Evolving a University product Design Program: An Approach for Contemporary Design Practice

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Abstract

The expanding nature of professional disciplines of product design has placed pressure on university product design programs to educate students across all potential aspects of the profession. At the University of Technology Sydney, the School of Design's move to restructure all design programs from a four-year to three-year degree, with a one year honours extension, presented an opportunity to rapidly evolve the product design program. The development of subjects in the new integrated product design degree seeks to establish a focus and identity for the program that will align more precisely with design innovation of artefacts within the broad spectrum of the product design discipline. Research into contemporary and predictable future practice of product design, taking into account socio-cultural and technological change (such as additive manufacturing), is guided by the strengths of the academic staff in the program. This research provides the foundation for new program directions. Comparisons made between a subject in the new degree, and the requirements and expectations of a compatible subject in the former degree reveal a number of valid conditions that guide the transition. These conditions include emphasis on the way design theory can be translated through practice-orientated learning while de-emphasising dated conventions and restrictions to engage in new, contemporary priorities in design. These findings serve to inform discipline and integrity in contemporary design practice. Further, connecting the research findings with the strategic goals of the Faculty provides a framework to shape the identity for the program that appropriately and effectively underpins teaching through research. This paper proposes a strategic approach to manage change in a product design program, driven by strong research directives to ensure the prosperity and future proofing of the teaching program.

Keywords: *Product design, academic product design research, product design education, design-driven innovation, practice-oriented learning, technology-led thinking.*

Introduction

In 2010, the Industrial Design (ID) program in the Faculty of Design Architecture and Building (DAB) at the University of Technology Sydney (UTS); recognised how socio-cultural and technological change had affected ID practice. The observation drove academic research in the area of product design; to develop strategies to address change and meet the needs of future product design graduates in contemporary design. An essential part of this study was to identify ways to link theory, research and practice as it relates to product design in the development of a new identity for the program. Change is underpinned and driven by both the strategic goals of the Faculty and the core competencies of the staff involved in the program. A further key aspect of the strategy for change, was to rebuild the core structure of the ID program to include strong emphasis on research and prototyping methods. Finally, an important feature of change saw the renaming of the program from Industrial Design to the new Integrated Product Design (IPD). The renaming seeks to reflect the new direction and intent of the program to reinforce a critical connection between teaching and research. The change goes beyond preparing students with important entrepreneurial and strategic approaches to deal with contemporary design problems (Teixeria, 2010; Ball, 2012; Walden and Kokotovich, 2013). The results of the comparative analysis indicate that pedagogical change informed through research undertaken by the academic team involved in the change, encourages a greater depth of outcome. Informed change driven by the research focus of the academic team has served to support an evolutionary shift in the way students develop tangible product design solutions. Where formally students were encouraged to adopt conventional incremental innovation, they are now supported in research based, design-driven product innovation that seeks to challenge the meaning of products (Norman and Verganti, 2014).

Literature

The systems and technologies used for the production of products are changing rapidly, and product design programs need to accommodate and prepare students for this reality. Additive manufacturing (AM), a general term used to describe a number of manufacturing technologies where parts are (3D) printed through adding layer after layer of material, has the potential to change all aspects of a product's lifecycle (Burkhart & Aurich, 2015). AM has been identified as the fastest increasing manufacturing technology, at a time when industrial companies realise that the customisation and individualisation of products is a growing trend (Schröder, Falk & Schmitt). AM is increasingly being used for end-use production applications due to the advantages it provides (Campbell, 2015) as either completed products or as a factor in hybrid manufacturing that combines AM and high-volume machines (and processes) together (Newman et. al., 2015). Broadly speaking, mass-volume manufacturing has a high cost of entry (Ball, 2012) and is therefore difficult to access. Consequently, and with the advent of easy access to global supply chains, the rise of specialised goods, designed for niche markets, that are made using a high level of craft skill are increasingly viable for an expanding number of makers (Anderson, 2012). Furthermore, finely crafted small batch production products (that may or may not incorporate AM) have the advantage of connecting sustainably with communities and cultures in ways that omnipresent, conventional, mass production cannot.

High volume production is no longer, necessarily, the most ideal commercialisation pathway for successful products. Lean, low-volume and small-batch production approaches have gained prominence due to their ability to deliver high-quality, customised products in a flexible manner (Zhang & Tseng, 2008; Ndahi, 2006; Anderson, 2012). Highly individualised designs commissioned to develop specialised technical functionality in areas such as engineering and health (Bongers et. al., 2014) and micro-businesses that use crowdfunding (Ball, 2012) that may be self-initiated designs (Walden, 2015) additionally offer viable alternatives for the commercialisation of products. This is made possible due to easier access to information, local production and global markets via the Internet.

The systems that define how technology-based products are socially and culturally situated have been referred to as product ecology (Forlizzi, 2008) where user-experience is paramount, and this has ramifications for all design programs. The design of products is no longer exclusively about physical elements (form, function and materials) but about the wider concern on the interaction between people and technology where products become platforms for experiences through service offerings (Buchanan, 2001). Companies are now interested in developing what has been referred to as hybrid products (Stickdorn & Schneider, 2011), where the product and service are developed to function inseparably.

Design-led innovation is necessary at a strategic corporate level to embrace exploration and achieve competitive advantage with designers that innovate beyond the traditional differentiators such as styling and user-centred focus (Verganti, 2009). Globalisation has led to a business landscape where firms are required to manage complex, fast-moving environments that require rapid experimentation and strategic insight to address an increasingly uncertain fast changing marketplace (Johnson et. al., 2013). Norman and Verganti (2014) identify the need for companies to move from strategies that deliver incremental changes to their products through technology-push innovation or market-pull innovation strategies alone; toward radical innovation and meaning change strategies that have a design-driven research basis in comprehending socio-cultural models.

Underlying and supporting this shift away from the dependence on mass-production are environmental concerns, particularly, as Parsons (2009) describes, there is a growing concern at over-production and resource use. Ecodesign conditions such as designing to address real, rather than market-driven needs are encouraged. The design of efficient parts that weigh less and adopt geometries that enable repair and serviceability, use local materials and resources where possible and dematerialise products into services wherever feasible (Fuad-Luke, 2002) are collectively less achievable with conventional mass-volume production businesses.

The emergence of multiple modes of design thinking both within the academic design community and as a way of addressing problems in associated professions such as in business (Martin, 2009; Dorst, 2011) has given rise to the need for design programs at a tertiary level to evolve. Notable transitions in design practice from a 'passive condition' where a designer's actions are governed by directives external to their will (Findeli, 2001) toward contemporary modes of working is evident. Contemporary design practice requires a greater focus on the 'knowledge of designing' (Giard, 1990), self-exploratory approaches (Leitner, Innelle & Yauner, 2013) and problem framing of open, complex design concerns (Dorst, 2015) with flexible, methodological prescription (Goldschmidt and Rogers, 2013).

Prototypes and models are made by designers to inform their decision-making processes. In contemporary practice, prototyping is a method used throughout the design process to explore, communicate and develop a product's qualities with users and clients (Milton & Rodgers, 2013). Considered an essential component of design thinking, prototyping has the significant advantage of enabling designers to design with other stakeholders in an exploratory and experimental way (Brown, 2009). Further, prototyping is now considered a central tool in design research, along with sketches, diagrams and scenarios as a core means of building connections between fields of knowledge (Stappers, 2007) and is also used to test (even embody) theory as “physical hypotheses” (Overbeeke et al. 2006). Stappers (2007) views prototyping as a design act and Koskinen (2011) describes expressions through prototyping as the ‘epitome of analysis’ in constructive design research. Prototyping represents the means by which a bridge between knowledge directed research enquiry and design practice, for the purpose of product realisation can be established. Prototyping has long been a key activity in the design of interactive systems (Buchenau & Fulton Suri, 2000) - one example being tangible interaction designs - that require embedded technologies to be tested against user experience. There are cases where prototyping relates closely to making, depending on the nature of the artefact and what the designer hopes to learn about the performance of the design at a given point in the process. As a process, making can enable a designer to achieve absolute understanding about the subject of the product (Crawford, 2009). Making, as a form of proprietary knowledge, only accessible through learning by doing, (Fingleton, 1999) must certainly inform the designer's domain knowledge in product design. This approach is a significant attribute in expertise development (Popovic, 2004) and in entrepreneurial design (Walden & Kokotovich, 2013).

Verganti (2009) states that research focus on meanings in design-led innovation is visionary and based on the designer’s own personal culture. That to differentiate for competitive advantage must not only take into account, but go beyond, styling and user-need for break-through innovation, to change the meaning of products. He refers to research that identifies that the emotional and symbolic aspects of consumption are as important as the utilitarian aspects. The complex combination of changes in the way things are made, consumer expectations and rapidly changing markets requires contemporary designers to be more astute at customising their process to the needs of the project. This will in turn require designers to reflect more closely on their way of working and the significance of their work. A study of self-initiated product design (Walden, 2015) identified that in the absence of upfront client criteria, designers are very capable of drawing upon their own background knowledge to frame, what might be primary generators (Darke, 1979) for design ideas, appropriately into projects that guide a product through to commercialisation. Research suggests that self-initiated design projects are a form of entrepreneurial design that cannot be described using a single design process diagram of tasks. Self-initiated product design as a structure is best described in terms of how the designers own background knowledge informs (as it is shaped by) three common parameters: the degree of control over the development of the outcome imposed by the designer, the nature of the designers support network consulted during the project and the terms of the novelty intrinsic to the uniqueness of the design (Walden, 2015). Both Verganti (2009) and Hara (2008) refer to the importance of culturally relevant design where the individuality of the designer is not suppressed by typical economic strategies of standardisation and mass-volume production.

These findings contribute essential material to inform the rapid evolution of the former program to the new Integrated Product Design Degree.

The IPD Research Unit

The transition from the former Bachelor of Industrial Design (ID) and the new Bachelor of Integrated Product Design (IPD) is considering a number of factors. These include: the change impacting on the professional practice of product design as discussed in the Literature Review section of this paper, the strategic goals of the Faculty of Design Architecture and Building (DAB) and ways of incorporating and adapting the core research competencies of the teaching staff into the program.

The DAB Faculty outlines a series of goals and objectives that combine collectively to guide the development of design program - both in the establishment of their research directives and teaching programs. Considering the influence of technological and socio-cultural changes impacting on the product design discipline, a combination of goals and objectives were selected to position our emphasis and to identify the new IPD program in the context of the Faculty:

SG Strategic Goal Description

1. Management of complex solution driven processes beyond the discipline
2. Entrepreneurial design thinking
3. Flexibility of thinking and solutions that have global impact
4. Interactivation, mapping of complex data and form generation
5. Technology-led thinking with an emphasis on prototyping
6. Socially significant research on the nexus between creativity and technology
7. Practice-orientated learning

(UTS:DAB Strategic Goals and Focus 2011 - 2015).

The members of the teaching team in the former ID and new IPD program have changed from time-to-time in the last four years. Despite this, there has been a long serving, core team with a clear and common approach to implementing the program in terms of their research, teaching and connections with industry. The IPD Research Unit was formed in 2014 to strategically coordinate a research strategy that combined our research strengths in connection with the Faculty goals and objectives to build a consistent identity for the program that can be made evident and be expressed through research output and student work alike. The IPD Research Units research focus is mapped against the DAB Faculty Strategic Goals as shown below. The development of the IPD Research Unit will evolve over time though at the time of writing this paper we describe ourselves as academic design practitioners that conduct knowledge directed enquiry through practitioner action, specialising in new knowledge, strategies and designs to develop the following areas:

IPD Research Focus Areas	SG
● University-industry collaboration (UIC)	1
● Entrepreneurial design	2
● Design-led innovation research	3
● Tangible interaction experience and co-design practice	4
● Additive Manufacturing	5
● Design for low-volume, small-batch, individualised production	6
● Prototyping and making processes	7

IPD Identity

The IPD Research Focus must be clearly specified for the purpose of selecting and working through projects to advance knowledge, forge external linkages and promote the impact of our contribution. Our focus therefore is well defined. Adapting this focus to a teaching program, however, requires an overarching vision statement fit for expressing an identity for the program to academic colleagues, industry partners as well as students and tutors. Our investigation of contemporary industry and practice indicates, found that there are three primary categories that can be broadly associated with the DAB Faculty Strategy and the Research Areas of the IPD Research Unit. These include: how design is delivered experientially and commercially (SG 1 & 2); a focus on people and well-being (SG 3 & 4); the creative integration and exploration of technology (SG 5, 6 & 7). The main contextual change from the former Industrial Design program structure to the new Bachelor of Integrated Product Design involved reflecting upon the way we frame the means whereby a student can establish explicit outcomes via the rationalisation of tacit knowledge. Design thinking involves harnessing tacit knowledge (Moggridge, 2007) in order to determine ways of making that knowledge translatable in embodied design outcomes - such as physical products. Analysis of the Bachelor of Industrial Design identified that tacit knowledge was deemed successfully translated into an explicit form (a product) by delivering outcomes constrained by engineering, business and market-driven constraints. To respond to the evidence of change described in the literature and to combine the identity of the program with the research strengths of the IPD Research Unit, the statement seeks to shift the focus back onto exploration of tacit knowledge through prototyping (expressions of three-dimensional form). It must acknowledge that the means by which products are made and sold are changing. There is an important shift back to product creation[1] through design that considers more than the physical element and is defined by the experience, system and service to which they belong. Consequently, the product success now rests on the experience it provides, placing people and culture at the centre of concern. The work of the IPD Research Unit, supports the new Bachelor of Integrated Product Design, address this problem by expanding the (explicit) terms by which a design (by student or academic) is judged successful, as follows:

To advance human well-being by understanding human experience and providing explicit outcomes that address technology and deliverability constraints through expressions of three-dimensional form.

Smart Design is a new Bachelor of Integrated Product Design 3rd year subject, delivered in 2015, to build upon a re-formated 2nd year Research Methods subject delivered last year. Smart Design replaces a former technology research focused subject that was defined as follows:

[1] For example, the Industrial Designers Society of America (IDSA) described Industrial Design in 2010 as a professional service of creating and developing concepts and specifications that optimise the function, value and appearance of products. In 2015 IDSA describes Industrial Design as a professional service of creating products and systems that optimise function, value and appearance.

The former product technology based subject: This subject makes an in-depth examination of how things work. It is intended to give students an understanding of the technology that makes products work and enables humans to interact and control product functions. The completion of a major project requires students to demonstrate an understanding of the creative application of technology to a product design of their own.

The projects inside the subject had restricted parameters such as requirements to use a ‘diverse range of sensors and actuators’, that the designs ‘must be portable’ and appropriate for ‘mass-production’ and have ‘an appropriate number of parts’. The topic for the projects were restricted either in terms of a requirement to design for a specific user-group or according to heavily focused, upfront emerging technology research. These factors combined, encourage what Norman and Verganti (2014) might describe as either technology-push innovation or market-pull innovation, both only capable of incremental meaning change. The subject does not suitably encourage students to experience design-led innovation that connects people and technology in contemporary ways. The subject restricts the opportunity for tacit knowledge exploration and therefore problem framing of complex design concerns, disencouraging iteration and flexibility in process. We must note that the former subject design was successful in the way it functioned in accordance with the old program structure and was also an appropriate translation of the DAB Faculty Strategic Goals. However, in developing the new program, researched information about contemporary product design industry and practice combined with the research strengths of the IPD Research Unit changes the emphasis we place on design tasks, set for the students. The new IPD subject, Smart Design adopts the following description:

Smart Design subject: As the world is experiencing many profound and rapid technological and social changes, students must be properly prepared to operate in this new environment. Students need to develop next generation products, systems, and environments which are a result of 'smart' thinking and are in themselves 'smart and innovative'. Drawing upon and developing the practical skill sets and design thinking experiences established in the first two years of the curriculum, this subject provides an in-depth examination of how things work, and should work, to benefit larger sociocultural contexts. It provides students with an understanding of the technology that makes products work and enables humans to interact and control products, systems and environments.

Smart Design Results

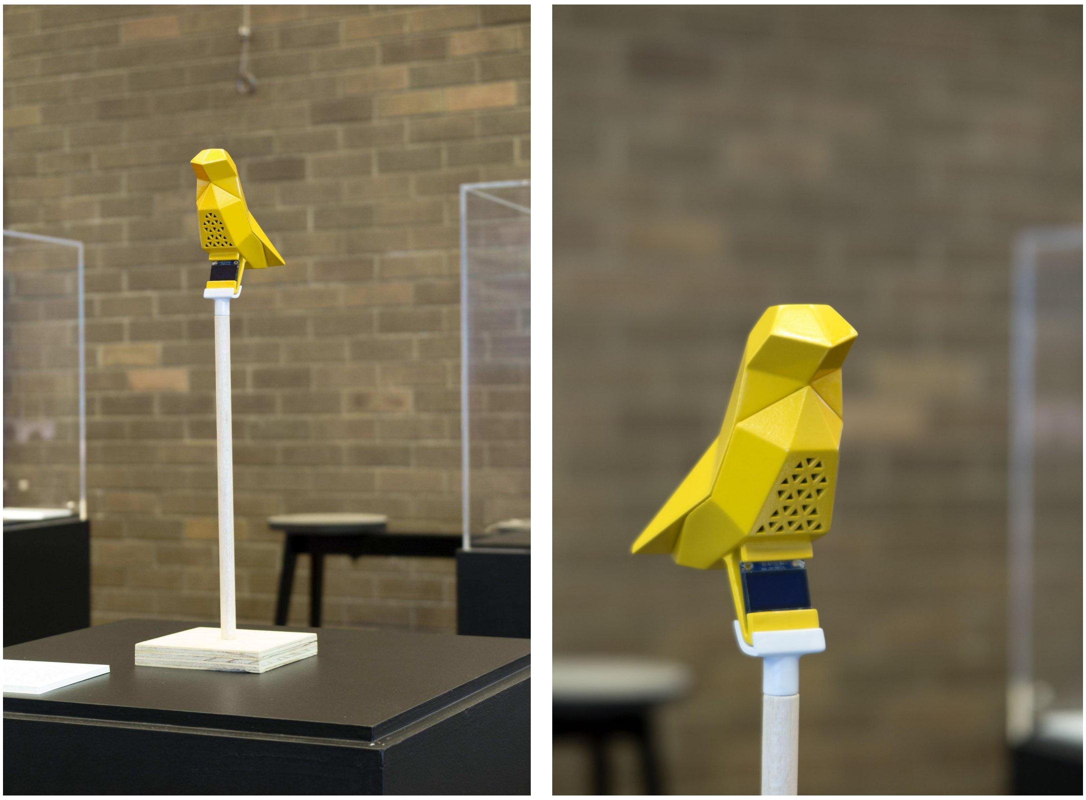

Figure 1 Smart canary

Project Leader: Stefan Lie / Studio Leader: Anton Nemme

Student Designer: James Lau

Description by the student: Animal sentinels have been used throughout human history to detect risks and provide warnings against danger. The “canary in the coal mine” concept provided miners in the 1900’s a method of detecting carbon monoxide and toxic gases as this bird is more sensitive to these gases. This animal-human relationship is also useful in the modern context of air quality in households. An Arduino powered particulate matter sensor (sensitive to smoke, pollen and mould) and an air quality sensor that has a wide scope for detecting harmful gases, makes this possible. The Smart Canary’s OLED screen and colour changing chest help users identify and change habits that may contribute to poor air quality. Creating habits such as turning on ventilation while cooking or vacuuming long before children get home allowing time for particles to settle.

Addressing the subject objectives in connection with the IPD identity statement, the project has been developed in response to the open, complex task, set by the subject, to design an artifact that makes digital data tangible (i.e. specifically not on a screen, as data is typically experienced). The outcome demonstrates how the IPD identity statement and subject description combine to encourage socially significant research to identify connections between technology and human experience. The casing is made using additive manufacturing and the electronics have been coded to make the product operational, demonstrating technology-led thinking and production viability, appropriate for its predictable commercialisation pathway. The design was developed through practice-orientated research prototypes as a means of capturing the cultural relevance of the design via its form.

Figure 2 To capture a moment

Project Leader: Stefan Lie / Studio Leader: Anton Nemme

Student Designer: Kim Stanek

Description by the student: What were previously poignant moments in one’s life are now snapped with a phone; the meaning gone in the fleeting means of documentation. Contrastingly there is still an innate human need to make these moments of time tangible. The constructed device is an exploration of the desire to keep a personal record of one’s life, from birth, to death. Over one’s life, this record will become rich and deeply personal and as the years pass the notated lower section will grow, likening to a tree ring, expanding with years of experience. The device is equipped with a pen that is magnetically connected to the side of the box (not shown in the image) in a specifically allocated position. When the pen is removed from that location to write a note, the mechanism, concealed at the back, is programed to advance the tape by the width of the aperture.

The project above responds to the second project in the subject that sets the task to design an artifact in response to keeping time. Again the brief is left open and encourages the students to conduct social research and technology-led research concurrently in order to identify an opportunity for design intervention. The product proposes a low-volume, high-craft production method appropriate given that the designer intends for the product to be installed in a home for a lifetime, unlike the Smart Canary which abstracts a living thing into a device through its form. The design-led innovation associated with this outcome represents a type of meaning change in the way it suggests a change in the meaning of a note. The design therefore goes further by expressing the designer's individuality and provoking questions about our society and how we record moments of time.

Figure 3 River Flow

Project Leader: Stefan Lie / Studio Leader: Alex Nam

Student Designer: Bradley Saywell

Description by the student: Water scarcity in most parts of Australia has led to strict monitoring and allocation of water resources. Maintaining water for aquatic balance is vital, when allocating river water to reliant industries. The object ‘River Flow’ creates a space and interface facilitating a user's understanding of local river conditions. The device takes data from the NSW Office of Water website that monitors the flow rate of NSW rivers. The flow rate of a river selected by the user is then fed to the device which causes the ‘reeds’ to oscillate in a wave-like motion mimicking the way reeds move in flowing water.

The River Flow project is in response to the data flow design task. Here the designer is proposing an alternative means of visualising the flow rate of a river. The product is large and can be perceived as a living sculpture, constantly moving. The coding and mechanical design required to make the product operate represents a significant amount of work, highlighting the importance of appropriately combining prototyping and technology-led research to iterate through ideas quickly and arrive at concepts early. The product in it’s current form may be interpreted as an individualised one-off product, appropriate given its size and possible application at a river data and flow laboratory. However, it may also be interpreted as a prototype, representative of a working principle, to be scaled down for a different product application. The project shows the emphasis on prototyping and practice-orientated learning. Thematically, the form at once references the graphs and charts normally produced to visualise river flow data while at the same time appropriates the look of the reeds, accurately reflecting their motion based on numeric data, capturing the pace and flow of the river.

Further Research

The IPD degree is part way through its transition. The work presented in this paper has been developed by students who will, next semester study another new subject called Innovation and Commercialisation. There was a deliberate intention in Smart Design to deprioritise manufacturing, commercialisation and marketing emphasis to best align contemporary design practice and build upon the research strengths of the staff group. However, as can be seen, commercialisation pathways for all of these projects are viable given the socio-cultural relationship with technology and making methods. Therefore the way that the Innovation and Commercialisation subject is structured must be designed and then analysed carefully.

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References

Anderson, C. (2012). *Makers : the new industrial revolution*. Random House Business, London.

Ball, R. & Overhill, H. (2012). *Design Direct: How to start your own micro brand*. Hong Kong: PTeC Publishers.

Bongers, A.J., Smith, S., Donker, V., Pickrell, M., Hall, R. & Lie, S. (2014). Interactive Infrastructures: Physical Rehabilitation Modules for Pervasive Healthcare Technology. In Holzinger, A., Ziefle, M. & Röcker, C. (eds), *Pervasive Health – State of the Art and Beyond*, Springer Verlag, London, pp. 229-254.

Brown, T. (2009). *Change by design: How design thinking transforms organisations and inspires innovation*, HarperCollins Publishers, NY.

Buchanan, R. (2001). Design research and the new learning. *Design Issues*, 17(4), 3-23.

Buchenau, M. & Fulton Suri, J. (2000). Experience prototyping. In *Proceedings of designing interactive systems*. (pp. 424-433). New York. ACM Press.

Burkhart, M. & Aurich, J. C. (2015). Framework to predict the environmental impact of additive manufacturing in the life cycle of a commercial vehicle. *Procedia CIRP*, 29, 408-413.

Campbell, I. (2015). Advantages of AM for production. In *Wohlers Report 2015 - 3D Printing and additive manufacturing state of the industry: Annual worldwide progress report*. (pp. 186-189). Wohlers Associates, Colorado, USA.

Crawford, M.B. (2009). *Shop Class as Soulcraft*. The Penguin Press, New York.

Darke, J. (1979). The primary generator and the design process. *Design Studies*, 1(1), 36-44.

Dorst, K. (2011). The core of 'design thinking' and its application. *Design Studies*, 32(6), 521-532.

Dorst, K. (2015). *Frame innovation: Create new thinking by design*. MIT Press.

Findeli, A. (2001). Rethinking design education for the 21st century: theoretical, methodological and ethical discussion. *Design Issues*, 17(1), 5-17.

Fingleton, E. (1999). *In Praise of Hard Industries*. Houghton Mifflin Company, Boston.

Forlizzi, J. (2008). The product ecology: Understanding social product use and supporting design culture. *International Journal of Design*, 2(1), 11-20.

Fuad-Luke, A. (2004). *The eco-design handbook: A complete sourcebook for the home and office*. Thames & Hudson, London, UK.

Giard, J. R. (1990). Design education in crisis: the transition from skills to knowledge. *Design Issues*, 7(1), 23-28.

Goldschmidt, G. & Rogers, P. (2013). The design thinking approaches of three different groups of designers based on self-reports. *Design Studies*, 34(4), 454-471.

Hara, K. (2008). *Designing Design*. Lars Müller Publishers, Switzerland.

Johnson, D., Wrigley, C., Straker, K. & Buculo, S. (2013). Designing innovative business models: Five emerging meta-models. In *Proceedings of the design management symposium* (TIDMS). (pp 70-77). Schenzhen, China: IEEE

Koskinen, I., Zimmerman, J., Binder, T., Redström and Wensveen, S. (2011). *Design research through practice: From the lab, field and showroom*, Morgan Kaufmann, MA.

Leitner, M., Innelle, G., Yauner, F. (2013). Different perceptions of the design process in the context of DesignArt. *Design Studies*, 34(4), 494-513.

Martin, R. L. (2009). *The design of business: Why design thinking is the next competitive advantage*. Boston, Mass., Harvard Business Press.

Milton, A. & Rodgers, P. (2013). *Research methods for product design*. Laurence King Publishing, London, UK.

Moggridge, B. (2007). *Designing interactions*. MIT Press.

Ndahi, H. (2006). Lean manufacturing in a global and competitive market. *Technology Teacher*, 66(3), 14-18.

Newman, S. T., Zhu, Z., Dhokia, V. & Shokrani, A. (2015). Process planning for additive and subtractive manufacturing technologies. *CIRP Annals*, 64, 467-470.

Norman, D. & Verganti, R. (2014). Incremental and radical Innovation: Design research vs. technology and meaning change. *Design Issues*, 30(1), 78-96.

Overbeek, K., Wensveen, S., & Hummels, C. (2006). Design research: Generating knowledge through doing. In Swiss design network. Drawing new territories. state of the art and perspectives. *Third symposium of design research*. 17-18 Nov., Geneva: Swiss Design Network.

Parsons, T. (2009). *Thinking, Objects: Contemporary approaches to product design*. Lausanne: AVA Academia

Popovic, V. (2004). Expertise development in product design - Strategic and domain- specific knowledge connections. *Design Studies*, 25(5), 527-545.

Schroder, M., Falk, B. and Schmitt, R. (2015). Evaluation of cost structures of additive manufacturing processes using a new business model. *Procedia CIRP*, 30, 311-316.

Stappers, P. J. (2006). Designing as part of research. In R. van der Lugt & P. J. Stappers (Eds.), *Design and the growth of knowledge*, Nov. 10, 2005, Delft, the Netherlands: Delft University of Technology, Faculty of Industrial Design Engineering.

Stickdorn, M. & Schneider, J. (2011). *This is service design thinking*. John Wiley & Sons, NJ.

Teixeira, C. (2010). The entrepreneurial design curriculum: Design-based learning for knowledge-based economies. *Design Studies*, 31(4), 411-418.

Verganti, R. (2009). *Design-driven innovation: Changing the rules of competition by radically innovating what things mean*. Harvard Business Press, Boston, Mass.

Walden, R. (2015). *Self-initiated design: Avenues for implementation and practice* (unpublished Masters thesis), University of Technology, Sydney, Australia.

Walden, R.J., & Kokotovich, V. (2012). Supporting Student Learning in Relation to Entrepreneurial Innovation in Self-initiated Industrial Design Major Projects. In H. Middleton (Ed.), *Proceedings of the 7th Biennial International Conference on Technology Education Research 2012*. Vol 2. (pp.155-164). Surfers Paradise, Australia: Griffith Institute for Educational Research.

Zhang, Q. & Tseng, M. M. (2009). Modelling and integration of customer flexibility in the order commitment process for high mix low volume production. *International Journal of Production Research*, 47(22), 6397-6416.