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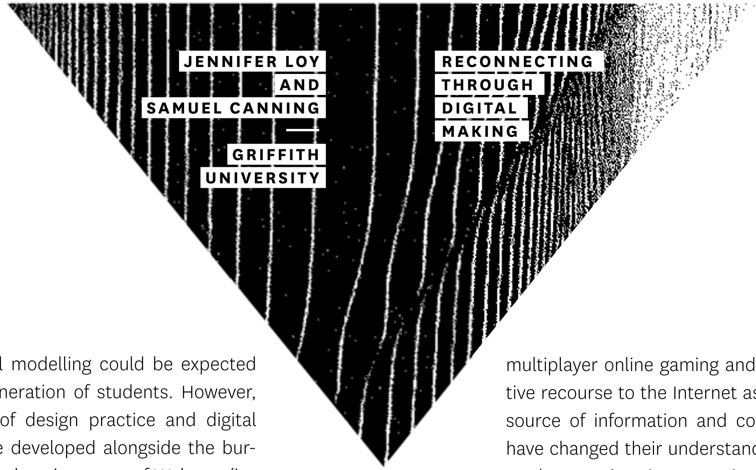

Reconnecting Through Digital Making

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INTRODUCTION: LEARNING BY MAKING

'Making stuff' in an educational setting has been an integral part of learning for Product Design since programs were first developed. Sketch modelling and prototype making have been fundamental to the working practice of professional product designers[1] and degree programs have traditionally emulated this practice. The value of learning by making and project-based learning has long been identified for applied design disciplines, from Fashion to Architecture.[2] Even so, there have been growing financial and health and safety pressures to move programs away from hands-on workshop practice and learning by making to purely lecture and studio based programs with virtual rather than physical modelling.

There is, however, a generation of unlikely saviours of workshop practice emerging. The latest cohort of high school leavers was born after the growth of the Internet in the mid nineties. These 'digital natives' have grown up with their teenage years predominantly spent in a digital environment. A further move from workshop practice to computer based visual modelling could be expected with this generation of students. However, new forms of design practice and digital making have developed alongside the burgeoning digital environment of Web 2.0 (interactive online facilities such as Wikipedia) that are challenging that assumption. This article considers the background to these changes and provides an example of practice supporting the argument that a re-invigoration of learning by making can occur in Product Design education through digital making.

A CULTURE OF DISCONNECT TO OBJECTS

Current high school students have life experiences dominated by online and virtual activities in ways that could not have been predicted.[3] Tweeting, texting, You Tube, multiplayer online gaming and that instinctive recourse to the Internet as the primary source of information and communication have changed their understandings and everyday practices in comparison to previous generations. This immersion in the virtual world could, theoretically, be causing these embryonic adults to become disconnected from the meanings and mechanisms of their physical environment.

In addition, Australian products are predominantly made in distant places, in ways that are unseen to the average school leaver, in a mass production system beyond the influence of individual consumers. Removing control from the user reduces the sense of responsibility of that user both for the object being brought into existence and for its fate at the end of its working life. A lack of understanding of making, and of how products are fundamentally constructed, because of that distance from production, is likely to result in a reduced ability to manipulate and repair objects or attempt to deconstruct them after use to reclaim parts or materials.[4] Current commercial products are rarely designed to be repaired by the user. Reducing learning by making in Product Design education is likely to contribute to this design trend.

A CULTURE OF DISCONNECT IN THE LEARNING ENVIRONMENT

Design is described as an iterative process developed through exploration, research, sketching, studio modelling, idea development, testing and prototyping as a seamless experience, with the ability to move between techniques and approaches to inspire, inform, develop and validate as necessary.[5] Yet the learning environment for Product Design in higher education has arguably not evolved in step with this intent. The studio culture[6] has receded in many Australian Universities in favour of either a 'hot desking' approach (where students use impersonal work spaces on an ad hoc basis) due to increased numbers, or a transient classroom, booked for contact hours only. At the same time, workshops are in danger of becoming over controlled spaces, discouraging experimentation, as risk management requires increased supervision by academics and pressures on the curriculum reduce the time available for students to gain sufficient skills to work to a standard unaided. Meanwhile, computer learning labs have come into being over the last twenty years and although they are heavily utilised,

1.Terstiege, G (Ed.) 2009 *The Making of Design*, Birkhauser, Basel.

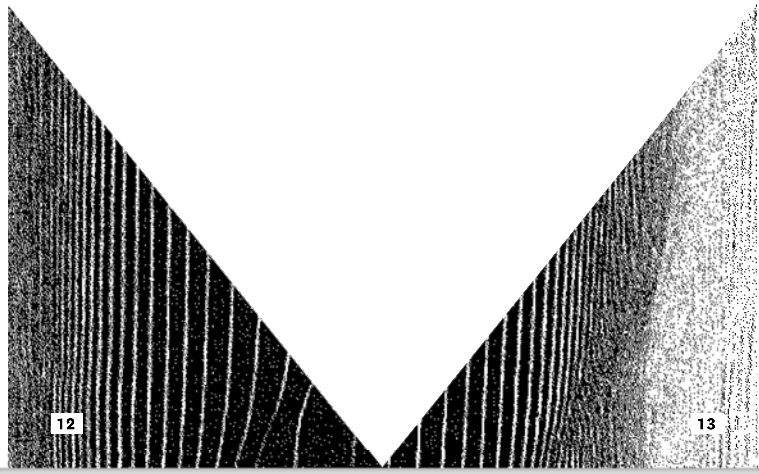
2. Wallis, LH, 2005 'Drawing conclusions from LBM studios (Learning by Making)', *Drawing Together: Convergent practices in architectural education*, 29-30 September 2005, Brisbane, pp. 42.

3. Tapscott, D, Williams, D 2006 *Wikinomics: How Mass Collaboration Changes Everything*, Portfolio, London.

4. Frayling, C 2011 'We must all turn to the crafts' *The Power of Making*, D. Charny (ed) Victoria and Albert Publishing, London p29-33.

5. Milton, A Rodgers, P 2011 *Product Design (portfolio)*, Laurence King, London.

6. Wallis, LH, 2007 'Building the Studio Environment', *Design Studio Pedagogy: Horizons for the Future*, Urban International Press, Ashraf M Salama and Nicholas Wilkinson (ed), Gateshead, pp. 201- 218.



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their design as learning spaces is rarely thought through further than rows of computers with a large screen at one end of the room. Computer aided design was initially seen by students as supplementing studio and workshop practice, but the quality of 3D modelling software and the rendering capability now is such that some students no longer understand the need to make physical models to communicate their design ideas. Worse, lecturers drawn to projects that are provocations, or based in an abstracted reality, can be equally seduced by the virtual world, valuing only the concept phase of a design project and stopping short of any practical realisation or testing of ideas that is regarded as fundamental to design development in the working practice of examples of leading professional designers.[7] Without that design development anchored in the reality of making, design stops short at an early concept stage of development, with the iterative practical development stage, where design ideas are fed by directed research into materials, processes, production, ergonomics etc, ignored. Design becomes a diluted discipline that 'anyone can do', without a valued body of knowledge, invaded by the humanities and in danger of becoming a transferable skill of 'design thinking' across multiple unrelated disciplines with the associated concerns raised by Crisp[8] and Loy[9] for the rigour and integrity of the discipline itself.

Overall, learning through making, already under financial pressure because of the burden of sustaining traditional workshops, loses traction with both students who are more comfortable in the digital world and disconnected to the construction of the objects around them, and lecturers looking to interdisciplinarity in a competitive funding and publication environment. It is difficult to defend workshop space when lecturers and students are themselves ambivalenta about even studio material modelling, let alone using resistant materials.

RECONNECTING THROUGH DIGITAL MAKING

Contrary to what could be expected with the rise of the Internet and the virtual environment, the Maker Society, as defined by Anderson in his book *Makers: The new industrial revolution*,[10] has not been killed off by the digital, but in contrast is experiencing a resurgence led by increased communication through Web 2.0 and new digital making opportunities. An example of this phenomenon has been the rise of the networked FabLabs.[11] These were an initiative by Neil Gershenfeld, the Director of the MIT Centre for Bits and Atoms, to provide open access to high technology digital making equipment. Initially set up as an experiment to meet his academic requirement for community engagement, this project has spread throughout the world, with 117 registered sites predominantly in Europe and America (plus officially in this part of the world one in Wellington and one planned to be opened in Brisbane in July) with some of the most innovative projects coming out of FabLabs in more remote locations, such as Afghanistan. CNC routering, laser cutting, digital embroidery, electronics and 3D printing (the common term for a range of additive manufacturing technologies) are provided in a FabLab. Gershenfeld suggests that the digital basis for the making facilities on offer reconnects the two worlds, digital and physical.

This link between screen and reality provides an opportunity to engage higher education students with making again. Advanced technology machinery can be installed in a University studio environment, rather than in a separate workshop. A studio equipped with computers and digital fabrication machinery changes the relationship of students to making, meeting them in a familiar space and building on their CAD modelling skills. Once their confidence is increased through digital making, they can then transition to a conventional workshop more easily. Subtractive digital technology (CNC and laser cutting) for digital making has been available in education for over a decade, but it is the 3D printer, directly linked to their comfort zone and translating the proficiency that digital natives demonstrate in 3D CAD modelling, that empowers the student and changes their relationship with the objects and mechanisms of their physical environment.

With this potential, it could be expected that Product Design educators would be at the forefront of driving additive manufacturing into the curriculum at every opportunity. Yet from a learning by making standpoint, if the hype on 3D printing was to be believed so that 'anything' could be printed and that complexity came 'for free' and that the build of support scaffolding was left to hidden agency in proprietary software, then the 'push button' making it provided would actually add to the disconnect between students and making, not address it. In reality,

7. Hudson, J 2011 *Process 2nd Edition: 50 Product Designs from Concept to Manufacture* Laurence King, London.

8. Crisp, A, Arthur, L, Hardy, C 2011 'Education: Creating Innovation' in proceedings *13th International Conference on Engineering and Product Design Education* A Kovacevic, W Ion, C McMahon, L Buck, P Hogarth, (Eds) pp 85-90 Institute of Engineering Designers, Wilts.

9. Loy, J 2012 'Creating confidence in an alienating educational environment' in proceedings *14th International Conference on Engineering and Product Design Education* A Kovacevic, W Ion, C McMahon, L Buck, P Hogarth, (Eds), Institute of Engineering

10. Anderson, C 2012 *Makers: The Next Industrial Revolution* Crown Business, New York. Designers, Wilts.

11. Gershenfeld, N 2007 *Fab: The coming revolution on your desktop—from personal computers to personal fabrication*, Basic books, New York.

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additive manufacturing, in all its forms, has as many constraints and design considerations as any other production process, as outlined by Gibson et al.[12] Educators have been exploring those realities themselves, as demonstrated by the Royal College of Art project in 2007 to challenge leading designers to 'mould the unmouldable'[13] and introducing projects addressing specific technologies, such as the University of Technology, Sydney's Digifracture project on selective laser sintering,[14] but, just as a drive for the uptake of 3D printing worldwide has come from the general public with over 300,000 designs uploaded on the hobbyist online service provider Shapeways, so too has there been a drive to bring digital making into learning by making in Product Design education from the students themselves.

EXAMPLE OF PRACTICE: DIGITAL MAKING IN THE CURRICULUM

The cost of stereo lithography for rapid prototyping over the last fifteen years meant that additive manufacturing was generally confined to research and postgraduate work in Product Design at Griffith University until a few years ago. Since then fused deposition modellers (class size with soluble support material and desk top with same support material) have become affordable for the classroom (RMIT, for example, have a personal 3D printer attached to each computer in their technology teaching space) but only a few universities, such as Auckland University of Technology, as yet have a selective laser sintering machine in house. In 2008 the Dutch company Shapeways launched an online 3D printing service that provided subsidised printing, introducing nylon products in 2009 and metals and ceramics since. In four years they have printed over a million objects and been joined by several other online service providers, such as imaterialise, and it is these services that has enabled a democratised uptake of digital making in undergraduate education.

In 2010 third year students at QCA Griffith University studying Product Design started using Shapeways to 3D print their prototypes across projects. Until then, visual models were limited to foam models they could produce in the workshop and mechanisms testing was either through working models they could produce or expensive samples they had made by a specialist, usually only for a competition. With the newly competitive online service providers, students were able to produce effective working prototypes of small items that were inexpensive enough to be developed—through several iterations if necessary—to achieve viable designs. This work was characterised by being prototypes with production detailing such as parting lines and draft angles as illustrated in figure 1 and 2.

01

◂ FIGURE 1 Matt Harcourt

02

◂ FIGURE 2 Ana Cespedes

In 2011, second year students were given a packaging project based on fused deposition modelling. The students were asked to produce a point of sale perfume display as part of their assessment where the bottle forms they produced would inform the final mass-produced bottles. Whilst students still predominantly thought in conventional manufacturing terms, there were examples of objects that could not have been produced by techniques requiring male and female molds. In addition, released from making the difficulties of making complex models in foam, students produced forms they would struggle to construct otherwise.

The creative potential for artistic work demonstrated by the work led to a collaborative 3D printing project where a postgraduate created a leather headpiece then translated by lecturers (authors Loy and Canning) into CAD suitable for printing. The finished item was exhibited at the Materialise conference, Belgium and Rapid conference, USA.

These activities demonstrated a potential for the development of new forms and ways of thinking, but the second year students involved had studied processes and materials in the first year and still came to the project from a starting point of conventional manufacturing.

A component approach was even clearer in the headpiece—although the product was not, and was never going to be, made in

12. Gibson, I, Rosen, D, Stucker, B 2010 *Additive Manufacturing Technologies: Rapid Prototyping to direct digital manufacturing*, Springer, New York.

13. Aldersley-Williams, H 2011 *The New Tin Ear: Manufacturing, Materials and the Rise of the User-Maker*, RSA Design Projects, London [www.thersa.org/events/audio-and-past-events/2011/less-stuff,-more-performance,-better-fit] checked 6.5. 2013.

14. Pandolfo, B. 2010, 'Digifacture: Industrial Design and Advanced Manufacturing - A New Relationship', *Fraser Studio*, DAB Doc, Sydney Design 2010.

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components that was how it was modelled because of the mass production experience that informed the lecturers' thinking. Just as professional designers have tended to approach additive manufacturing as a replacement for other polymer processing techniques, so too will lecturers, such as the authors, whose careers have been built in the conventional manufacturing environment. Professional development opportunities are needed to make that transition in thinking to explore the potential of 3D printing. To understand and anticipate the opportunities for future graduates emerging through the digital environment, from screen to reality, is a challenge. This is illustrated by considering the changes in Product Design practice over the last four years—the length of an Honours degree—through the digital environment. The rise in crowd sourcing in Product Design, for example, as used by leading design consultancy IDEO[15] and the introduction on online mass customization, championed by Assa Ashuach with the co-design web site UCODO and developed with Lisa Harouni through the company Digital Forming, both change the way Product Designers in the future can interact with users and impact on Product Design education. Manufacturers who have been able to exploit the advantages of additive manufacturing by working with organisations with an in-depth knowledge of the technologies, such as hearing aid manufacturers Phonak working with research and development leaders Materialise, are gaining significant advantages through innovative thinking informed by understanding.

15. IDEO 2011 *Human-Centered Design Toolkit: An Open-Source Toolkit To Inspire New Solutions in the Developing World*, IDEO, London (offices worldwide).

From dentures to spare parts, new ways of working through additive manufacturing allows for innovation and preparing students to graduate with an understanding of that potential in four years time requires a reevaluation of educational practice.

FIGURE 10 ► Example of first year project work: Megan Rowe

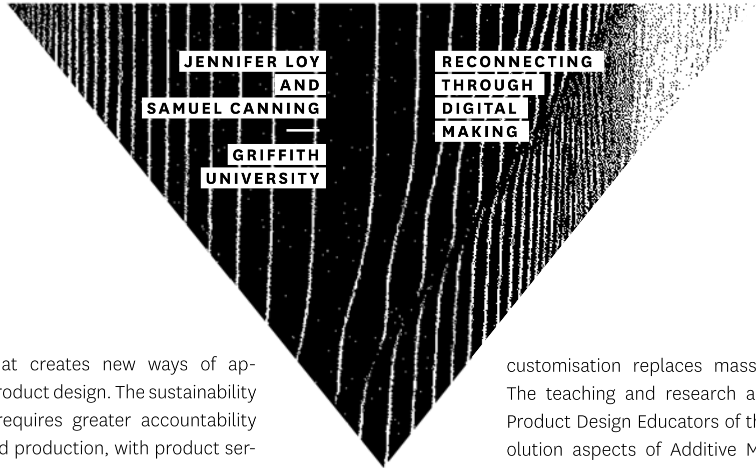
FIGURE 11 ► Examples of first year project studio making: Paul Bardini, Alessandro Innocenti

Based on this thinking, the decision was made that additive manufacturing would become the first manufacturing process the students would learn when they started their degree. The first year processes and materials course, introducing workshop practice, was turned on its head with additive manufacturing the first process students experienced, with established production methods, such as injection moulding, then introduced in comparison, rather than the other way around. The packaging project was brought into the first year, with the added proposal that the client had asked if the bottle could be produced using 3D printing for a short run, niche market.

In addition to the point of sale display, students were required to research a report on the viability of that proposal in comparison to using more conventional processes and outline the considerations for the client. The first year CAD course was rewritten, ramping up learning to allow students to model their own designs by the end of the semester.

The fact that the work was to be physically 3D printed and laser cut generated heightened excitement and enthusiasm, with students' motivation and willingness to interrogate their own CAD work noticeably increased.

To connect studio design, CAD and digital making for a more iterative process, students worked in an advanced technology studio environment that combined computers, table space for drawing and sketch modelling, an enclosed CNC router, A3 laser cutter and desktop 3D printer to encourage an integration of computer modelling, studio design development and digital making. Although the class sized fused deposition modeller was available, students were encouraged to first gain hands on experience of the more accessible digital fabrication equipment. The project work was student led, where they mapped what had to be done, their risk assessment, brought in materials, created CAD drawings and made test cuts and 3D prints as they saw fit (Figure 10 and 11). A woodwork workshop was immediately next door and students had the option of being inducted into using some of the machinery and hand tools in there and were actively encouraged to use the bench spaces for jig making. Once the students were comfortable in the mixed environment, they



were then given a demonstration of vacuum forming in the plastics workshop and shown strip heaters. They were encouraged to make foam formers for the vacuum former and create inserts for their packaging to fit their designs.

Based on student feedback, the biggest difference in working this way to introduce a cohort from the 'digital native' generation to workshop practice and learning by making was that they felt empowered by the learning experience and not frustrated by the standard of work they were able to produce, as had been the feedback on the workshop component of the course in previous years. Student evaluations gave the course overall positive feedback and from a lecturer point of view, the positive experience of having to prise students out of the workshops hours after the contact time reinforced the value of learning by making in the current curriculum, adapted to encompass digital making, not in conflict with it. The student work was made to a sufficient production standard that it could be included in the exhibition that accompanied the 3D printing forum organised by the authors at Griffith in conjunction with Materialise Europe, QMI and The Edge alongside work from postgraduates and leading European designers.

CONCLUSION: DIGITAL MAKING AND INDUSTRIAL REVOLUTION 2.0

Additive manufacturing has only had viable direct manufacturing capability in the last five years. Already it is impacting a broad range of industries, from medical to automotive. In each case, it is the customisation potential that creates new ways of approaching product design. The sustainability imperative requires greater accountability in design and production, with product service systems thinking and invested design principles driving the redesign of products. UK Designer and Commentator, Geoff Hollington, suggests that the dominance of mass production is being challenged by the potential of additive manufacturing as a transformative technology 'with the potential to transform both the global economy and the consumer society'.[16] Digital natives are using Web 2.0 as pro-sumers or co-consumers in increasing numbers, rather than as the passive recipients of anonymous product. The first industrial revolution has even been described as a 'temporary interlude' if distributed manufacturing again becomes prevalent and demand for mass customisation replaces mass production. The teaching and research advantage for Product Design Educators of the social revolution aspects of Additive Manufacturing is that the impacts touch on vital areas of consumption, socio-cultural sustainability, urban planning and regional economic development with extensive literature on the subjects, for example in the collected essays in Open Design Now, the essay by Atkinson[17] of particular relevance.

Teaching additive manufacturing will not be like teaching other production processes. Product Design students need to graduate into the digital world grounded in the physical world, with an evolving understanding of the context they operate in. They need to be prepared to lead the redevelopment of consumer products within the sustainability imperative and be equipped to make a living within the profession whilst influencing the changing production landscape positively with informed thinking and practice. The digital realm may have contributed to the alienation of the younger generation to the built environment, but conventional production methods had the major effect in creating low value, disconnected products. There are examples of designs that contribute to a reconnection of users with the mechanisms of products (for example in the transparency of the working of the Dyson cyclone vacuum), but this needs to go further for product service systems to be effective, with design for disassembly and repair fundamental for future products. Additive manufacturing, with personal printing and distributed manufacturing has the potential to make that a reality. Embracing it as a driver for learning by making for grounded, reality based projects reconnects future product designers to the objects they design and supports a positive future in a digital realm beyond current understanding.

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16. Aldersley-Williams, H 2011 *The New Tin Ear: Manufacturing, Materials and the Rise of the User-Maker*, RSA Design Projects, London [www.thersa.org/events/audio-and-past-events/2011/less-stuff,-more-performance,-better-fit]checked 6.5. 2013.

17. Atkinson, P 2011 'Orchestral Manoeuvres in Design' in B Van Abel, L Evers, R Klaassen & P Troxler, (Eds) *Open Design Now*, BIS, Netherlands.