated staff research project to illustrate the role of Universities can play in engaging in the debate around developing a more sustainable future. In this project rapid prototyping product development processes are used as the primary methods with which to explore a recently developed sustainable design approach.

INTRODUCTION

Sustainable development is defined as "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED1987, p47). The activities associated with, and definition of sustainable development is in constant evolution. Few scientific, social and political areas have avoided scrutiny from a sustainability perspective (García-Serna et al. 2007). Historically, it was generally believed that ecological sustainability could only come at the expense of economic profitability. More recently, a triple bottom line approach has become more prevalent and recognises that a long-term solution requires balancing social equity, economic health and the environment (Elkington 1997). This approach has been criticised for being divisive rather than unifying, and is based on an artificial division between society, environment and the economy (García-Serna et al. 2007).

What is more clear however, is that humanity is rapidly consuming the planet's remaining resources more rapidly than they can be renewed by ecological processes. Since the industrial era, the "needs" and demands of humanity have resulted in advanced negative impacts on climate change, ecological degradation and pervasive human poverty (Doppelt 2003). The current ecological footprint of humanity is now thought to exceed the world's ability to regenerate it by approximately one quater (Leape 2006). Consequently, the next period of humanity will be confronted by the negative environmental and social impacts of human development. This current era will be defined by how people respond collectively to these social and environmental challenges. This transition towards sustainability, in its everyday dimension, requires billions of people to quickly redefine their life projects (Manzini & Jegou 2006).

I. SUSTAINABLE PRODUCT DESIGN

Design practitioners are able to promote positive societal change. This may be especially true for changing unsustainable behaviours (Sosa & Gero 2008). Furthermore, designers have a moral and ethical obligation with respect to their designs, and should be conscious of the potential social and environmental impacts of their work (Papanek 1971, Whiteley 1993). Many products highlight the fusion of design and consumerism, and in doing so reveal a lack of value and ambition (Papanek 1971, Whiteley 1993). For the

role and values of design to change, so does the design industry's relationship with society. This requires designers to reflect on whether they are to serve industry needs or can play an informing role through intelligent thought and action, and in doing so positively contribute to the global ecological balance (Whiteley 1993).

The design community has responded to social and environmental issues by developing concepts and frameworks to guide sustainable design activities (Sherwin 2004). These concepts are generally centred on acknowledging ecological limits and demonstrating responsibility, as while increasing contribution to both society and the environment (Sherwin 2004). In general co-design approaches aim to minimise environmental impacts, justified by the economic gains associated with financial savings associated with greater "efficiencies" (Tischner & Charter 2001, Glavič & Lukman 2007). However while environmental impacts may be reduced during during production, a product's environmental impact may not be considered after it has been sold (Ljungberg 2007).

Sustainable design goes well beyond eco-design principles to incorporate greater innovation and include socio-economic and ethical dimensions of sustainability. Sustainable design frameworks have been described as utilising ecological principles as methods of design. However, these are often in direct conflict with the 'triple bottom line' solutions, as described by Tischner and Charter (2001) and Sherwin (2004). In reality, few product examples of exist and are often experimental (Zafarmand et al. 2003, Sherwin 2004).

II. Product Design at Auckland University of Technology

The three-year undergraduate product design programme at AUT University was developed in 2007 and launched with the first intake of students in 2008. In 2011, the programme will have approximately 80 students across the three years as well as eight studying at postgraduate level. The student profile indicates that the undergraduate students in the programme have predominantly transitioned directly from secondary school with a small percentage of students in the 20 to 30 year age bracket.

The development of a new academic programme presents a unique opportunity to develop new teaching and learning approaches, in the absence of constraints of institutional history and tradition. An innovative pedagogical approach to product design is currently being developed in the product design programme at AUT. The definition of a 'product' has been expanded to consist of a range of outcomes including 'the product of' a creative design process' rather than requiring more tangible physical 3D product outcomes. Further to this, and as a response to emerging world sustainability issues, sustainable design is currently being deeply embedded in the curriculum, pedagogy and focus for the entire programme. A number of initiatives are seen by the department as a catalyst to assist in building knowledge and capability in the area of sustainable design and to start to gauge student, interest awareness and understanding of sustainably issues.

A. The Sustainable Product Design Research Group

The Sustainable Product Design Research Group at AUT was established to further inter-disciplinary collaboration and continue research into developing sustainable products and services. The group's main objective is to develop and perform research to underpin innovative sustainable design. A core activity of the group is to grow and develop a quality postgraduate research capability. Ongoing staff research will align with student projects in an effort to develop a greater research capability in the department. Industry support for student projects is considered vital to this process and developing industry partnerships is seen as essential to a successful post graduate programme.

B. Challenges When Engaging Students with Sustainable Design

A recent undergraduate project was undertaken to introduce some of the fundamental concepts of sustainability and sustainable design to undergraduate students, with expectation that the students would deliver practical and tangible outcomes following a creative design process. It was also hoped that the project would also assist students to become engaged with broader issues around the role of design in creating a better future. For the purposes of the project the focus was limited to environmental dimension rather than social dimension of sustainability.

Given the complex and often 'negative impact', focus of environmental sustainability an optimistic approach to the project was developed to inspire and motivate students. Ramirez (2006) argues that sustainability education should be both optimistic and empowering for students. The "Everyday Interventions "project focused on a human-centred approach to sustainable design with positive, practical human behavioural change outcomes centred on the domestic situation. Students were encouraged to see themselves as possible agents of change, rather than focusing on simply trying to reduce a products' environmental impacts products through (eco-efficient) design.

The student responses for this project were generally in line with what is commonly presented in international eco design books (i.e. Fuad-Luke 2009, Proctor 2009) and student design competitions, where design responses are often centered identifying issues of toxicity and lowering material impacts, while minimising the impacts of human consumption/activity. Anecdotally while most students appeared to have some understanding of sustainability they failed to grasp the breadth, depth, scale and complexity of sustainability issues. However, students became more interested, motivated and engaged by sustainability throughout this project. Subsequent to this, class discussions indicate that students are more aware of their (and their friends and families) 'unsustainable' behaviors. Many have indicated that they have now begun to engage and debate sustainability issues with them as well. The design outcomes produced by students demonstrated the use of 'design thinking' to push beyond physical 3D products to higher level services and system based solutions.

While this project did provided a good platform to begin to engage students with issues around sustainability and

sustainable design, there is a need to engage students more deeply with a deeper understanding of ecological systems and processes. This may involve engaging students in real environmental design problems by working alongside biologists and ecologists. This will help encourage a greater level of ecological literacy, which will consequently help students' engage in eco-design projects in a more meaningful way. It will provide them with better tools to challenge their design actions and impart them with the knowledge of what questions they should be asking, and what specialists may be able to help them answer these questions. It is anticipated that an important outcome of this approach is that design students learn to acknowledge the complexity of ecological systems. Furthermore, this project has helped to raise the importance of staff and postgraduate research to inform teaching, and provide positive and influential examples of sustainable product design.

C. Design for Biodiversity: Ceramic Printing a 3D Structure for Biodiversity

Cradle to Cradle (C2C) is a sustainable design framework for designing products inspired by looking to natural systems (Braungart et al. 2007). Braungart et al. (2007, p1338) suggest their "eco-effective" approach "*proposes the transformation of products and their associated material flows such that they form a supportive relationship with ecological systems and future economic growth*". The authors claim this generates a synergy between economic and ecological systems. Eco-effectiveness starts with a vision that industry is 100% good. The concept of waste does not exist, as all outputs from one process become inputs for other processes. Consequently, this approach may result in the replenishment and regeneration of natural systems, as well guaranteeing that we are able to develop a world that is culturally and ecologically diverse (Braungart et al. 2007).

The C2C approach was recently explored from an ecological perspective in an attempt to determine the potential of this approach for the product design (Reay et al. *in press*). A series of semi-structured key informant interviews with senior New Zealand scientists were undertaken to broadly explore the biological processes, and the development of materials and processes that may be required for the development of sustainable systems (Reay et al. *in press*). Participants were given a copy of Braungart et al. (2007)'s C2C article prior to being interviewed.

A dominant theme that emerged from the interviews was the complexity associated with understanding the interactions of humans, societies and their environments. To adequately address sustainability issues requires an ability to explore and work within complex systems and demands (Bradbury 2002, van Roon & Knight 2004). This requires the capacity to ask questions framed in an appropriate context and the aptitude to interpret and discuss complex results. The participants' considered the environment as the foundation of sustainability. Therefore the protection of biodiversity and the natural systems in which it persists is fundamental to sustainability (Reay et al. *in press*). In general participants' expressed caution when approaching the C2C concept of biological nutrients as a simple solution to sustainability problems. While participants' generally favoured the C2C rationale, most considered it to be idealistic: a good idea in principle, but not in practice and C2C was not widely accepted as a framework that would reflect the realities of complex social and environmental ecosystems.

The loss of biodiversity, arguably the dominant contributor to environmental sustainability, is considered one of the greatest threats to the continued survival of humans on earth (Wood 2000). The destruction of biodiversity and associated failure of ecological systems resulting from human activities is a main factor contributing to the collapse of many societies throughout history (Diamond 2005). In addition, our reliance on ecosystems, and the likely failure of these ecosystems to further adapt to human impacts, will have serious implications on the health and wellbeing of future populations (Walter-Toews 2004).

The key findings from Reay (2011) were used as a starting point to develop and propose a new design approach that places biodiversity central to the design decision-making process. This design approach is intended to be used as a concept ideation tool, and to support subsequent design process. The approached builds on Braungart et al.'s (2007) concept of a biological nutrient. The resulting "Design for Biodiversity" is relatively untested approach, and attempts to encourage the designer to consider the ecological implications of their design process in a more rigorous way.

The Design for Biodiversity approach recognises higher levels of complexity and the connection and dependence of people and ecosystems. With this approach, a primary role of products is to support biodiversity, while satisfying human user requirements. This approach is the result of applying the discipline of design to current ecological issues. Using this approach helps recognise the ecosystem as the basic unit of ecology and represents the systemic relatedness of everything to everything else (Park 2000). This approach acknowledges the importance of human impacts on ecosystems, and "the intimate, and reciprocal, relationship between human activity and the health and integrity of ecosystems" (Van Root & Knight 2004, p269), and attempts to enhance the positive nature of these relationships.

People are highly dependent on the natural systems in which they live, and are an integral part of them. These systems are in turn highly depended on, and vulnerable to people's actions and activities. Ultimately, the Design for Biodiversity approach may be used as an overarching anchor, to guide, inform and affirm the projects' ethical and moral integrity, with regard to sustainable design.

The current research project described here is a unique opportunity to use an inter-disciplinary approach to explore a design solution by bringing rapid product development technologies with design thinking. While historically advancing technologies may have been viewed as in direct conflict to furthering ecological sustainability, this project proposes applying new prototyping and production methods to sustainable design. We believe that better collaboration between disciplines is necessary to explore the sustainability challenges facing our societies, and to help address and increase the understanding of issues centred on sustainability,

framed in the context of understanding ecological systems. Furthermore, it is a unique opportunity to further develop specific additive manufacturing processes, while exploring the design of products to support biodiversity. In doing this, we are establishing a programme of collaborative staff research that should also inform both graduate and undergraduate teaching.

III. Enhancing Biodiversity Project

The project described here, "Enhancing Urban Biodiversity", is the first major applied research project by the Sustainable Product Design Research Group. The goal of the project is to research and develop innovative ceramic tiles for building facades and fences that serve as ecological habitats for indigenous plant and animal species in urban environments.

The first phase focuses on the research, development and testing of material formulas and processes for a innovative, additive ceramic 3D printing method, the development of a detailed set of design parameters including ecological, functional and visual criteria, design work and the production of 'proof of concept prototypes'.

This entails detailed research and exploration of a new and emerging area of 3D printing using ceramic powders process. In this process ceramic parts can be printed with unique structures, which are not possible using traditional slip casting and other methods. The research will draw upon existing research in this area including identifying existing material formulas and processes. It is envisioned that following this, a range of experiments will be conducted through the printing of sample parts to establish optimum ceramic powder and binder formulas.

The outcome of this initial research phase will be the design and production of a prototype, 'proof of concept' 3D cladding tile to be attached to existing structures and new developments. The design will exploit the potential for 3D ceramic printing technologies to provide an internal cavity that is able to 'house' plant and animal species. This 'living' substrate will not require seeding of initial colonisers, but as a substrate will provide habitat for a range of species, that may colonise when ecological requirements are satisfied by prior successional colonising organisms.

It is anticipated that in its initial state the tile will most probably represent an aesthetically 'clean' and simple structure. Over time this structure will weather, require minimal or no maintenance and will start to 'wear' as biological entities adhere and develop. It is anticipated that the structure will transform to become a dynamic structure that harbours and supports on-going ecological activity.

The second phase will involve the collaboration of a range of experts from a diverse variety of disciplines including engineers, designers, ecologists, conservation experts and social scientists, as well as potentially providing a platform for further postgraduate student projects. The main objectives will be to test the prototype blocks in a range of urban environments to assess biological activity over time, and to explore urban communities' perceptions of biological diversity.

IV. Examples to Date

To date the "Enhancing Urban Biodiversity" project has facilitated the development a unique ceramic printing recipe, and the printing of a number of initial tile concepts.

Fig. 1 Samples of prototype cylinders developed using additive manufacturing processes in preparation for material property tests.

Fig. 2 Samples of prototype cylinders developed using additive manufacturing processes in preparation for material property tests.

Fig. 3 Samples of a prototype ceramic structure developed using additive manufacturing processes.

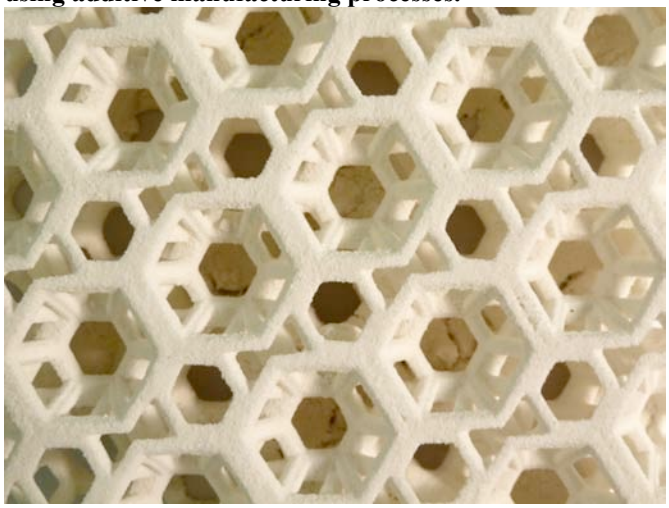
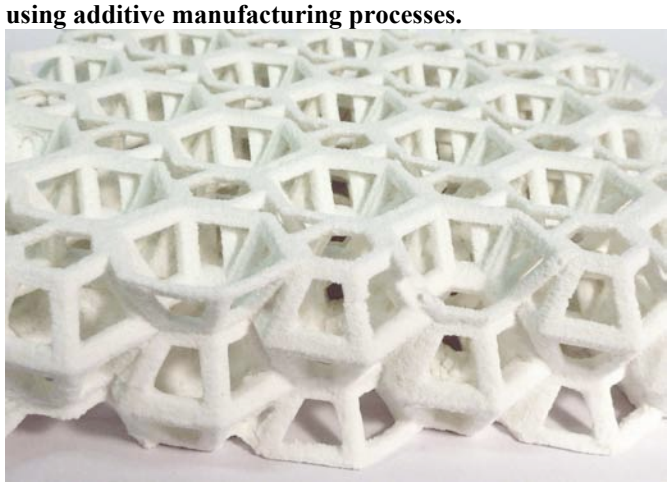


Fig. 4 Samples of ceramic prototype structure developed using additive manufacturing processes.



VI. Conclusion

This paper has presented an overview of sustainable product design in the new product design programme at AUT University. It illustrates some of the challenges when attempting to engage students with sustainable design. Furthermore, it is important to continue to challenge students to move beyond simple eco design strategies and responses. In order to achieve this requires that design educators help find projects that challenge students and require that they engage with environmental issues at a deeper level. What is becoming clear is the need for greater interdisciplinary research and collaboration.

Specifically, this paper illustrates the importance of using advanced rapid prototyping and manufacturing technologies, such as additive manufacturing to develop sustainably designed products. It has described a project currently underway in the Sustainable Design Research Group at AUT that brings together a scientific approach, to design thinking using innovative additive manufacturing, 3D printing processes.

It is essential that universities and institutions of higher learning engage students with sustainability. It is also essential that the teaching of sustainable design be embedded deeply into the curriculum of design programmes. By educating a new breed of environmentally aware designers will ultimately help to demonstrate the value of design to external stakeholders involved in the environmental, agricultural and conservation sciences.

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