INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8 & 9 SEPTEMBER 2016, AALBORG UNIVERSITY, DENMARK

BETTER INNOVATION BY DESIGN? CAN A COLLABORATIVE CROSS-DISCIPLINARY APPROACH ASSIST A PARADIGM SHIFT IN EDUCATION PRACTICE?

Paul McELHERON and Malene Pilgaard HARSAAE
Assistant Professors - Via Design & AU

ABSTRACT
This paper is a case study aimed at exploring the cross-disciplinary synergy between design thinking and product engineering. Teams of Bachelor of Engineering students were given a product engineering innovation challenge and asked to solve it using a design thinking methodology. The results were compared to similar groups who did not make use of design thinking. The questions were: would design thinking assist in the development of innovative product design solutions and if it does – how & why? What are students really thinking & doing when engaged in creative product design innovation? The results indicate that the processes, practices and persona inherent in design thinking do indeed facilitate innovative product design.

Keywords: Design thinking, innovation, strategic design practice, product engineering, education.

1 INTRODUCTION

In a world of growing uncertainty, there is an increasing need to tackle problems of growing complexity and ambiguity in innovative ways. Similarly, the expectations concerning the competencies required of tomorrows graduates are also expanding. The need for T-shaped skills, a metaphor for the depth and breadth of an individual's expertise [1] resonates within many industries. The challenge for educational institutions is one of combining discipline based teaching with a cross-functional approach where collaboration is required across a range of knowledge bases. The questions explored in this paper are: does a design thinking approach to idea generation & problem solving add value to product engineering in terms of the design of innovative products & if so, how & why? This paper suggests such potential for cross-disciplinary synergy between the design & engineering approaches to innovation exists and we provide some suggestions as to how & why this is the case.

Our research into design thinking over the past two years has included carrying out workshops where students and participants from the business & design communities are confronted with a difficult, complex challenge of an often ambiguous nature and encouraged to develop solutions using a design thinking methodology we have developed called Strategic Design Practice, (SDP). The outcome of these workshops is that, when groups are presented with a challenging design problem, whether this is with an artefact, a process, or a system, innovative solutions are often generated. This is of course very convenient for proponents of design thinking but why is this so? Are we dealing with some kind of Hawthorne Effect where individuals modify or develop aspects of their behaviour in response to awareness that they are being observed [2]? From Champniss et al. [3] we know that social identity can be a factor in creativity. Simply suggesting to groups put together purely at random that they have been selected on the basis of their superior creative skills boosts their creative output. Perhaps, for the duration of the workshop were we just being good managers, i.e. motivating participants by setting clear goals, providing adequate resources, a creative environment and support & encouragement throughout the process? This case study aims to isolate these effects.

2 DEFINING DESIGN THINKING & ITS LINK TO INNOVATION

There are two, in many ways distinct discourses regarding the history & development of design thinking. The first discourse, is sometimes referred to as the design methods movement & focuses on what designers do and how they might think while they are designing, Kimbell [4]. It has been suggested that interest in this area was initiated by a need to find a systematic structure to the way designers work in light of emerging complex technologies that had the potential to have an impact on humanity, such as nuclear power stations & supersonic flight [5]. Herbert Simon in 1969 was influential for providing a framework that other researchers have built upon. He saw design as a core human activity: "Everyone designs who devises courses of action aimed at changing existing situations into preferred one" [6]. The "design methods" discourse continued as researchers strived to gain an understanding of the methods & processes used by successful designers especially in situations where they were faced with complex design problems [4], [7]. Schön [8] identified the "reflection-in-action" nature of the way designers work, reframing problems in light of experience. Research by Rowe [9], Cross [10] and Lawson [11] described the thought processes used by designers in action: their "*designerly ways of knowing"* [10] or design thinking [9]. Buchanan's [7] paper "Wicked Problems in Design Thinking" moved design from a cognitive style towards a more generalized design thinking approach that could be applied to problem solving and framing in a wide range of contexts. According to Buchanan, design problems could be ambiguous & ill-defined, so-called "wicked" problems [12], to which the designer brings a new way of looking at problems & finding solutions [4]. More recently, theories of design have moved even further away from design as a cognitive style towards viewing design as a social process requiring cooperation & collaboration.

A later, more recent discourse, (some term the "design management" movement), first appeared in the early 2000's, initiated by books & articles written by members of design consultancies such as IDEO. There is little in the way of sustained development of the design methods (academic) discourse [13], rather, the design management discourse considers design thinking to be more of a "human-centred method for innovation & creating value". According to IDEO's Tim Brown, design thinking has three primary attributes: it is human centred, collaborative & participatory; and is driven by experimentation. Many practitioners perceive design thinking as originating with IDEO [15], and this approach is gradually finding application in business, education & other areas. Brown defines design thinking as "….a discipline that uses the designers' sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" [14].

This later design thinking approach has attracted some criticism for its lack of theoretical grounding, shortage of empirical evidence and for presenting a prescriptive even idealistic view based of anecdotal evidence rather than empirical, theoretical support [16]. Others have doubts about both the validity & originality of design thinking. Norman [17] calls it "a public relations term for good old-fashioned creative thinking".

In terms of design thinking's role in innovation, interest in alternatives to the analytical, linear approach to innovation has led an increasing number of people within business and academia towards the concept of design thinking. Some regard it as a "powerful, effective, and broadly accessible" approach to innovation "that can be integrated into all aspects of business & society" Brown [18]. Martin [19] has called it the next competitive advantage and Plattner, Meinel & Leifer [20] state that "design thinking is a catalyst for innovation" and "great innovators and leaders need to be great design thinkers".

No universally accepted definition of design thinking appears to exist and its underlying mechanisms are poorly understood [21]. However, the increased focus on the design process, and how it may be applied in other areas has provided substantial inspiration for design thinking, and its role as an important tool for innovation, Lockwood [22], Martin [19], Brown [18]. This has resulted in a quest for a common understanding and framework for the various elements included in the design process enabling designers and non-designers to communicate better and create a common culture and language. Integrating the design methods, design thinking & soft systems approaches has led us to view design thinking as comprising of three overlapping elements: a process, a set of practices & a persona. (Note others have reached similar conclusions e.g. Hassi & Laakso,s [15] - practices, thinking styles & mentality and Di Russo's [23] – process, methodology & mindset.

Our approach to design thinking: Strategic Design Practice, (SDP) – the 5F Model, McElheron & Harsaae [24], comprises of: a **Process**, consisting of five stages starting with a research phase (Find)

to establish stated needs, a re-framing phase (Frame) where the problem is defined, an ideation phase (Form) where ideas are generated and refined using rapid prototyping (Fabricate) followed by a test & implementation phase (Fulfil). The **Practices** support the process including such techniques as visualization, pattern finding, brain storming, body storming, (thinking by doing), use of multi-disciplinary teams, & a combination of divergent & convergent approaches. The design thinking **Persona** requires participants to assume the role of a design thinker which requires a collaborative, ambiguity-tolerant, solution focused approach to idea generation that makes use of abductive as well as deductive & inductive reasoning and takes an optimistic future orientated, holistic view. We have found the idea of adopting a persona, that part of yourself you present to the group, helps group members to rapidly acquire the design thinker mind-set.

3 METHODOLOGY

In order to better understand design thinking's contribution to product design innovation and shed some light on what engineering students actually think & do when engaged in creative innovation we designed an experiment. Our approach was to take four teams of 2nd semester BA Global Business Engineering students, (these students go onto specialize in ICT programming or as mechanical engineers), give them a product design challenge and attempt to evaluate the results in term of the level of innovation of their ideas. This study did not involve multi-disciplinary teams and in our experience this does aid idea diversity. However the teams in this study were not completely homogenous, there was an even split between males & females, it was an international class with six nationalities represented and students had taken different educational routes to get onto the program. The challenge was to design an urban bicycle based on the bike design challenge sponsored by Oregon Manifest [25]). All students were taken through the design brief specifying the requirements of the design, (new generation of urban bike, quality of design, flexibility, integration of features, aesthetics, mandatory features etc.). Also, the criteria on which their designs would be evaluated: user desirability, business & technical feasibility and level of innovation [18]. A bike was chosen for the challenge, as it was a piece of technology that students are familiar with, (12 of the 14 students classified themselves as daily or frequent cycle users). Students were then divided, at random, into four teams. None of the participants were aware of the purpose of the experiment, other than to develop an innovative urban bike concept, or had any prior knowledge of design thinking or that the teams were to be treated in any way differently. The four teams were then separated into two classrooms on the pretext of allowing them more space to work.

Two teams, the control group, were given a short lecture on the contemporary focus on design as a creator of solutions then given two hours to develop their concept bike. The other two teams, (the SDP group), were given an 30 minute introduction to design thinking - process, practices and persona before also being given two hours to develop their concept.

All teams were supplied with drawing materials, flipchart paper, sticky notes & prototyping materials and facilitated throughout the challenge. The role of the control group facilitator was to ensure the teams stayed on track and answer any questions about the challenge or how the results were to be evaluated. The SDP teams had additional materials in the form of a poster-sized SDP model (see fig. 1) for attaching ideas to and a Sudoku chart, (see later), the facilitator's role included ensuring teams followed the process and clarify any of the practices if required. Neither facilitator made any contribution to the generation or selection of ideas. At the end of two hours each team was instructed to upload their concepts (pictures & brief description of innovative elements) onto the college's crowdsourcing site for evaluation. All teams were observed throughout the design challenge and recorded using video cameras for later analysis. Each team was given a post-challenge interview to capture their experiences throughout the challenge and complete a simple projection exercise.

4 EVALUATION OF THE CONCEPTS

The team concepts were evaluated by a group consisting of one expert, (a bicycle mechanic), two lecturers, (one design, one marketing), and two final year BA students, again one design, one marketing. All judges described themselves as keen cyclists and none were involved in or had knowledge of the purpose of the trial. The concepts were evaluated against the design brief for user desirability, business viability & technical feasibility [14], each on a scale of 1-5 and degree of innovation on a scale of 1-10. The aggregated results are shown in table 1.

The clear "winners" were teams three & four and these were from the SDP group, teams one & two were the control group. Significantly, both SDP teams scored highly on innovation & this will be elaborated on later. Again, a convenient result but the questions are why & how? Observations made on the way the teams approached the challenge suggested some answers. Taking the control group first, team one leapt straight to solution mode and started to "Google" bikes and this generated several ideas. However, there was little structure to the process or in the recording of these ideas. The end result was a list of ideas that were not connected despite this being a key part of the design brief:
"Integration: *Individual design solutions and features should be integrated into a complete, harmonious aesthetic and functional whole, rather than a checklist of details. Each design element/feature should meld seamlessly with the entire bike".*
Also, there was little in the way of innovation in the opinion of the judging panel, (few novel ideas), in fact the concept revolved around a single idea which was a collapsible bike held together with magnets which the panel could see several problems with and this affected the desirability & feasibility scores. Team one scored 2/10 for innovation.
Team two experienced some difficulty getting started. They spent considerable time looking at the design brief but not in any systematic way. There then followed a period of brainstorming which resulted in a mind-map of ideas but it ended there. The evaluating panel appreciated the number of ideas, some of them were considered novel but these were not integrated into a finished concept.
Some social loafing was observed in one of the control teams with one or two members taking a passive role for about half of the ideation phase of the project. This is a familiar problem in group-work, however we tend to observe it less in SDP workshops due to their inclusive nature.
The SDP teams performed quite differently. Both teams spent a significant part of their design time in the research stage of the SDP 5F model, (Find), specifically trying to establish a fundamental understanding of user needs, also the characteristics of the market and the prevailing technology. They also spent time in the problem definition stage, (Frame), attempting to prioritize real needs and come up with alternative ways of approaching the challenge while keeping within the design brief.

	Gr. 1	Gr. 2	Gr. 3	Gr. 4
DESIRABILITY	2	3	4	4
VIABILITY	2	3	4	4
FEASIBILITY	1	3	4	4
INNOVATION	3	3	8	8
TOTAL	8	12	20	20
NOVEL IDEAS	3	5 *	8	8

*though not integrated in final concept

Table 1. Aggregate team scores from the evaluating panel.

5 IDEA GENERATION

All the teams generated a significant number of ideas so why did some make their way into the final concept and others not? Study of the video footage suggested some answers. In the control group, ideas were generated and sometimes accepted but more often they were ignored, rejected or just forgotten. In the SDP lecture session the concept of building on the ideas of others was emphasized and reinforced in the facilitation of the idea generation process. The result was that ideas were generally listened to and recorded. Ideas were written down on sticky notes or sketched and placed on the Form section of the 5F model wall chart, they were later grouped using a Sudoku chart which allows ideas to be synthesized & grouped, and patterns of related ideas connected. As Johnson [26] has suggested, chance favours the connected mind. Both SDP teams made full use of low fidelity rapid prototyping to demonstrate, communicate and get feedback on ideas, this appeared effective and was frequently observed to stimulate thought, [8], which generated related ideas. Both SDP teams made a dive for the prototype boxes at the earliest opportunity the control teams did not use prototyping though materials were available. The sketches and prototypes were observed to serve as a record of the design process and help with the synthesis of ideas in the final concept. Abductive reasoning, taking leaps in imagination, imagining the future is an important concept in design, much of design is abductive as was the case in this challenge. This was something covered in the SDP lecture and students were given several examples of how it can be used. The SDP groups were observed to take several abductive leaps in the

ideation stage of the process & helped team three develop a novel lighting system and team four an imaginative approach to an anti-theft device.
Both SDP teams produced integrated design concepts including prototypes which fulfilled all the requirements of the design brief and in the opinion of the judging panel, scored high on innovation.
Team three came up with a chip-lock system that locks both wheels & handle to prevent theft, a lighting system that illuminates the wheels, a reflective frame, several self-maintaining mechanical innovations including a self-lubricating chain and an aesthetically unisex design though with a choice of seat designs for males & females. Team four developed a three part anti-theft system that was, according to our "expert" panellist unique to bikes and feasible, a back rest to improve posture, a solar panelled lighting system & a well-designed waterproof load carrier and a novel cup holder.

6 POST CHALLENGE INTERVIEWS

We were interested in obtaining feedback from all teams participating in this engineering design challenge. This was done by interviewing each group immediately following the challenge and asking each team member to complete a projective exercise as a structured indirect way of getting the "whys" of the situation. The student feedback is briefly summarised in the table:

Common to all teams	Control teams	SDP teams
• Interesting, relevant, creative, innovative challenge • Could have done with more time	• Hard to get started • Idea generation challenging • Hard to keep track of ideas • Hard to design something innovative • Group dynamics - good (team 1). Two of us active, two passive, (team 2). • Overall satisfaction with the outcome: Good (team 1), okay (team 2) • Fun challenge (2 of 7)	• Surprising it was possible to come up with so many new ideas • Pushes your thinking • Good group synergy • Design thinking tools helped the creative process • Offered many possibilities for us to be innovative • Very satisfied with the result • Fun challenge (6 out of 7)

Table 2. Feedback, most frequent comments, (combined interview & projection) from the control & SDP teams

All teams regarded the challenge as interesting & relevant which suggests it could be used as a basis for further studies. There were clear differences between how ideas were generated and made the way into a final concept.

7 CONCLUSIONS & FURTHER RESEARCH

Helping students think creatively and understand what is required to make innovative ideas feasible is becoming increasingly important and, as seen in this study, ideas are vulnerable in their infancy [27]. The application of a design thinking process, practice & persona to a product engineering design challenge did result in concepts evaluated to be more innovative than the products produced by a control group without the use of design thinking, even in this short intervention challenge. Observation of the design process and idea generation & selection revealed that the design thinking process, in this case the SDP model, helped students spend more time evaluating & prioritizing real user needs. Design thinking practices such as visualization, pattern recognition and rapid prototyping helped communicate ideas and synthesize them into a final concept. Adopting a design thinking persona requiring a collaborative approach comfortable with a level of ambiguity combined with abductive reasoning helped drive ideas forward.
This was a small trial with four teams but the results support our findings from previous trials. Design is a social process and should not only de regarded as a problem-solving activity but also as a knowledge generation & integration activity [28]. We plan to do further studies looking at the value of design, also at ways of developing team dynamics and the role of individual abilities on the outcomes. A bike is a very tangible thing and it will be interesting to see how design thinking contributes to more intangible design challenges such as the design of processes, services and strategies. Also how design thinking can be integrated into the design & delivery of our programs across disciplines, how it can be used to create & maintain dialogue between students and how we assess their work.

REFERENCES

[1] Guest, D. (1991). *The hunt is on for the Renaissance Man of computing*. The Independent, 10 September.

[2] McCarney, R., Warner, J., Iliffe, S. van Hasalen, R. & Fisher, P. (2007). *The Hawthorne Effect: a randomized control trial.* BMC Medical Research Methadology. DOI: 10.1186/1471-2288-7-30.

[3] Champniss, G., Wilson, H. N. & Macdonald, E. K. (2015). *Why your customers' social identities matter*. Harvard Business Review, January-February 2015 pp90-96.

[4] Kimbell, L. (2009). *Beyond Design Thinking: Design-as-practice and designs-in-practice.* Paper presented at the CRESC Conference, September 2009.

[5] Beckman, S. L. & Barry, M. (2007). *Innovation as a learning process: embedding design thinking.* California Management Review Vol 50, No. 1 Fall 2007.

[6] Simon, H. A. (1996). *The sciences of the artificial* (3rd edition). Cambridge; MA: MIT Press.

[7] Buchanan, R. (1992). *Wicked problems in design thinking*. Design Issues, 8(2), 5-21.

[8] Schön. D. (1983). *The reflective practitioner: How professionals think in action.* New York Basic Books.

[9] Rowe, P. (1987). *Design Thinking.* Cambridge: MIT Press.

[10] Cross, N. (2006). *Designerly ways of knowing.* Berlin, Springer.

[11] Lawson, B. (2006). *How designers think* 4th edition. Oxford: Elsevier.

[12] Rittel, H. (1972). *On the planning crisis: Systems analysis of the first & second generations.* Bedriftsokonomen, 8, October 1972, 390-396.

[13] Johansson, U. & Woodilla, J. (2010). *How to avoid throwing the baby out with the bathwater: An ironic perspective on design thinking*. EGOS Colloquim 2010: June 30 – July 3, Lisbon, Portugal.

[14] Brown, T. (2008). *Design Thinking*. Harvard Business Review. June 2008 pp84-92.

[15] Hassi, L. & Laakso, M. (2011). *Conceptions of design thinking in the management discourse: defining the elements of the concept*. Proceedings of the 9th European Academy of Design (EAD), Lisbon.

[16] Badke-Schaub, P., Roozenberg, N. & Cardoso, C, (2014). [on-line]. *Design Thinking: a paradigm on its way from dilution to meaninglessness?* Available at: https://www.researchgate.net/publication/265403729. Accessed on 09/12/2015.

[17] Norman, D. (2010). *Design Thinking: A useful myth.* Core 77. [online]. Available at: http://www.core77.com/posts/16790/design-thinking-a-useful-myth-16790. Accessed on 05/06/2015.

[18] Brown, T. (2009). *Change by Design*. New York: Harper Collins.

[19] Martin, R. (2009). *The Design of Business.* Harvard Business School Publishing.

[20] Plattner, H., Meinel, C. & Leifer, L. (2011). *Design Thinking: Understand, improve, apply*. Springer Heidelberg Dordrecht London New York.

[21] Reimann, M. & Schilke, S. (2011). *Product Differentiation by Aesthetic and Creative Design: A psychological and natural framework of design thinking.* In Design Thinking: Understand, improve, apply. Plattner, H., Meinel, C. & Leifer, L. (eds.) 2011. Springer.

[22] Lockwood, T. (2009). *Transition: how to become a more design-minded organization*. Design Management Review, 20(3), pp. 29-37.

[23] Di Russo, S. (2014). *The Fabs & Fads of Design Thinking.* DESMA Chat – episode 01. Available at: https://www.youtube.com/watch?v=MVJoOObuvcs. Accessed: 04/10/2015.

[24] McElheron, P. J. & Harsaae, M. (2015). *Bridging the Education Gap between Design & Business Education*. Summer Cumulus Conference, Politecnico Di Milano, 3-7 June, 2015.

[25] Oregon Manifest. (n.d.).[on-line]. *The Bike Design Project*. Available at: www.oregonmanifest.com. Accessed: 06/02/2016.

[26] Johnson, S. (2010). *Where good ideas come from: the natural history of innovation*. London: Penguin Books.

[27] Blakely, S. (2013). *SPANX founder Sara Blakely on CNN.* Available at: https://www.youtube.com/watch?v=_lOiiQDGfwQ. Accessed 17/01/2016.

[28] Hatchuel, A. (2002). *Towards Design Theory and Expandable Rationality: the unfinished program of Herbert Simon.* Journal of Management & Governance 5:3-4 (2002), 260-73.