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Design and Technology Education: An International Journal

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This special issue of the Design and Technology Education Journal showcases a number of papers from the Design Research Society’s Biennial Conference for 2014. It was the DRS’s 7th Biennial Conference and it was held in Umea, Sweden from 16 to 19 June. As Umea is at a very northerly latitude even by Sweden’s standards, this meant that it was the time of year when the sun did not dip below the horizon, and so there was perpetual daylight. This was just one of many ways in which the conference was memorable. It was very well attended with over 400 delegates. Entitled ‘Open by Design’ it was generally regarded as friendly, innovative and efficient in a typically Swedish manner. It was sub-titled ‘Design’s Big Debates’ and its most original feature was the unusual presentation. In addition to the conventional papers, workshops, and doctoral symposia, there were innovative open debate formats. The most prominent were three ‘Big Debates’ which featured two presenters, one for each side. They replaced the keynote speeches which are a feature of most conferences. (The debates are still available online from the conference website). They were followed up by ‘Conversations’, as arenas for further discussion.

However for the journal our concern is with the high-quality academic papers which were also a feature of the conference. They had been selected from full papers rather than abstracts, and then subject to peer review. At the conference their presentation was in thematic groupings. For a number this aligned them with one of the six Special Interest Groups of DRS. Of these the most relevant is the Design Pedagogy SIG which was incidentally also contained the largest number of papers at three times the size of the next largest SIG. It is from these papers that the selection for inclusion in this issue has been made.

The contributions are from a good geographical spread. As might be expected Scandinavia is well represented with papers from Denmark, Norway and Sweden. The origins of the remaining three are more widely dispersed with Turkey, Australia and the UK with Botswana. This is a modest but good reflection of the international character of contemporary design education research. The first featured paper is by three authors from different establishments in Denmark, Anne Louise Bang, Sille Alberthe Kamille Friis and Anne Katrine Gøtzsche Gelting. Entitled ‘Designerly Ways to Theoretical Insight’ it covers visualisation as a means to explore, discuss and understand design theory. It is based on teaching experiences from an MA course in design methodology at Design School Kolding in Copenhagen. The authors discuss a number of reasons why the educational approach where design students read, analyse, and visualise theory, appears to be beneficial to the students’ learning process. They argue that their experiments with integrating visualisation as a tool for exploring and making sense of theory can be of value to design education as a whole. This is because it applies a type of practice that the students are familiar with, and supports the construction of new knowledge, by allowing them to express information and concepts in ways that are personally meaningful. They both make sense of it and synthesise it through sharing the representations with other groups, supporting each other and creating an overview. The use of several smaller groups with shared use of the same texts helps to even out understanding and discuss perspectives on the material.

The second paper also features visual thinking. By Marianella Chamorro-Koc, Andrew Scott and Gretchen Coombs from Queensland University of Technology in Australia, it is engagingly entitled ‘Bombs Away: visual thinking and students’ engagement in design studio contexts’. It is based on the curricula of first and third year industrial design students and focuses on design studio sketching or visual thinking as part of processes that assist students to achieve final design solutions. The authors engage in a variety of teaching pedagogies from which they identify ‘Concept Bombs’ as instrumental in the development of students’ visual thinking and reflective design process, and also as a vehicle to foster their positive engagement. The approach can employ a range of different scales of intensity from 20-minute projects to more complex team activity. They report consequential improvements in the intensity of the teaching experience through the use of a technique, which is robust, flexible and worthy of more widespread adoption within their program.

The third paper also makes significant use of visual material. By Koray Gelmaz and Humanur Bagli from the Istanbul Technical University in Turkey it is entitled ‘Learning from Students: Reflections from Personal Magazines in Basic Design Course’. It is concerned with the use of reflective processes. The study focuses on reflections captured from students via two different media – personal magazine and an online questionnaire. On the basis of written and visual diaries the basic design course students created personal magazines. These provided very useful feedback and assisted in inculcating a reflective approach more generally. The personal magazine became a tool of free expression, which served as mediator,
The authors focus on design-driven innovation and its occurrence in design education through two case studies. The first is an example of design practice which includes observation and cooperation process maps in an offshore project. The study demonstrates how a company innovates through a design-driven process with complex knowledge transference and systematic planning and improvisation. The second is an example of product design education which includes observations of teamwork, team member interviews and archival studies. The study shows students managing their design processes through concept generation in a less complex trial and error process. Through the criteria of network paradoxes, knowledge exploration as a part of design activity was analyzed. Based on the case study, and externally based on other design practices and design research a pedagogic concept has been synthesized and validated as Knowledge Transfer Flow [KTF]. The KTF concept can help to orient design students within the information-saturated design processes integrated within complex innovation systems.

These six papers illustrate the range and depth of design education research which is being pursued, and give some indication of the wide spread of countries in which design is an established discipline at university level. We can be fairly confident that it also has a presence in various forms at other levels in the education system in many of those countries. The design pedagogy strand was not the only area of the conference where the papers had emerged from an academic setting. The majority of the delegates were from places of education and much of what was presented had relevance to design education.

The long established series of Design Research Society Biennial Conferences has now been joined by a second series which occur on the years which alternate with the main series. These have emerged from the DRS Special Interest Group in Design Pedagogy and were initiated by DRS in collaboration with the CUMULUS organization. They are wholly devoted to design education research, with the first taking place in Paris in 2011, and the second in Oslo in 2013 (see issue 19.1 for details). The third in this series is now scheduled for later this year on June 28 - July 1, 2015. It will be held in Chicago in the USA.

Entitled 'Learn x Design, The 3rd International Conference for Design Education Researchers' will be hosted by the School of the Art Institute of Chicago SAIC. This journal is a formal partner and further details of the conference can be found on http://www.learnxdesign2015.com
I was reading a report from The Royal Society for the Arts concerning climate change. Or rather… it was about attitudes to climate change. Polls taken for the RSA and published in the report show that 80% of Britons are worried about climate change but only 14% say they have altered their behaviour accordingly. Rowson (the author) points out that that leaves 66% (two thirds of us) as Climate Ignorers – a condition of polite apathy. (Rowson J. 2013. RSA).

There were two things in particular about the report that made me ponder… and neither of them was really about climate change. First I was forced to recognise that I am in the 2/3 that he has identified. I don’t refuse to fly in aircraft, nor do I have an electric car, or restrict myself to bike travel, and whilst I do insulate my house I realise that my motivation is more about saving money on energy than on avoiding climate change. But second – and what really engaged my interest – was a fleeting reference in the report to a Chinese philosopher Wang Yangming, who argued that “to know and not to act, is not to know”. This instantly transported me back to the 1960s when I was studying the philosophy of Education – and in particular the Confucian tradition of philosophy.

It’s worth pointing out that at that time and in fact up to (about) 1980, philosophy was a compulsory part of the teacher education programme. There was a team of philosophy tutors at Goldsmiths – including Richard Pring – and whilst I cannot claim that I enjoyed philosophy tutorials, I certainly did appreciate the opportunity to engage with issues that go beyond the ‘how’ and the ‘what’ that tends to dominate current classroom debate. **What** we should teach – and **how** we should teach it are all very well as issues for discussion, but they pale into insignificance beside the **why** questions. Why bother with educating young people? What does it mean to be educated? Why bother with D&T? Why should we spend millions on workshops and specialist teachers? These (and so many more) questions cannot be answered by reference to empirical data – from Ofsted or anyone else. They are questions about meaning and purpose and value. They were at the heart of the philosophy courses that were commonplace in the 1960s and that had pretty much disappeared by the 1980s. They were progressively supplanted by what might be called ‘the managerialist tendency’… preoccupied with ensuring that new teachers had good classroom management skills. Sociology and psychology were the disciplines at the leading edge of these studies – and philosophy was quietly sidelined and then dropped. Whilst no-one could deny the value of classroom management skills, there is a significant part of me that regrets the absence of those challenging and liberating philosophical debates around the ‘why’ questions.

The Confucian tradition of education originated in the 5thC BC with Confucius’ claim that heaven is aligned with moral order but dependent upon human agents to actualise its will. Moreover he argued that moral states are contagious…you ‘catch it’ from the family and of course from teachers – who have responsibility for diffusing this moral order. Two thousand years later, in the 15th C, Wang Yangming (a neo-Confucian) had been a very able administrator and military official and his contribution to the debate lay in his claim that people are naturally good and that personal morality is the main source of social well-being. Social problems, he argued, lay in the failure to understand one’s self and its relationship with the world…and thus fail to live up to what one could be. This led him into the interesting stuff about the relationship between knowledge and action and to the notion quoted by Rowson that ‘to know and not to act is not to know’. And this is where the real connection lies to our world of designing.

(Wang Yangming 1472-1529)

In 1991 we concluded the Assessment of Performance Unit (APU) design and technology project and published the final report. In it we described a view of designing that stood in sharp contrast to the conventional models of designing that were popular at the time. Instead of describing designing as a linear progression from brief>specification>research>ideas>making>evaluating, we saw it more as an idea journey that iterates between active and reflective modes of operation. We start with an idea (in the head) and immediately externalise it through discussion, sketching or modelling and this allows us to see the idea more clearly and think more deeply about it. We argued that these two sides of performance (active and reflective) were complementary and fed off each other.
We were fortunate that the APU assessments that we had run in 1988 provided us with an enormous archive of 20,000 pieces of designing by 15 yr old learners, so we had masses of exemplification to illustrate different styles of designing. Amongst the most obvious differences in performance were those that resulted from an imbalance between action and reflection. If learners tried to tackle a design task through dominantly reflective behaviour… thinking about the context of use and the nature of the user and considering how other factors (like safety / saleability / function etc) might bear upon the outcome, then frequently those learners never got round to making any substantive design proposal at all. All the issues they raised clouded their ability to take direct action. At the other extreme some learners were so keen to get into direct action that they just wanted to be provided with materials so they could start making it (when it was far from clear what the ‘it’ was that they had in mind to make). Such dominantly active behaviour was frequently unreflective and resulted in inappropriate outcomes.

Significantly the best performance was evident when learners balanced reflective and active behaviour. Making proposals, thinking about the consequences for users, modifying the proposal, reflecting on what elements worked well and which didn’t, refining and prototyping and reviewing the work through the eyes of others. Such balanced performance was typically stronger than the work from either extreme of imbalance. This all seems a long time ago, and those 15 yr olds are now in their early 40s. But recently, ‘iterative design processes’ have become all the rage; in the KS1-3 programmes of study, the GCSE consultation, and in the wider literature. (See eg Norman at http://www.ldpress.co.uk/iterative-model-designing-2/).

But it was that fleeting reference to Wang Yangming that really sparked my interest, reminding me of my old philosophy tutorials. So I dug around a bit. Remember that Wang Yangming was writing in the 15th C, and (by way of context) this is when Henry VII was seeing off Richard III at the battle of Bosworth… ‘a horse, a horse, my kingdom for a horse’. While we were battling it out in our muddy little island, Wang Yangming was following in a 2,000 year tradition of thinking about education. And he produced his treatise about the ‘Great Learning’. At the heart of his educational philosophy was what he described as the unity of knowledge and action. It’s necessary to see his use of the word ‘knowledge’ not as we now do, as an intellectual repository of stuff to be remembered. Rather he saw knowledge more as knowing; as the working of the mind.

On the one hand, “there is a type of person in the world who foolishly acts upon impulse without engaging in the slightest thought or reflection. Because they always act blindly and recklessly, it is necessary to talk to them about knowing….”

On the other hand, “[t]here is also a type of person who is vague and irresolute; they engage in speculation while suspended in a vacuum and are unwilling to apply themselves to any concrete actions” These latter people benefit from advice that emphasizes action, without necessarily discussing knowledge. (Tiwald, Justin and Bryan W. Van Norden [eds.] 2014 p268)

In a nutshell he describes the two extreme states of distorted designing performance that we exemplified in 1991.

All of which encouraged me to speculate a bit more about the cost of losing philosophy from our education courses. Within the philosophy programme we were required to develop new courses of study for schools (in my case D&T but in my tutorial group there were also maths, English, geography and PE students) and I had to argue why I would include it in my design and technology curriculum and (if necessary) why other existing elements should be removed. I use the words deliberately… it was my curriculum. In a small way, we were required to develop a personal philosophy of learning and to exemplify it through real courses of study for schools.

In the last twenty years we have all witnessed the danger of removing that responsibility from teachers. It is now Mr Gove’s curriculum (or perhaps Nicky Morgan’s), and our students talk of ‘delivering’ it, a bit like a postman taking someone else’s mail and depositing it here and there.
The ‘Why?’ questions

Teacher as civil servant; a manager doing someone else’s bidding. Which is sadly a long way from teacher as autonomous educator. I can almost hear Wang Yangming turning in his tomb.

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Rowson J. (2013) *A new agenda on climate change. Facing up to stealth denial and winding down on fossil fuels*. December 2013. RSA

Designerly Ways to Theoretical Insight: Visualisation as a means to explore, discuss and understand design theory

Anne Louise Bang, Design School Kolding, Denmark
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Abstract
This paper set out to investigate how design students learn from visualising theory in design education. The exploration rests on the assumption that the application of tools and techniques from design practice supports design students with an entrance to the theoretical part of the field.

The paper is based on teaching experiences from an MA course in design methodology at Design School Kolding where we use visualisation as a tool to discuss, explore and understand design theory. To throw light on the question, student evaluations and feedback has been included together with a classification of the material from one visualisation exercise. In addition, theories for how to understand designerly ways of knowing and constructing knowledge have been applied as tools to think with in the discussion.

The educational approach where design students read, analyse, and visualise theory, appears to be beneficial to the students’ learning process for a number of reasons, which will be discussed in the paper. The main findings indicate that visualising theory is beneficial because it applies a type of practice that the students are familiar with, and supports the construction of new knowledge, by allowing the students to express information and concepts in ways that are personally meaningful to them.

Key words
visualisation, designerly knowing, design education, design methodology

Introduction
The use of visualisation as a design tool has been discussed in various ways within the field of design research and in textbooks. During many years design researchers have studied, discussed and acknowledged sketching and drawing as a tool for reflection as well as designing in various ways (see for example Schön, 1983; Cross, 1995; Lawson & Dorst, 2009; Goldschmidt 1991, 2013). Visualisation has also been the subject or included in textbooks across different design domains, see for example Buxton (2007) on user experience, Olofsson and Sjölen (2005) on product design or Gaimster (2011) on Fashion design) Also method card collections usually include methods where visualisation plays a central role (IDEO, 2002; DSKD, 2011). Additionally visualisation has been discussed as an ‘assisting’ tool in communicating design and design processes (see for example Roam (2009) on visual thinking in business innovation, Sibbett (2010) on visualisation as meeting facilitation and Rohde (2013) on visual note taking). Thus, there is a large and diverse body of knowledge and a vast amount of literature, which is concerned with visualisation as a communicative or reflective tool in the design process.

In this paper we are specifically concerned with visualisation as a reflective tool but we take a slightly different perspective than most of the cited literature since our aim is to discuss visualisation as a teaching approach in theoretical courses in the design education. We use this study to claim that there is an educational potential in using a designerly approach when teaching theory in design schools. Therefore, instead of exploring visualisation as a design tool, we discuss ways in which visualisation can be integrated as a tool for exploring and learning theory in design education.

In recent years at Design School Kolding in Denmark we have applied visualisation exercises in various cross-disciplinary courses at all levels as a tool to discuss, explore and understand design theory. Back in 2009 one of the authors introduced students to the use of visualisation as a tool for dialogue when reading and making sense of theory (Gelting, 2009). We decided to further explore the integration of visualisation using examples from an MA course on Design Methodology. The exploration rests on the assumption that the application of tools and techniques from design practice supports design students with an entrance to the theoretical part of the field and holds the promise of improving the students’ learning outcome. Feedback and evaluation by the students indicate that they do indeed experience that the visualisation approach helps them engage with theory at a new level, and in this way supports the learning process.
Designerly Ways to Theoretical Insight: Visualisation as a means to explore, discuss and understand design theory

We use the paper to reflect on the teaching approaches and learning outcome of the course. During the three times that we have run the program, we have received positive feedback and evaluation from the students, indicating that applying visualisation as a tool for exploring and making sense of theory provide them with the ability to grasp and discuss theoretical concepts – see different perspectives and being able to address them together. We use a combination of structured reading assignments, group work and visualisation exercises. What we would like to focus on in this article is the visualisation exercises, how and why that helps the students process the readings. The overall question, which is explored in this paper, is therefore: How do design students learn from visualising theory in design education? The overall purpose is to gain a better understanding of why it works well to use visualisations as a pedagogical tool – and how does it work?

Before we lay out the theoretical foundation we introduce the case, which we build upon, namely the course in design methodology, and the empirical data produced by collecting and clustering the visualisations from the first exercise in the 2013 course.

Teaching Design Methodology

The Design Methodology course at Design School Kolding in Denmark encourages the students to work in-depth with design theory in an active and participatory way. The students are expected to acquire an overview of design methodology and in-depth knowledge of selected literature. Furthermore they are expected to reflect on methodological aspects in relation to their personal design practice. It is a mandatory course offered to all MA students in their final year. This means that we teach an interdisciplinary group of 60-80 students coming from Fashion, Textiles, Industrial Design, Graphic Design, Illustration and Interaction Design.

From a didactic perspective the large size of the group is a challenge. How can we secure the individual learning and at the same time encourage the students to contribute to common knowledge generation and learning? Another main challenge is that the students are highly dedicated to design practice and how to act as designers. It can be difficult for some students to understand that their design practice can benefit from theoretical insights. On top of that many students suffer from dyslexia. Finally, if there is any international students present the course is taught in English, which is not the native language in Denmark.

We are a group of three teachers/researchers, who develop and run the course together. The course was offered for the first time in September 2011. In September 2012 and 2013 we had the opportunity to refine the course, building on experiences from the previous year(s). The course is a 2-week course. Teaching is 4 days a week from 9.00 to 12.15.

The students pass this course by attending a minimum 75% of the time. Therefore the learning impact cannot be measured in terms of exam grades or by analysing written assignments but is related to an expected learning outcome for the students. The expected learning outcome is to be able to discuss design process and method from a historical perspective and to possess knowledge on how the field of design relates to methodological research and approaches of other disciplines. It is also important that the students gain an overview of the most important design theorists’ design methodological stance and to be able to use this knowledge to understand contemporary prevailing approaches. Last but not least the students must be able to reflect on design methodology in relation to design practice.

The pedagogical key elements in the course are: group work, a process of structured reading assignments and visualisation as a tool to think with. As a preparation for the group work we provide the students with a short introduction to the selected literature and an assignment, which guides them in the subsequent reading process. Each assignment encourages the students to reflect on structure as well as content in selected text(s). The expected outcome is a written summary and a visualisation. The visualisation is expected to communicate the main points in the text(s) using drawing and short statements. Over the years we have learned that the visualisation appear to serve the purpose of further understanding and remembering the theory if it is hand-drawn and in poster size.

The 2013 course consisted of three assignments. Each assignment had a specific goal: 1) to understand a single text in-depth, 2) to conduct a comparative analysis of two texts, and 3) to understand design methodology in a historical context. The group size was two to four students to increase the likelihood of everyone in the group participating actively. The students read in groups, they explored, discussed and solved the assignment together. One full day was allocated for each assignment.

Subsequently we arranged discussions and presentations in smaller groups. This was an alternative to plenum discussions, which we reduced to a minimum in order to let each student be as active as possible.
Empirical Data and Examples

In this section we use material from the first assignment to exemplify and cluster ways in which the students visualised single texts. In the first assignment the students worked in pairs. They were asked to read one text and subsequently demonstrate the insight in the form of a written summary and a hand drawn visualisation in poster size.

First we present a classification of the different types of visualisation, which we have received. We have registered 26 visualisations, which we have divided into three main groups. Each group reflect a certain type of visualisation: 1) Mainly text based, 2) Mainly narratives and/or symbols based, and 3) A combination of statements and narratives/symbols. Secondly we exemplify ways in which the visualisations were used as a means for knowledge sharing between the groups.
The smallest group of visualisations is mainly text based (5 out of 26). As Figure 1 shows the text often appears in an organised and structured way, which resembles bullet points organised in diagrams. The diagrammatic character indicates an order or a system of reading and understanding the visualisation. This type of word-based visualisation presents the main points of the text. The reader gets a clear view of the relation between the main points due to the way they are structured and organised on the poster. This type of visualisation appears close to an objective depiction of the text, bringing forth key terms and concepts.

The visualisations that are mainly based on narratives and/or symbols appear to reflect a more subjective depiction of the text (8 out of 26). It is a translation of the text into something personally meaningful. It fits with how designers and architects use a concept as a means for grasping, framing an idea…’if we make it like a…’. Using metaphors, analogies and associations the text is transformed from something difficult and abstract into something more relatable and known. In other words the visualisation based on narratives and/or symbols is a concrete bid on the essence of the text (Figure 2). Some of these visualisations are difficult to understand if one is not familiar with the text or has witnessed the presentation of the visualisation.

The largest group of visualisations is a combination of narratives and/or symbols and short statements (13 out of 26). As Figure 3 shows this type of visualisations is in many respects a mix of the two other types. It is characteristic that the text appears as short statements, which enhances the chosen narrative or symbol(s). Some of the visualisations have a diagrammatic character like the text-based visualisations and some of them are closer to the visualisations mainly based on narratives and/or symbols. Common for this type of visualisations is that words and images supplement each other.

Figure 2: These posters exemplify visualisations mainly based on narratives and/or symbols (photos: S. A. K. Friis).
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Visualisations based on a combination of text and narratives/symbols

Figure 3: These posters exemplify visualisations using a combination of narratives and/or symbols and short statements (photo: S. A. K. Friis).
When we first introduced the visualisation assignments in 2011 several students found it odd. The students clearly expected a highly theoretical course with classic lectures and one-way communication from teacher to students even though this is rarely the case at Design School Kolding. They assumed that we included the visualisation assignment in order to ‘bribe’ them to ‘love’ theory by letting them use well-known tools from design practice. While we were not out to ‘bribe’ them, we did want to provide them with a familiar entrance to exploring and making sense of theory. Fortunately, in the course evaluation, the term ‘bribe’ did not come up and students emphasised how much they actually learned from taking the visualisation assignment seriously. The task of visualising forced the students to discuss and identify the content and main points of the texts. Otherwise they wouldn’t be able to decide for a way to visualise it. Said one student in 2013: “I love visualisation. It helps dive into the texts and making it enables you to see if you understood it!” (09.2013). A group of students explained it this way: “It’s great to meet up in a small group when you have read the text, to talk about it, make sense of it, and circle the most important points together. And when you have to make the visualisation together, and tell each other about ideas for how to do it, there is another point of discovery: Do we have a shared understanding or are there things, which we have understood differently? Not until you make the visualisation, do you really understand it [the text]” (09.2013). Two students described what happened when they were comparing visualisations of the same text: “It was fun – there were two groups that had read and visualised the same text. But the visualisations made them see that they had understood the text quite differently. The visualisations acted as drivers for a rich discussion, which gave room to new perspectives” (09.2013).

The first reading assignment was followed by knowledge sharing in groups of 2-3 pairs of students. We asked the students to use the visualisations disseminating the generated knowledge to fellow students (Figure 4). Afterwards we had a short plenum discussion, which included a brief feedback on the use of the visualisations. Several of the students mentioned that the visualisations helped in their understanding of the texts presented by fellow students. It was also mentioned that it was easier to...
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remember the main point of the texts when they were accompanied by a visualisation. Finally the visualisations served as a starting point for discussing diverging understandings of the same text.

Theoretical Foundation
The next section seeks to provide a theoretical foundation for the further discussion of the research question: How do design students learn from visualising theory in design education? Design students are special in the sense that they are trained to use the power of conjecture (Lawson, 2006) for instance through sketching and visualising possible solutions (Schön, 1983; Cross, 1995). This is an important factor when trying to understand how MA design students in their final year learn from visualising theory – the training of the students cannot be separated from the teaching methodology that we apply and investigate. We therefore find it appropriate and worthwhile to use design theory – with a special attention to designerly ways of knowing – since the visualisation approach to exploring, discussing, and understanding design methodology is applied in the context of design education. Thus, the present paper builds on theory from the field of design, and particularly the designerly ways of exploring and knowing as described by Cross (2007), Lawson (2006), Schön (1983), Goldschmidt (1991) and Kolkó (2010). While the visualisation approach to exploring and understanding theory might also be fruitful in other disciplines, it is not part of this investigation.

Constructive Thinking in Education/Cognitive Potential
According to Cross (2007), there are large areas of human cognitive ability that have systematically been ignored in our educational system. He argues that numeracy and literacy have been favoured whereas the culture of constructive thinking has been neglected: “This culture relies not so much on verbal, numerical and literary modes of thinking and communicating, but on nonverbal modes. This is particularly evident in the designer’s use of models and ‘codes’ that rely so heavily on graphic images – i.e. drawings, diagrams and sketches that are aids to internal thinking as well as aids to communicating ideas and instructions to others” (Cross, 2007: 28-29).

Based on the work of Piaget and Bruner he further argues that cognitive development is a continuous process of interaction between different modes of cognition. “That is, the qualitative different types of cognition (e.g. ‘concrete’ and ‘formal’ types in Piaget’s terms, ‘iconic’ and ‘symbolic’ in Bruner’s terms) are not simply characteristic of different ‘stages’ of development, but are different kinds of innate human cognitive abilities, all of which can be developed from lower to higher levels” (Cross, 2007: 28).

Solution Focused Strategies
Several researchers have pointed out how designers are trained to explore and understand by conjecture. Lawson (2006) studied design behaviour through a series of experiments and came to the conclusion that while scientists problem-solve by analysis, designers problem-solve by synthesis. He also concluded that the design behaviour is learned by education since 1st year BA students did not display distinct solution focused strategies. Says Cross “A central feature of design activity, then, is its reliance on generating fairly quickly a satisfactory solution, rather than that of any prolonged analysis of the problem” (Cross, 2007: 23). “Designing is a process of pattern synthesis, rather than pattern recognition. (Cross, 2007: 24). By doing so, trying out solutions, “they learn about the nature of the problem” (Lawson in Cross, 2007: 23).

Reflective Practice
Looking at design as a unique way of thinking and acting, Schön (1983) has provided significant insights into how this takes place in practice. Schön explains how the architect/designer uses a complex combination of different materials, medium and language to engage in the creative process. This process creates unintended consequences that feed back into the process and creates a new understanding of the project and process. “He shapes the situation, in accordance with his initial appreciation of it, the situation ‘talks-back’, and he responds to the situations back-talk” (Schön, 1983: 79). This process Schön names as having a conversation with the materials of the situation. Just like Cross, Schön understands the designers’ approach from a constructivist perspective – knowledge is being formed in the individual human being when new information meets existing knowledge generated from previous experience – “The solution is not simply lying there among the data, like the dog among the spots in the well known perceptual puzzle; it has to be actively constructed by the designer’s own efforts” (Cross, 2007: 24).

Externalization as a driver for Sense – and Synthesis –Making
Kolkó (2010) explores how designers use externalisation of data and thoughts to fuel synthesis and to make ideas external and sharable: “Common to all methods of synthesis is a “sense of getting it out” in order to identify and forge connections. This is an attempt to make obvious the sensemaking conditions described above; emphasis is placed on finding relationships and patterns between elements, and forcing an external view of things. In all of the methods, it is less important to be “accurate” and more important to give some abstract and tangible
form to the ideas, thoughts and reflections. Once externalized, the ideas become “real” – they become something that can be discussed, defined, embraced, or rejected by any number of people, and the ideas become part of a larger process of synthesis. Essentially, sensemaking is an internal, personal process, while synthesis can be a collaborative, external process.” (Kolko, 2010: 18). Alas, Kolko makes a distinction between ‘sensemaking’, which is described as internal and personal, and ‘synthesis’, which can be collaborative and external. This point will be further explored in the discussion in relation to the approaches, which were applied in the present course.

Seeing That and Seeing As
Based on the assumption that the practice of sketching is helpful to architects’ thinking, Goldschmidt (1991) is interested in the underlying cognitive operations behind sketching. She describes a protocol study of 8 architects working on a specific building design and how they use sketching to pull thoughts onto the paper but also create new ideas and thoughts in the process. Sketching being a visual conversation and meeting place between paper, pen and ideas. In the analysis Goldschmidt defines two different ways in which architects use sketching: seeing as (when thinking in metaphors or figural thinking, synthesising) and seeing that (non figural, and analytical thinking). Sketching being used to trigger alternately seeing as and seeing that thus aiding the architects’ development of ideas and creative process. Kolko’s findings – that the externalization is a way to make sense and create synthesis – appears to be in line with Goldschmidt’s definitions of seeing as and seeing that. However, while Kolko differentiates between two processes as being either internal and personal or collaborative and external, Goldschmidt points out the cognitive operations supported by different types of sketches.

Discussion
In this section theory from the previous section is applied to analyse and discuss the main question of how and why design students learn from visualising theory in design education. As a part of this we address the role that the type of visualisation plays for the individual understanding of the text and the role that the visualisations play in the presentations of the texts to fellow students.

Lawson’s findings concerning how scientists and designers prefer to work (2006) is relevant to the present study, since design students are asked to use both approaches: firstly, they analyse the text, using a series of guiding questions in relation to content and structure, and render the significant points in a summary. This is a straightforward understanding exercise, making the strange familiar in a quite objective way. Secondly, the students are asked to visualise the text, to synthesise their findings in a hand-drawn illustration. This is a transformation exercise, making the familiar strange in a subjective way, allowing the students to reflect while constructing, and bring forth something of them selves in the illustration of the text. However, depending on the type of visualisation that the students make, the activity can be placed on scales between ‘subjective’ and ‘objective,’ ‘concrete’ or ‘abstract’, and ‘diagrammatic’ and ‘narrative’ – the transformation being more evident in the subjective, concrete, and narrative representation than visualizations at the opposite end of the spectrums. This relates well to Goldschmidt’s findings of different types of sketches supporting different types of cognitive operation, which is further addressed later in the discussion.

In the present case, the situation can be said to be opposite to the one depicted by Cross when suggesting that constructive thinking has been neglected in culture. Master students in their final year are familiar with using drawings, models, and sketches in their everyday work whereas reading and analysing theory is something, which they in general are less comfortable with. However, Cross’s point about the different cognitive abilities is still of interest to the present study where the educational approach encourages students to switch between these different cognitive modes. By visualising the text that they have read and analysed, the students thus apply an approach, which Cross would refer to as a designerly way of knowing: making their mode of problem solving solution focused, making their mode of thinking constructive, using ‘codes’ to translate abstract requirements into concrete objects, and using these ‘codes’ to both ‘read’ and ‘write’ in ‘object’ languages.

The students in doing a visualisation transformation or synthesis of the text goes into a dialogue with the text in a tangible way. Thus, they create a situation where the visualization “talks back” to them and force them into a conversation with the text (Schön, 1983). The material nature of the handmade visualisation invites the students to physically explore the text. Rather than designing beautiful visualisations meant for broader knowledge dissemination the students use visualization as a tool to think with. Thus, these may not reflect the actual drawing skills design students on MA level are supposed to possess.

Comparing Goldschmidt’s findings to the classification presented in section 3, they seem to be in accordance:
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Some students use seeing as visualisations where they create a poster, which is narrative and metaphorical (Figure 2) and some students use seeing that sketching were they use a diagrammatic and analytical way of visualising the text (Figure 1). Some students use the visualisations to move between the different ways of reflecting upon the text and getting an understanding of it (Figure 3). Pulling thoughts from a tacit state to an explicit state. In coming courses it may be interesting to increase the attention to the type of visualisations the students come up with or be more precise when giving the student’s the visualisation assignments, altering between different types of visualisation for different purposes or maybe even asking the students to make a series of visualisations, for instance starting out with the sensemaking visualisation, seeing that, and continuing with the synthesis visualisation, seeing as.

Kolko also explores the significance of external representations, however, suggests that sensemaking is internal and personal, whereas synthesis can be a collaborative and external process. When looking at the present course material, it is not readily clear whether sensemaking is only an individual process – or whether it can happen between design students working together on a visualisation. As a matter of fact, a consistent feedback from the students is that working in groups together is supportive in both the exploration and understanding of a theory. However, answering the question goes beyond the scope of the present study.

To summarise the findings of the present study, the educational approach where design students read, analyse, and visualise theory, appears to be beneficial to the students’ learning process for a number of reasons.

a. Applying visualisation tools and techniques support design students with an entrance to the theoretical part of the field, because it constitutes a familiar way of exploring and making sense of a situation.

b. When moving from reading and analysing to interpreting and visualising, the students make connection across different cognitive ways of operating, such as for instance the verbal and non-verbal modes of thinking. This continuous process of interaction between different modes of cognition supports the construction of connections and the ability to remember what was constructed.

c. Working with visualising a text takes the students away from prolonged analysis, which is unfamiliar territory to many design students, inviting them to investigate and understand the text by trying out solutions (constructive thinking).

d. Visualisation, particularly in the case of visualisations that are mainly narratives and/or symbols based, has to do with synthesising and translating the text into something personally meaningful. In the visualisation process, new information (the theory) meets the students’ existing knowledge and experiences, and new knowledge is constructed.

e. Visualisation, particularly in the case of visualisations that are mainly text based and diagrammatic, enables visual analysis and sensemaking of a theory, enabling abstract and objective representation.

f. ‘Getting it out’ as suggested by Kolko, enables the students to make their ideas, reflections, and thoughts ‘real’ and they can use the externalised version to further discuss and make sense of the concepts and ideas. It moves the exploration and sensemaking from a largely individual process to a shared process.

g. Presenting and seeing other student groups’ visualisations enables students to identify and forge connections and produce new understanding together.

Conclusion
The present paper set out to investigate how design students learn from visualising theory in design education. To throw light on the question, student evaluations and feedback has been included together with a classification of the first visualisation exercise in the 2013 course program. In addition, theories for how to understand designerly ways of knowing and constructing knowledge have been applied as tools to think with in the analysis and discussion.

The research is still in its early phases and the findings are tentative. However, we argue that our experiments with integrating visualisation as a tool for exploring and making sense of theory can be of value to design education as a whole. In a time where many design schools move from arts and crafts based approaches only to also include more academic ways of learning, and where the production of theory is increasing, it seems appropriate to think of ways in which we might tailor theory based programs to design students.

The main findings is that ‘yes’ – visualising theory is beneficial to MA design students, because it applies a type of practice that they are familiar with, and supports the construction of new knowledge, by allowing the students to express information and concepts in ways that are personally meaningful. ‘Getting it out’, putting it on paper, enables students – within the groups – to make sense of and synthesise new meanings together. When sharing with other groups and seeing their visualisations, the
student groups as a whole, support each other in creating an overview.

A downside might be that some groups have misunderstood a text or they might only show a fraction of a theory in the visualisation, leading to the fact that other students, who have not read the text themselves, are ‘cheated’ on important information or directly misled. When running a course for this many students, and presentations are run in smaller groups, the teachers cannot be present everywhere at the same time. However, the fact that several groups read the same texts and get a chance to present to each other and discuss perspectives might in part make up for this.

Further Work
Would visualisation work as an educational lever within other educations as well? It is a good question whether the visualisation approach to text reading can be transferred to other disciplines and fields and it might be a subject for further research. As mentioned above Lawson argues that design students are trained to use their powers of conjecture to find solutions and for example a biology student might not be able to benefit from the visualisation exercise in the same manner as the design student in his/her final year. But all the same, thinking about Cross’s argument, that numeracy, literacy, and nonverbal models and codes are all innate human cognitive abilities – all of which can be developed from lower to higher levels, one would think that the visualisation approach to text reading can be transferred to other disciplines and fields. With the proper introduction, the above mentioned biology student might be able to benefit from the visualisation exercise by getting some training in visualisation and applying it to theory understanding.

However, we are teachers and researchers at a design school and it would be appropriate to consider further research worth to discuss within the community of design research and from which the design students could benefit. In this paper we have started to identify different categories of and approaches to visualising. Studying in-depth the roles the different types of visualizations play in teaching design theory might be a fruitful and highly interesting subject for further research.

References


Bombs Away: Visual thinking and students’ engagement in design studios contexts
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Abstract
In design studio, sketching or visual thinking is part of processes that assist students to achieve final design solutions. At QUT’s First and Third Year industrial design studio classes we engage in a variety of teaching pedagogies from which we identify ‘Concept Bombs’ as instrumental in the development of students’ visual thinking and reflective design process, and also as a vehicle to foster positive student engagement. In First year studios our Concept Bombs’ consist of 20 minute individual design tasks focusing on rapid development of initial concept designs and free-hand sketching. In Third Year studios we adopt a variety of formats and different timing, combining individual and team based tasks. Our experience and surveys tell us that students value intensive studio activities especially when combined with timely assessment and feedback. While conventional longer-duration design projects are essential for allowing students to engage with the full depth and complexity of the design process, short and intensive design activities introduce variety to the learning experience and enhance student engagement. This paper presents a comparative analysis of First and Third Year students’ Concept Bomb sketches to describe the types of design knowledge embedded in them, a discussion of limitations and opportunities of this pedagogical technique, as well as considerations for future development of studio based tasks of this kind as design pedagogies in the midst of current university education trends.

Key words
visual thinking, design sketches, design studio, student engagement, thematic coding of visuals, industrial design

Introduction
In any design studio on any given day, someone will always be working with pens, pencils and paper. Whether it’s a mock-up, mood board or concept, sketching is the quickest way to explore product ideas. Sketching constitutes a natural thinking process in design. It is through the iterative practice of sketching that design students learn about design visual thinking; that is, the process by which visual elements – codes, symbols, and other representational forms – are integrated into the tangible forms (whether drawings, prototypes, etc.). Final design drawings are approached through a series of drawings (sketches); it is the designer’s dialogue with his/her ideas, and contributes to design studio pedagogies in traditional design education (Cross 1999).

In this paper we introduce “Concept Bombs” as one of the approaches employed in design studio pedagogies at the Industrial Design discipline of the Queensland University of Technology (QUT). Concept Bombs are design studio tasks that require students to engage in a rapid visual thinking process to generate a conceptual solution to a supplied design problem in a very short time. The context is the design studio and thus this paper reviews key literature on design studio pedagogies and visual thinking. Through the analysis and comparison of First and Third Year students’ Concept Bomb sketches, this paper describes the types of design knowledge embedded in students’ sketches; benefits, limitations and opportunities of this pedagogical technique.

Finally, the paper presents a discussion of how this kind of studio activity promotes reflective design process and consideration for future development as design pedagogy in the midst of current university education trends. Amongst other challenges for educators, current higher education trends promote an ‘outcome focused’ approach where students, instead of being deeply immersed in the process of learning are eager to complete tasks, finish assessments, graduate and become employed. While this is understandable in light of economic trends, processed based learning task become more crucial for a student’s education and development as good designers (Taboada & Coombs 2013).

Design studio pedagogies, design sketches and visual thinking
Design studios are the traditional educational models in design education and it has also been seen as producer of knowledge and social practices in design (Dutton 1987, p.17). The design studio pedagogical approach is widely known as foundational for design education and is an important part of the educational curriculum. The primary aim of studio-based teaching is not only focused on how to design but on what design is through a creative and analytical way of thinking. The design studio is the first place where a design student will experience the design process. This view is firmly supported on the Architecture
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Traditionally, the design studio provides the physical setting that enables a pedagogical basis focused on the ‘design problem’ and on ‘learning by doing’ (Broadfoot & Bennett 1991). Studios are usually organised upon replication of professional task performance; this means, through the use of client design briefs that present ill-defined design problems. This problem-based context prompts students to experience ‘designing’, through the exploration and redefinition of the problem as part of the design problem-solving process. Schön (1992) described this experience as ‘reflection-in-action’ and identified it as the basis of any design process. He furthered described that there are types of ‘know-how’ revealed in our intelligent action: knowing in action (tacit knowledge), reflection in action (questioning and challenging taking place while designing), and reflection-on-action (questioning emerging after design solution has been reached). One of the manifestations of this process is evident in the development of conceptual design sketches.

Design sketches are commonly employed by designers to develop ideas. Schön defined the sketching process as a conversation between the designer and the drawing (1983), a process in which designers do not only record an idea but generate it. Along this idea, Menezes and Lawson (2006) state that conceptual sketches are at the core of emergence and reinterpretation during the design process. As new ideas emerge and are drawn (emergence), drawings become visual clues that trigger and help developed and transform new images during sketching. In earlier design studies, drawings have been seen as communication aid but also as part of a cognitive process of thinking and reasoning. According to Do (1996) design reasoning is embedded in the act of drawing, as it supports rapid exploration, and incremental definition of ideas.

Studies about sketching in design as a cognitive reflective thinking process (Schön 1992); have found different stages of visual thinking. The dialectics of sketching discovered by Goldschmidt (1991) refers to: ‘seeing that’ (reflective criticism) and ‘seeing as’ (analogical reasoning and reinterpretation that provokes creativity). The importance of design thinking activity has been eloquently described by Cross (1999, p. 36).

Without writing, it can be difficult to explore and resolve our own thoughts’; without drawing it is difficult for designers to explore and resolve their thoughts. Like writing, drawing is more than simply an external memory aid; it enables and promotes the kinds of thinking that are relevant to the particular cognitive tasks of design thinking.

In design research, drawings have been employed in the study of design knowledge and as a source to analyse visual thinking and the design activity (Dahl et al. 2001; Rosch 2002; Tang 2002). These studies assert the notion that there is a relationship between drawing and experience, and that drawing is an iterative act that involves seeing and thinking. According to Kosslyn (2003) visual mental imagery is seeing in the absence of an immediate sensory input, and it is related to human experience where memory not only comprises an image or an event, but also information about its sensorial context. Therefore, it can be said that knowledge in visual thinking is associated with contextualised human experience. For example, a study conducted by (Chamorro-Koc et al. 2008) in which design sketches from novice and expert designers were compared, identified four types of knowledge embedded in visual representation of concepts: familiarity (experience from seeing), individual experience within context (experience from doing), principle based concept (knowledge of product from experience of using it), descriptive based concept (knowledge of product from seeing it). Their analysis of those four types of knowledge embedded in sketches led to discover references to: individual experience, knowledge to a product’s use, and its context of use and revealed that particular areas of human experience that trigger people’s understandings of products. Figure 1 illustrates it by comparing sketches of a novice (left) and expert designer (right) done as part of such study. Drawings were produced during a collaborative design task where both novice and expert designer were asked to discuss while designing in response to a given design brief (Chamorro-Koc et al. 2009).

One conclusion emerging from the analysis of these drawings established that novice’s visual thinking demonstrate an emphasis on features, functions and mechanisms of the product being designed, while the expert’s visual thinking demonstrate understanding of principles of use and of the functionality of the product.
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This type of analysis mostly focuses on the action of sketching and visual thinking and not the specific type of knowledge embedded in the sketches themselves. It adds to the extant theory postulating that drawing and re-interpretation support different kinds of cognitive activities in design. So we ask: could this approach be instrumental in design pedagogy to understand students’ learning? What types of knowledge/thinking processes are manifested in design sketching during Concept Bombs tasks? And why is this important to understand in the shifting context of educational delivery systems (blended learning environments) and an outcome-focused approach to education?

Concept Bombs: a visual thinking technique as part of design studio pedagogy

A pedagogy that utilises visual thinking through rapid sketching in our Industrial Design studio sessions is the ‘Concept Bomb’. This format consists of a short design task undertaken in class followed by immediate staff and peer feedback. In First Year, students are given a five-minute briefing and asked to generate one or more design concepts for a simple product. In Third Year design studio we adopt various formats which include: five-minute briefing or thirty-minute expert briefing, individual or team based task, single task or a consecutive series of tasks, twenty-minute or three-hour design work in class. The brief could be focused on: a ‘blue sky’ and conceptual challenge, or on elaborating on particular aspects of a larger project. In each case the task is achievable in a short space of time. The session concludes with immediate tutor-guided peer-assisted formative assessment during the same session. In this paper we compare First and Third Year Concept Bombs.

In First Year, Concept Bombs are 30 minute design tasks. The design brief is usually comprised of a single design challenge with two or three factors for students to consider. Each tutor presents the design brief to their studio group and responds to questions before the design phase commences. Students produce one or more design concepts.

Figure 1. Segments from a novice (left) and expert (right) designer sketches

Figure 2. A First Year student’s Concept Bomb (left) and the Concept Bomb design brief (right)

Easy-to-use Door Handles

Design door handles that clearly communicate how the door opens (pull or push). You can design a pair of handles—one of the push side, another for the pull side—or a single design that serves both purposes.

1. Features
   a. must clearly communicate how the door is used
   b. commercial market (offices and public buildings)
   c. lockable
conceptual sketches in marker on A3 paper briefly annotated to facilitate explanation of the design ideas. At the end of the session students pin up their sketches and review each other’s work. Sometimes time is provided to review the work of other studio groups who have been working in parallel. Teaching staff review the work simultaneously and the group reassembles for a brief public critique of noteworthy work. Figure 2 shows an example of a First Year design Concept Bomb and the design brief.

Concept Bombs in First Year design studios are employed for two different purposes: (a) to ‘pace’ tasks and projects within the semester; and (b) to give students the opportunity to refine their understanding of sketching for rapid ideation in a supervised setting. Therefore, these concept bombs follow four characteristics:

**Pace and focus:** Three to four Concepts Bombs in a semester help punctuate the semester experience within or in between larger projects (Figure 3). As some First Year students experience difficulty maintaining engagement and motivation throughout long design projects, Concept Bombs provide a change of pace. The briefs are ‘object’ oriented with topics based on familiar daily experience that don’t require research. Students apply the foundational design knowledge and methods they have been learning in class.

**Rapid feedback:** Concept Bombs enhance learning by closing the feedback loop. As there is little pause between doing the sketches and getting feedback and assessment they provide ‘instant gratification’ to students. Staff moderated peer feedback also encourages student engagement with assessment criteria and promotes peer learning.

**Ideation technique:** Concept Bombs are about using sketching as a rapid ideation tool. Given the same project brief as homework students would likely spend four or five times as long on it. Left to their own devices novice designers tend to draw slowly and carefully investing too much time on too-few sketches without necessarily engaging in deep ideation. Forcing students to practice rapid sketching forces them to streamline their technique and see the value of sketching without the formality of formal project presentation. Doing this within a supportive studio context and with an imminent deadline encourages useful engagement with relevant skills. Students learn that fast sketching is a means to become more efficient and explore more ideas in a shorter time (Figure 4).

**Repetition:** Repetition is a key part of Concept Bombs both in the development of sketching skills and in managing performance pressure for students. Since Concept Bombs are effectively an examination of sorts, students might be forgiven for feeling considerable pressure to perform. This is managed in two ways. Firstly the assessment weighting for Concept Bomb assessment within the unit is quite low—rarely more than 20%. Secondly this mark is derived from the best three out of four (or best two out of three) Concept Bomb
submissions. The consequences of poor performance in any single Concept Bomb is thus quite low and the addition of a ‘spare’ gives students a safety margin that moderates the pressure they feel on any single exercise. The outcome is that students report high levels of engagement and enjoyment with Concept Bomb activities.

Third Year Concept Bombs present different formats which differ in level of complexity and could be an individual or team based task, a single task or a consecutive series of tasks towards one common objective. Complexity in this context is defined by the type of previous knowledge (from previous design units) that students are prompted to refer to, or to integrate from, for the resolution of the concept bomb task. Depending on the level of complexity concept bombs could require five-minute briefing or a thirty-minute briefing led by an industry expert; and could take twenty-minute or three-hour design work in class. Third Year concept bombs requiring low level of complexity are often short 20 minute individual design tasks but they form part of a larger project and prompt students to explore particular aspects of the main semester project. Three design briefs take place one after the other during a single intensive design studio session with minimum time allowed in between for pin-up of the work. This experience is repeated at key stages of the semester project. Design briefs are delivered to students by including a user scenario to help contextualise particular design problems. The expected outcome is blue-sky design propositions which form the basis for later in-depth exploration. At the end of the third task, students review each other’s work and indicate, on a feedback label that accompanies each submission, the best of the three designs from each student. In some projects it has been possible to engage industry collaborators in the feedback phase which gives students ‘real world’ input via informal conversation on the merits and limitations of their ideas. Figures 5 and 6 show examples of Third Year students’ concept bomb sketches and the associated design brief.

Figure 5. A Third Year design student’s Concept Bomb sketch (left) and the design brief

CONCEPT BOMB #1: “Collecting information on the go”
Your client is a high-tech product developer and is planning the next generation of wearable devices the techno-savvy group of users. This market niche is comprised of people who ‘collect information on the go’ in their lives with the goal of selling this information to specialised wholesalers information distributors. The interactive designed object should:
• be wearable,
• be appropriate to use for the user group ‘on the go’,
• have a GPS which allows identify location of the ‘news/information being transmitted’,
• rely on gestural and tangible interactions for ‘sensing and transmitting’,
• not include GUIs.

Figure 6. A Third Year design student’s Concept Bomb sketch provided by industry collaborator

CONCEPT BOMB guided by industry collaborator (*)
• Choose an assistive technology from the ones presented in the exhibition
• Role-play a device of your interest, imagine using it in your everyday life
• Assess the device affordances and think how could it benefit other users
• In your teams (4), re-design the device by extending its functionality to a broader range of users.

*In this case, our industry collaborator is a non-for profit organisation that provides information and services to people with disabilities and the senior population.
More complex Third Year concept bombs involve three-hour design tasks requiring both individual and team work, and comprising a series of consecutive design tasks. They are often industry-led and focused on a specific aspect of a project. We have introduced this approach in our first semester 2014 as a ‘walk through’ process to assist students in understanding the rationale behind a particular ‘design for manufacturing’ process. The industry expert presents a case and an exemplar, followed by a structured design task. Each step is timed (twenty to thirty minutes) and treated as a single concept bomb task with its own introductory briefing and conclusion. These concept bombs mainly focused on the ‘how’ rather than on the ‘what’. The session ends with students’ presentation of their work as a team, and with a ‘Master Class’ from the expert, highlighting the achievements, gaps and issues that need further revisions. The expected result of this activity is to expedite students learning process of design techniques they need to employ in the development of a larger project. Figure 7 describes the segments a three-hour session format.

Concept Bombs in third year design studios are employed for two different purposes: (a) to encourage focus on particular areas of the project that are of pedagogical interest, and (b) to give students the opportunity to enhance their sketching techniques and visual thinking skills. The application of Concept Bombs in Third Year shows four characteristics:

**Pace and focus:** Concept Bomb briefs focus on particular aspects of a project that otherwise students would not explore at first. Such areas are usually related to new theory being presented to them. In order to bring all elements together in a concise format for students, Concept Bomb tasks use scenarios (or case study) to

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**Figure 7. A Third Year industry-led session format**

**Figure 8. Third Year concept bombs stimulate the early phases of larger design projects.**
introduce a design problem, illustrate a user situation and the context of use (Figure 8). Design requirements are presented as a set of problem boundaries.

Rapid Feedback: The tight loop between the sketching activity and feedback allows students to quickly learn from the experience and bring their learning into the semester design project. Peer feedback plays a more important role with these students as there is no formal assessment attached to the task. Peer feedback becomes a vehicle for students to expose their ideas and be competitive, be aware of how effective they are at communicating their design ideas, appreciate differences between what they think is their best concept design versus what other people perceive is the best, push themselves out of their comfort zone and think about design aspects they would not consider otherwise. In higher complexity concept bomb tasks, expert feedback in the form of a Master Class at conclusion of the task, provide students with real-world industry input, which is highly appreciated.

Ideation technique: As in First Year, Third Year Concept Bombs cultivate student sketching as a rapid ideation tool however here there is a higher expectation of design resolution and effective visual communication.

Repetition: Repetition of Concept Bomb activity within same studio session allows students to quickly gain confidence from Concept Bomb task one to task three. Usually by Concept Bomb three students are working at that most confident and effective level.

There are evident differences between outcomes from the two students cohorts. It is interesting to observe that beyond the quality and detail of the design development observed in the sketches, there are different types of experiential knowledge embedded in the visuals. Input from a Second Year unit, *Culture and Design*, seems to contribute to Third Year students design thinking when addressing the Concept Bomb briefs, as in this unit students explore how culture influences product design and how people interact and use products in everyday life. The following section presents an overview of a comparative analysis that aim to uncover characteristics described in this section.

Understanding visual thinking behind Concept Bombs: an initial analysis
An initial exploration of sketches produced by First and Third Year design students was conducted to find out what aspects of the learning experience of designing and visual thinking can be evidenced through Concept Bomb tasks. This analysis is based on Chamorro-Koc et al (2009) study in which design sketches were categorized to reveal types of individual knowledge.

Analysis of students’ Concept Bomb sketches
The analysis of sketches was assisted with ATLAS.ti, a software-based qualitative analysis package. A system of categories was employed that focus on identifying elements in sketches that reveal students’ individual experience, knowledge of the product, and of the product’s context-of-use.

Drawings were analysed and interpreted to identify references made to students’ knowledge of the product design, their individual experience with similar products, and references to context of use employed in their design concepts. The following table shows the coding system.

The coding system reveals different types of knowledge due to individual experiences: individual experience with similar products (tacit knowledge), reference to a particular experience situated in a particular context (individual or episodic experience). The coding system was applied to the appropriate segments of drawing. For example Figure 9 shows how the coding was applied to a student’s Concept Bomb sketch. It uses images and written notation to describe a design concept for a product with three components, a bracelet, an earpiece and a screen, and the gesture-based interface of the device. It can be seen that the drawing does not provide detailed design features however, arrows, annotations and images provide a sense of the principles behind the functionality of the design. Thus PBC – Principled based concept – is the code applied to the segment of the drawing where it clearly indicates how bracelet, screen and earpiece interact. The segment showing a detail of the earpiece placed on the ear indicates IU – intended use. The segment showing the earpiece with an annotation (“capture a photo”) is coded DBC – Descriptive based concept – as it only represents...

<table>
<thead>
<tr>
<th>Categories</th>
<th>Subcategories</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience</td>
<td>Features with indication of usage</td>
<td>FE</td>
</tr>
<tr>
<td></td>
<td>Individual experience within context</td>
<td>IEC</td>
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<tr>
<td></td>
<td>Episodic data</td>
<td>ED</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Principle-based concept</td>
<td>PBC</td>
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<tr>
<td></td>
<td>Description-based concept</td>
<td>DBC</td>
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<tr>
<td>Context-of-use</td>
<td>Intended use</td>
<td>IU</td>
</tr>
<tr>
<td></td>
<td>Situation</td>
<td>ST</td>
</tr>
</tbody>
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*Table 1: Coding system*
Bombs Away: Visual thinking and students’ engagement in design studios contexts

Figure 9: Exemplar of a coded Concept Bomb

what it is, but does not provide more references as to the purpose or context of use.

A comparison between First and Third Year students’ sketches

As expected differences in the quality and detail in Concept Bomb drawings of First and Third Year design students are evident. Additionally the thematic coding identifies differences in design knowledge prompted by Concept Bomb pedagogical objectives. The following table presents a comparison:

The literature indicates that the notion of students’ engagement is one with many meanings (Bryson 2007), usually referring to: behaviours in the classroom, staff-student interaction, cooperation among students, and a dynamic relationship between learner and environment (Chamorro-Koc & Scott 2012). In our experience student engagement tends to be viewed as a reflection of learning processes and it is a crucial means of an educational process that establishes the foundations for successful later year studies (Krausse & Coates 2008). As a pedagogical tool to support for students engagement, Table 2 shows differences between First and Third Year students in each of the four identified Concept Bomb characteristics. Pace grows in intensity, focus changes from object to context, feedback shifts from individual gratification to peer pressure through formative assessment, ideation moves from the facilitation of fast exploration of ideas to the facilitation of fast exchange of ideas.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>First Year Students</th>
<th>Third Year Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pace and Focus</td>
<td>Three to four times during semester.</td>
<td>Enabled twice or thrice in the same session, several times during the</td>
</tr>
<tr>
<td></td>
<td>Object oriented.</td>
<td>semester. It focuses on people’s relationship with objects in everyday</td>
</tr>
<tr>
<td></td>
<td>Promotes engagement with fundamental design process.</td>
<td>life practices. Use of scenarios allows quick engagement with new theory.</td>
</tr>
<tr>
<td></td>
<td>Instant gratification.</td>
<td>Promotes engagement with the larger design project.</td>
</tr>
<tr>
<td>Ideation Technique</td>
<td>Promotes rapid ideation skills.</td>
<td>Refines rapid ideation skills.</td>
</tr>
<tr>
<td>Repetition</td>
<td>Promotes skill development and confidence.</td>
<td>Single-session repetition refines skill development and confidence</td>
</tr>
</tbody>
</table>

Table 2: Comparison of characteristics of Concept Bombs in First and Third Year design studios
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As a pedagogical tool to understand ‘how’ design students conceptualise their design propositions, the analysis of students’ Concept Bomb sketches reveal that their work moves from basic descriptions of features or functions to descriptions of context and practices. This could be a reflection of students’ enhanced understanding of social issues learned through the Second Year Design and Culture unit. For example, hand gestures showed in Figure 5 indicate a Gen Y form of gestural communication. In this case, this Concept Bomb reveals the learning from socio-cultural issues previously learned from case studies, and shows how a student might design an object with social considerations in mind.

Discussion: concept bombs, digital media and studio teaching

Design studio is the context where learning emerges through action; it is distinguished by emphasis on project-based work, learning through praxis, learning through workshop, and learning through first hand observation (ALTC 2011). In this paper we have described our approach to the use concept bombs in First and Third year industrial design studios. Through a comparison and coding of the experiential knowledge embedded in students’ sketches we have gained an initial understanding of the type of experiential knowledge embedded in students’ design work at different stages of their education. This has helped inform our design studio pedagogies and to devise strategies to foster positive students’ engagement. In the midst of current educational trends and the increased demand for use of digital media in all aspects of education, we enquire about the possibilities of this kind of design studio approaches and its benefits to be delivered via online studio formats.

It is well known that universities are currently facing a range of challenges, from diminishing government funding, institutional amalgamations, internal restructures, changing expectations among students, as well as challenges around the appropriate adoption and adaptation of digital technologies (Zehner 2008; Carey et al. 2013; Lockett 2008). Today’s generation of students have grown up immersed in digital technology, digital media is deeply embedded in all aspects of their life, and they expect this technology to be a part of not only their social lives but also their academic lives (Brown 2001).

Studies have found that digital media, wireless broadband and mobile communication have provided remarkable opportunities to incorporate blended learning models into studio teaching (Fisher 2010; Hill and Hannafin 2001). For example, the incorporation of digital media into studio teaching can be used to: enhance resource-based learning that involves the reuse of available information assets to support varied needs (Beswick 1990), cultivate students’ capacity to employ independent learning, facilitate students’ access to resources at any time or location that suits them and not solely on campus (Hill and Hannafin 2001; Fisher 2010). However, despite all these advantages and the promise of digital media to enhance both teaching and learning of the creative disciplines, there is still a lack of consensus on the best ways these technologies can be incorporated into studio pedagogies (Hill and Hannafin 2001; Harris, Mishra and Koehler 2009; Brown 2001).

In Australia, one of the forms in which digital media has been employed in design studios is the online or virtual design studios (VDS). Developed since the 1990s, VDS is defined as networked design studio accessed online (Shao, Daley and Vaughan 2007). A first large VDS project was run in 1999 by the University of New South Wales with fifty students from different countries participating (Bennett 2001). The VDS teaching model instead of focussing on a final product or design, emphasises the design process encouraging students to review and evaluate their learning progress and focuses on communication and collaboration between not only students but also the teacher (Shao, Daley and Vaughan 2007). There are evident benefits to the use of VDS based on participation and collaboration aspects relevant to studio teaching and learning processes, which would also address issues about students’ engagement. However, it remains unexplored the ways in which VDS could be employed to produce the type of learning experiences prompted by face-to-face concept bomb activities, where aspects such as: immediacy, intensity, timing and complexity, dictates the teaching and learning experience. Further research into this aspect and students’ design processes; require involving observational studies and retrospective interviews to further understand the experiential and conceptual considerations informing student’s design decisions during Concept Bombs activities and the possibilities to transfer similar type of experiences to an online environment.

Conclusion

This paper has described Concept Bomb approaches in design studio that promote students engagement and visual thinking skills. Deploying this approach in both First and Second Year classes, both as independent exercises and integrated within larger projects, demonstrates that the formula is flexible and adapts readily to pedagogical requirements. The intensity of the experience is engaging for students and builds their confidence in their own skills through via immediate feedback and peer learning. This improves the quality of the studio experience, something
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perceived as under threat in the current academic environment (ALTC 2011). These outcomes suggest that the Concept Bomb approach is robust, flexible and worthy of more widespread adoption within our Industrial Design program.

Exploration of the differences between novice design students and their more experienced later-year colleagues may reveal useful insights into their learning processes. One approach for this may be to conduct identical Concept Bomb design briefs with both the First and Third Year cohorts to afford more direct comparisons of the outcomes.

In the shifting context of educational delivery systems we wonder how this type of experience could take place in emerging educational contexts such as virtual design studios. In a virtual studio, the dynamic of Concept Bombs would certainly change but benefits may remain if the immediacy of the experience can be duplicated. This is one possible avenue for further research.

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Bombs Away: Visual thinking and students’ engagement in design studios contexts


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Learning from Students: Reflections from personal magazines in basic design course
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Abstract
Reflective writing is an efficient way of getting feedback from students. Paper-based or web-based course evaluation questionnaires alone may lack of collecting specific and detailed information, especially for the fields like design education. This study focuses on reflections captured from students via two different media – personal magazine and online questionnaire – in 2012 Spring Semester conducted in Basic Design II in the Department of Industrial Product Design at Istanbul Technical University (ITU), Turkey. Throughout the semester, each student was encouraged to write a diary weekly and expected to submit a photocopied page of it to reflect freely their impressions about the course and their experiences, written or visual, or both. At the end of the semester, students were expected to submit their diaries in the form of personal magazines. This data is valuable to see the development of the student in terms of design awareness and perceptions about the course specifically. Moreover, a specific web-based questionnaire is prepared and delivered to students in order to see the general tendencies about the course. Based on these data, we explore how we can learn and benefit from students’ reflections for Basic Design course mechanism and design education.

Key words
design education, basic design, industrial design, reflective writing, writing-to-learn, learning

Introduction
Especially in project-based courses, face-to-face relationship with students is apparently important both for students and instructors. This mutual contact makes students to get involved in the course with more enthusiasm and also instructors are able to get more feedback regularly.

Since the student quota for the Department of Industrial Product Design at ITU was increased from about 30 to 45 step by step in recent years, the problems about constituting face-to-face relationship became more obvious especially for 1st year courses. It has been demanding for instructors to deal with the huge number of students. Basic Design courses, which are compulsory introductory courses in Industrial Design curriculum, were affected in such a way that direct and one-to-one interaction almost disappeared. Therefore, the tutors of these courses – also the authors of this paper – had to invent and implement methods to get feedback from students.

This paper aims to discuss these methods and reveal their outcomes. In order to capture reflections from students two different media were used; namely personal magazine and online questionnaire.

1. The Issue of Reflection in Design Education
In student-centered approach, the actions that student does are more crucial than those that the teacher does (Rogers, 1951). This idea also suggests that students’ experiences and perceptions influence the methods of learning and the things that are learnt. At this point, reflective process is considered as an important tool where student can play an active role (Kolb, 1984). According to Moon (1999), there are different understandings on reflection, which can be seen in Dewey (1993), Hullfish and Smith (1961) and King and Kitchener (1994). These understandings can be summarized as:

…[reflection] impl[ies] a form of mental processing with a purpose and/or an anticipated outcome that is applied to relatively complicated or unstructured ideas for which there is not an obvious solution. This suggests close association with, or involvement in, learning and the representational learning (Moon 1999, p. 4).

Reflection is particularly critical in the fields involving practice such as design. According to Schön (1982):

Through reflection, [practitioner] can surface and criticize the tacit understandings that have grown up around the repetitive experiences of a specialized practice, and can make new sense of the situations of uncertainty or uniqueness which he may allow himself to experience. (p. 61).
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He points out two major notions: reflection-in-action and reflection-on-action. While “reflection-in-action” corresponds to thinking on feet, “reflection-on- action” implies re-considering a practice later. The former one is highly related to considering experiences, feelings and theories in use. By this way, practitioner can inform his actions with new approaches. However, the latter one refers to thinking on past actions. Therefore, practitioner can examine his actions by revisiting them (Schön, 1982).

In summary, reflection is closely connected with the action; and practitioners should learn frame and reframe the problems and make necessary changes during actions (Schön, 1982).

As Dewey (1993) posited, “The function of reflective thought is...to transfer a situation in which there is experienced obscurity, doubt, conflict, disturbance of some sort, into a situation that is clear, coherent, settled and harmonious” (p. 100-101). This becomes more crucial in the context of design-related domains where problems are wicked; and thus ambiguous (Buchanan, 1992; Rittel and Webber, 1973).

Based on Schön’s “Reflective Practitioner”, there has been a tendency to search for getting reflections from students. In this context, the idea of reflective journal offers a tool for “inner dialogue that connects thoughts, feelings, and actions” (Hubbs and Brand, 2005, p.62). Specifically, the personal journal/diary (personal magazine in this paper) is considered as a narrative descriptive writings where students can share their secrets and no interaction between tutor and students occurs (Hubbs and Brand, 2005).

In short, diaries are used with the purpose of “help[ing] the students reflect on their own learning process, including subjective experiences, and relate learning from literature to their ongoing design project” (Lee et al., 2011).

In this study, personal magazines (a compilation of diaries in a graphically arranged format) are used to capture reflections in Basic Design course.

2. A Brief Glance Into Basic Design Course
Basic Design is a compulsory and introductory course in the first year of the curriculum in design education. Many design educators regards it as ‘indispensable’ (Özer, 2004). The course can be considered as practice-based, focusing on visual perception, principles of basic structures, form-function relationship, and color theory. The foundation of the Basic Design concept is highly connected with the perception theories of Gestalt, which created the curriculum of Bauhaus school (Denel, 1981). Denel (1979) defines Basic Design as a mental system emphasizing on the visual dimension and considers it as the foundation of and beginning of architectural education. He asserts that it is problematic to implement Bauhaus practices entirely and without questioning; and proposes holistic approaches in the studio classes and a modification for specific conditions (Denel, 1979).

Inevitably, the ever-changing approaches and evolving concepts affect the understanding of design education. Kolko (2000) criticizes today’s design pedagogy approaches for still being focused on form-giving, rendering, model making and styling instead of business strategies, user-centered design and service design etc. However, Basic Design courses seem to have a very important role as an introductory course in Industrial Design curriculum in the appearance of these new trends with a broader perspective.

According to Boucharenc (2006), Basic Design education is still a very crucial element in design education curriculum in most of the countries. More specifically, Blachnitzky (2011) explores whether there is a consensus among first year design educators in basic design principles (two- and three-dimensional basics, shape, color and experimentation with materials). In short, since human sensation remains the same, in today’s design education it is still valid to include these principles in order to develop a common visual language, to practice their perception, and to cultivate a specific way of learning. Not surprisingly, some of the educators believe that teaching design basics in general is not adequate and propose that real-world design projects should also be engaged in Basic Design (Blachnitzky, 2011). At the same time, it is also vital for instructors to seek proper methods for design pedagogy and to be aware of different pedagogical attitudes (Farivarsadi, 2001). Therefore, besides generating the design projects to be assigned to the students, it is significant to develop proper methods to establish coherent communication with the students.

Since this study is based on students’ reflections in Basic Design II in the Department of Industrial Product Design at Istanbul Technical University (ITU), the series of exercises conducted throughout semester will be introduced briefly in this section.

Basic Design II is a compulsory course, which has a prerequisite of completing the Basic Design I, for Industrial Product Design students at ITU. The course content is basically composed of:
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Three dimensional, structural and basic functional design exercises, Building structural designs with different materials, Experimental exercises on Motion, Structure, Mass, Texture and Light, Design as problem solving method, Creative strategies in design. Experimental design and applications, Design problems of 3-D functional systems and experimental 3-D design studies (ITU Course Catalogue Form, 2009).

Even if the course content shares some similar characteristics with Bauhaus ecole, the course tutors are seeking new approaches by adopting new design exercises and applications for today’s student profile and conditions. Getting reflections by using personal magazine is the result of this approach.

In 2012 Spring Semester, the following exercises were assigned in Basic Design II course:

• Body Extension: Focusing on the interaction between human body and object
• Color and Objects: Differentiating objects by the element of color
• Logo and Layout: Designing logo and developing layouts
• Solid, Liquid, Gas: Expressing states of matter in 3D
• 3D Abstraction: Abstracting a pinecone and analyzing its structure
• Music Abstraction: Expressing music styles in 3D
• Structure: Elevating a heavier than 80 kg person to 25 cm high with corrugated cardboard
• Reaction to Wind: Developing a system that reacts to the wind
• Award Set: Designing an award set for an event or competition
• Pure Function: Designing a system that holds, carries, displays and charges a cell phone
• Collapsible Seating Unit

3. Method and Data Collection
In this study, mainly two media were used for data collection about reflections of students about the course: the personal magazines and the online questionnaire. While personal magazines provide students’ insights, online questionnaire offers general tendencies on the course.

3.1. Personal Magazines
Students were encouraged to write a diary weekly and expected to submit a photocopied page of it each week throughout the semester. Via diaries, they could reflect their impressions generally about their journey in relation to the course, visually, literally or both. At the end of the semester, students were expected to submit their diaries as a personal magazine, i.e. arranged in a graphically designed format. As tutors, we did not interfere with the content and the format of personal magazines so that they could freely express themselves (Figure 1 and Figure 2). We named it as “personal magazine” for two reasons. First, “personal” makes it specific to the students, which encourages them to share their personal insights and stories with us. Also, magazine implies the idea of arranging the pages in a coherent manner. Coherency is one of the important dimensions of Basic Design, where students are supposed to reflect visually with a proper layout and design elements. Therefore, the visual arrangements of magazines are also important where students can reflect their visual understandings gained through semesters.

The texts in the magazines were analyzed and revealed qualitatively since they contained rich and contextual
Learning from Students: Reflections from personal magazines in basic design course

We started to the semester with body extension. I made an extension that I could put on my hand. We have to make a pinecone abstraction and draw it on A3.

Since these kinds of statements do not include enough analysis and elaboration, we did not consider them as a research input in this study.

However, personal insights were clustered into highlights. While composing these highlights, we used both the excerpts from the personal magazines as well as our observation throughout the semester.

3.2. Online Questionnaire

Online questionnaire was conducted at the end of the semester to gather general tendencies about the course. 29 students filled in online questionnaire.

The first section of the questionnaire contained general evaluation questions about the course. In the first section, we aimed to check if there was a problem with the course mechanisms, tutors’ methods/attitudes and to learn students’ approaches in general.

The first section of the questionnaire reveals that students mostly agreed that the course was conducted properly and the students were motivated for the course sufficiently. However, most of them think that there were some problems regarding assessment and workload.

The second section of the questionnaire included the course-specific questions. In this way, we aimed to gather data specifically related to the course. Therefore, we prepared questions on the projects assigned during semester. Also, we asked them which skills that they gained during the course. In this question, there were 22 skills listed, which can be categorized into 3 categories: Skills related to problem definition and process; technical skills and personal skills.

- Skills related to Problem Definition and Process: Time planning, Defining problem, Problem solving, Experiencing design process properly
- Technical Skills: Ability to work individually, Ability to work in groups, Concept development, Analyzing form-function relationship, Visual presentation quality, Verbal presentation quality, Ability to analyze materials
- Personal Skills: Critical thinking, Curiosity in profession, Creative thinking, Abstract thinking, Working in a disciplined way, Self-confidence, Courage, Communication with tutors, Learning from others, Learning from environment, Openness to criticism

4. Highlights from Personal Magazines

In this section, highlights from personal magazines will be revealed in relation to the skills listed in the online questionnaire: Skills related to Problem Definition and Process, Technical Skills and Personal Skills. In order to give clues on contextual information, the projects’ names are given in brackets.

4.1. Problem Definition and Process

As online questionnaire shows (Figure 3), 76,9% of students think that they gained skills on defining problem very much (19,2%) and much (57,7%). In personal magazines, apart from mere descriptions we can also see several statements on defining problem. The fact that
Learning from Students: Reflections from personal magazines in basic design course

students try to define the problems by using their own words can be considered as a positive effort for internalizing problems:

Even though we have difficulties in understanding in the beginning and our projects were not good, we understood it in the end: Explore your body! [Body Extension]

…the exercise related to music must be done with the feeling. [Music Abstraction]

That was one of the hardest projects for me and it possibly was the hardest one. Mutant pinecone work is an abstraction exercise in order to understand the structure and graphic values of the pinecone. [3D Abstraction]

This initial exercise of the semester was very important and taught us a lot of things. It enhanced our observation skills and exploring the things we were surrounded, and the most important was the interaction between human body and the product. [Body Extension]

80.8% of students believe that Basic Design course affected their problem solving skills much or on an average. Finding excerpts regarding problem-solving skills from personal magazines is difficult because this is a skill embedded to students’ projects. Here are some examples from their magazines:

The most important thing in abstracting a pinecone was not about what you were thinking. The important thing was the final product. [3D Abstraction]

I tried to internalize what abstraction was. While abstracting an object, we had to ignore certain features and differentiate it. At the same time, we had not to lose the origin. [3D Abstraction]

From questionnaire, we can see that there is almost an equal distribution on the contribution of skills related to time planning. In personal magazines, some students complain about the problems they faced to due to the time limitation. This problem may occur due to the lack of their experience. Since they cannot foresee unexpected problems, they can have problems with time:

Since I could not think of binding details and the system, the time I spent at the atelier got longer. As I was working, I faced with new problems and tried different solutions. [Collapsible Seating Unit]

In some cases, time can become an obstacle that affects their thinking:

Time limitation restricts our creative thinking; and this shows us the importance of time for our occupation. [Body Extension]

4.2. Technical Skills

As we can see from online questionnaire (Figure 4), students think that Basic Design II contributed on the ability to work individually much more than that to work in groups. This may occur because most of the exercises conducted in this course were designated to work individually. We observed some problems in assigning exercises for teamwork such as heterogeneity in composing groups, difficulties in assessment and distribution of work. That’s why, only 1-2 short-time group works are given to students; which are specifically designed for teamwork (see Bagli and Gelmiz, 2013). Therefore, this limitation may turn out lack of improving ability to work in groups. However; as we can infer from the personal magazines, even these limited group exercises make them to be aware of the difficulties in working in groups:

I was convinced that working in groups was very challenging. [Structure]

There were three of us in this project. Working together was different. Whereas you could implement what you are thinking in individual projects immediately, you had to tell and convince others in group projects. [Structure]

Also, they can notice the positive aspects of group projects:

…this makes us to gain experience on working in groups as well. We saw that opposite ideas might refute ours. Besides, since this project improved the ability to work in groups, it was very important and beneficial. [Body Extension]
There were a plenty of statements in personal magazines on analyzing materials, which is an important aspect of the course. In almost every exercise, we try to allocate time to focus on exploring different materials and understanding their nature; and thus their capabilities and restrictions. That's why; we are able to find a lot of statements about materials in personal magazines especially in 3D structural exercises:

The strength of corrugated cardboard is obvious. You cannot expect much from it. Here, design comes into play. [Structure]

Our project was not successful in 3D. In fact, it would have been more effective if we had implemented our ideas into our 3D model. [Structure]

For a long time, we could not do anything. After we recognized the material, we saw the capacity of it. [Structure]

Although I tried to make models around my scenario, I could not reach to the result that I desired due to the wrong material usage. But it helped me to think about all materials’ and forms’ structures in nature. [3D Abstraction]

The type of the material and the dye was very important. They had to match. Each dye might not fit to each material. [Color and Objects]

The fact that material was compelling affected the class very much. [Structure]

The most important thing was to explore the facet of runnels. [Structure]

In addition to these specific examples, some students would like to make general inferences regarding materials:

What is interesting is; howsoever strong the material and binding details, if the system is not durable, it is inevitable that the structure will collapse. [Structure]

In structural systems, using the material properly increases durability. [Structure]

The fact that we worked on various subjects in Basic Design provided us to see new materials and thus we found opportunity to focus on our future directions and field of study. [Color and Objects]

There are also few examples of skills related to verbal and visual presentation quality:

…but I could not explain my ideas with my model and speech. That’s why, my presentation was not good. [3D Abstraction]

Additionally, I had difficulties in layout of the presentation. But I love my drawing. [Color and Objects]

I think I did not solve presentation techniques. I could not understand because of either time limitation or obstruction in thinking. [Color and Objects]

4.3. Personal Skills

In personal magazines, there are a lot of expressions about how the course contributed to their critical thinking, which is also supported by the questionnaire (Figure 5). This shows that students are mostly aware of what they gained from the course. This is also a sign that they become reflective where the degree of self-questioning and elaboration are high. They even criticize their works or processes showing that they internalize being critical:

My drawing was weak; however, they were good as product family. [Color and Objects]

I guess I played safe. Actually, this project was suitable for being experimental [Solid, Liquid, Gas]

Thinking like that does not mean that I can find good ideas and implement them. [3D Abstraction]

I understood wrong, I still can’t believe how I did it. [Body Extension]

Scarcity in projects and difficulty in working show me that it is really hard to change things that one is used to and is conditioned unconsciously. Although I am not satisfied with the result right now, this exercise is a good beginning for making more innovative things by breaking some biases. I think creating awareness is already a positive aspect of this class. [Color and Objects]

I tried to make a style with lines but this was not good either. That is, it was boring as well as nothing different and unique to me. [Award Set]

In this course, it is also crucial to get collective feedback. In other words, we encourage students to listen and contribute to the critics about projects of their friends where they can learn even more. They seem to highly agree with this as we can see from the questionnaire (Figure 5). Some students mention on learning from others in their magazines:

Additionally, my friends’ projects with extrusion drew my attention. Rather than a real 3D, these projects offered fake 3D as I did in my graphic design works. [Award Set]

What I gained from the successful examples was that I learnt how to use the material. They helped me while I was making the project again. [Structure]

At my first trial of coloring object I was not successful enough, however I did it better after I heard comments and saw the other works done by my friends. This project teaches us a lot. [Color and Objects]

I was really confused at first. After critics, it was clarified. [Reaction to Wind]

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I think I did not solve presentation techniques. I could not understand because of either time limitation or obstruction in thinking. [Color and Objects]
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When I looked at other projects in the class, watching studio critics was very useful for me. Because I could not attend to the class, I could not get feedback. Since I did not know what they were talking, this was a disadvantageous for me and I had to follow the class back.

Apart from these highlights, we have difficulties in finding statements on skills we did not mention in highlights such as curiosity in profession, creative thinking, abstract thinking, courage etc.

4.4. Other Highlights

Apart from the highlights, mentioned above, we also observe that students tend to reflect their experiences from daily life and their emotions, which can be regarded as a special effect of free writing as a method. As we can see from the magazines, students are affected from their experiences especially while initiating a project. For instance;

Since I am living in dormitory, I have troubles with the cables. This triggers my project.

The first thing that came to my mind was heater because I have problems with one-sided heaters.

A speaker in a seminar – I could not remember name – talked about designing hexagonal office units for Herman Miller. This came to my mind and I continued to the project with this.

Also, students want to reflect their emotions evoked during their design processes. We can also observe these during our classes especially in the verbal presentation of their project juries. The fact that they both feel negatively or positively during the process shows that they tend to build strong emotional attachments with the projects and thus the course. From the excerpts below, we can see the effects of happiness, fear, and excitement etc.:

Getting positive comments in the jury makes me happy.

After long trials, I finished the project. I was really happy.

I did not assert that I designed a good logo but it was not so difficult that I feared in the beginning.

In fact, the feeling of remembering previous projects and benefitting from our experiences make me excited all of a sudden. I hope I can learn to direct my excitement in a positive way for my projects in the future.

Starting to the issue of structure with this way was a bit scary.

As usual, we felt lonely in a middle of a big sea again. Even if one knows swimming, he cannot reach to the land. The saver might be a rope from a boat. Again we are feeling the same.

Perceiving the shapes on the pinecone was an amusing process.
Learning from Students: Reflections from personal magazines in basic design course

As seen from the excerpts, there is a wide range of emotions that students mention in their magazines. This implies that most of the students feel free while reflecting themselves as a positive effect of free writing.

Conclusion
This paper investigates capturing reflections from students via free writings in the form of personal magazines in a Basic Design course, which is supported by the data of an online course evaluation form. It is observed that personal magazines have contributed to both students and tutors as a strong and rich way of reflection.

As seen from the rich data gained from the excerpts in the magazines, most of the students become reflective in terms of transferring their impressions on Basic Design course. This is considered as a positive long-term trait for students as individuals. According to Moon (1999), “a person who is reflective seems to be someone who comfortably and successfully engages in the mental activity of reflection and would make decisions that are well considered” (p.5). For the first year design students, we think that it is noteworthy to gain these skills and become aware of them for their professional development.

One of students questions herself and reflects her opinions referring to the nature of design that involves uncertainty:

I found a chance to think on while we were completing our Basic Design course. I asked myself questions and as usual I could not find certain answers (I guess this is Industrial Design tradition). However, with this second semester, I am aware of the change happening inside me.

Moreover, students’ reflections influence not only tutors’ motivation but also tutors’ perspectives while building their on-going and future courses. Therefore, reflections can become one of the main tools to learn from students and rethink, develop and transform the content and the style of the course itself accordingly.

In summary, personal magazine as a tool of free expression surely serves as mediator, facilitator and also a translator that enables to understand students’ dialects. It is also a strong emotive and cognitive link between student and tutor, student and his/her learning process, tutor and the course design.

Acknowledgements
Thanks to our students who took Basic Design II courses in 2012.

References


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Learning from Students: Reflections from personal magazines in basic design course


Framing Behaviours in Novice Interaction Designers

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Abstract
Framing design problems and solutions has been recognised in design studies as a central designerly activity. Some recent findings with expert designers relate framing practices to problem—solution co-evolution and analogy use, two further widely recognised design strategies. We wanted to understand if interaction design novices also use co-evolution and analogies to frame their thinking. Furthermore we wanted to see if there are any differences across cultures. The paper reports an analysis of data gained from protocol studies with novice interaction designers in the UK and Botswana. Novice interaction designers in the UK and Botswana show some similarities in framing behaviours using co-evolution and opening analogies to develop metaphorical themes in framing. But within these observations we also found differences across the cohorts, such as different numbers of co-evolution episodes or opening analogies. The implications are discussed in the light of adopting appropriate design pedagogy for novices in different cultures. To increase reframing and generation of more ideas in UK design novices, educators would need to increase the number of leaps between problem and solution spaces. To encourage Botswana groups to frame ideas and work them through in depth, educators would need to discourage students from building too many bridges. Educators are also encouraged to experiment with prohibiting opening analogies to see what other framing behaviours occur.

Key words
co-evolution, framing, analogy, design novices, interaction design, culture

Introduction
Two related aspects of expert designer behaviour have attracted increased attention from researchers: framing and co-evolution of problem and solution. During framing, designers create a particular view on the design problem. Cross wrote: “…designers appear to explore the problem space from a particular perspective in order to frame the problem in a way that stimulates and pre-structures the emergence of design concepts.” (Cross, 2007 p. 94). The way designers frame a problem implies certain early solutions.

Several design researchers have found that problems and solutions co-evolve over time (e.g. Maher, 1996, Dorst & Cross, 2001), and that there are two types of episode in this behaviour: parallel co-evolution of problem and solution, and bridge building between these two spaces. The first type of episode involves a progression of parallel thought in both solution and problem spaces. In the second, intermediate solutions ‘talk back’ to the designer to help understand and frame the problem. The ‘talk back’ situation is understood as a shift in focus between problem and solution spaces (Dorst & Cross, 2001). It can also be understood as a bridge being built between the two spaces. Bridges can be built in both directions. Bridges seem to be built to reconsider the suitability of the current frame and to devise a new solution if the original solution does not satisfy the evolving problem conceptualization. Parallel episodes seem to progress solution and problem criteria without major shifts in either space. Other than this, little is known about the different functions that parallel co-evolution and bridges between these spaces play in the development of a design solution. What we do know is that problem–solution co-evolution as a whole helps experts to frame their design thinking.

Building on this seminal work in problem–solution co-evolution and framing, a new intensification in research around this topic has emerged. Recent studies look at expert designers’ use of framing strategies. Dorst (2011) argues that the activity of framing open and complex design problems is at the heart of design thinking. “Experienced designers can be seen to engage with a novel problem situation by searching for the central paradox, asking themselves what it is that makes the problem so hard to solve. They only start working toward a solution once the nature of the core paradox has been established to their satisfaction.” (Dorst, 2011, p. 527).

Dorst and Tomkin (2011) then found that ‘metaphorical themes’ act as bridges between problems and solutions in a co-evolution process. A theme is a central metaphor,
Framing Behaviours in Novice Interaction Designers

which creates a rich mental image and steers the designers' thinking about the situation in a particular direction. They are neither problem nor solution but 'neutral ground' between problem and solution. The neutral ground seems to be the bridge between problems and solutions.

Similar to the idea of a metaphorical theme in framing, Wilschnig, Christensen and Ball (2013) found independently that analogical reasoning is linked to co-evolution. Analogies occur more frequently in problem–solution co-evolution episode than outside of co-evolution episodes in expert designing. Metaphorical themes and analogies seems to be core drivers for framing experts' design thinking. However, little is known about analogy use in either parallel co-evolution or bridging. Wilschnig et al's analysis didn't focus on the distinction between parallel and bridging co-evolution episodes.

In previous work we have made this distinction and could demonstrate how interaction design novices in the UK and Botswana use problem–solution co-evolution in the sense Maher (1994), and Dorst & Cross (2001) have observed in experts (Authors, 2013). We have also identified a new type of co-evolution in novices from Botswana, in which co-evolution does not start from a detailed decomposition of the problem. Instead, a solution is used to first co-evolve both spaces in parallel before bridges are built between those spaces. Wilschnig et al (2013) have observed a similar change in directionality ("solution attempts spark off the analysis of requirements and possible changes to those requirements" (p. 529)) in expert designers' framing.

Dorst and Tomkin (2011) have argued that understanding framing in more detail is desirable in the study of radical innovation. We believe that understanding framing in novices is also desirable to study and improve design education. Almendra and Christianss (2011) found that students had difficulty with framing their designing. Also, Lindner (2011) has shown that helping students to frame problems leads to more diverse solutions. This paper investigates framing behaviour in novice interaction designers. Specifically, we examine how novice interaction designers in the UK and Botswana use analogy and metaphorical themes in co-evolution and framing. Two questions are addressed here:

1. How do novices in the UK and Botswana frame interaction designs?
2. How are analogy, co-evolution and metaphorical theme used in framing designs in novices?

Based on our findings, the paper discusses some implications for design pedagogy in both settings.

Methodology
The Setting and the Module
The research built on a five-year teaching partnership between the Open University in the UK and Botho University in Botswana. The two cohorts of participants studied the same self-contained module, called "Fundamentals of Interaction Design", consisting of a main textbook (Sharp, Rogers, & Prece, 2007) and wrap-around materials. Both cohorts were given exactly the same materials, the same study path, and the same assessment.

Protocol Study
The protocol study sessions were run just after the students had completed the module's design assignment. Each session lasted about 2 hours, and was structured as follows: introduction, warm-up activity, main study task (lasting about an hour), design presentation to a facilitator. Materials provided were: module books, design method summaries (usability and user experience goals, scenarios, storyboards, card-based prototypes and interface sketches), paper, pencils, refreshments, and a participant booklet each. The participant booklet contained: study background, consent form, warm-up activity (Towers of Hanoi), and design brief. The design brief described the problem and implications around forgetting to take medication and asked students to design an interactive product that will help ensure sick people living at home take the right medication at the right time.

The sessions were recorded using audio and video equipment, and a facilitator was present in the room throughout.

Data Collection
Data collection was adjusted to the way students in each location would usually work. Data collection in Botswana used constructive interaction, i.e. students were paired (O'Malley Draper, & Riley, 1985). Constructive interaction helps overcome problems of concurrent verbalization including silence and inhibition; in addition, students in Botswana usually worked together. We decided against using think-aloud in Botswana because of the possible cultural influence in concurrent protocols reported by Clemmensen, Hertzum, Hornbaek, Shi, & Yarmiyavar (2008). Participants were allowed to choose a preferred local language. Eleven sessions were conducted in Setswana and two in Kalanga. The participant booklet was translated, and local staff members facilitated the sessions.
In the UK, participants used the think-aloud technique and worked alone. A facilitator was present throughout the session. To maintain consistency, facilitators in both countries worked from a common guide. In Botswana, 30 participants were chosen from 70 volunteers, making 15 sessions. Two sessions were not usable because the participants were too quiet. In the UK, 7 participants were recruited. One session was not usable.

Data Analysis
The transcripts were analysed using a modified and extended version of Valkenburg and Dorst (1998)’s notation to identify the processes in Schön (1983)’s design and reflection cycle: naming, framing, moving and reflecting. The extended version includes signature frame matrices to more clearly identify frames (Authors, 2012) and a more detailed notation that highlights the distinction between thinking in the problem space and in the solution space (Authors, 2013). The notation allows visualising exactly when problem and solution space co-evolve in parallel and when bridges between the spaces are built. We also coded the use of analogies (Christensen & Schunn, 2007). An analogy helps to transfer elements from the familiar (a source) to use it in constructing a novel idea. Ideas can be transferred from similar problems or solutions to the current situation. The coding was completed by two researchers independently and challenged by two others on a regular basis. This produced 21 annotated transcripts, 6 from the UK and 13 from Botswana.

Based on these detailed annotations we extracted all episodes that showed parallel co-evolution and bridging within and outside of a frame. We split co-evolution into two separate types of episode: parallel co-evolution and bridging between problem and solution spaces. We also tabulated analogies that occur within and outside of frames, and within and outside of co-evolution episodes. In addition to this, and in line with Dorst and Tomkin’s (2011) definition of themes, we summarised the main theme for each co-evolution episode and analogy. While the frame column is a representative word, shorthand for talking about the frame, the metaphorical theme column gives a description of both the problem criteria and solution ideas that frame the designers’ thinking. An exemplar table for Botswana pair 8 with all the extracted

<table>
<thead>
<tr>
<th>Pair 8: lines</th>
<th>Frame</th>
<th>Metaphorical theme</th>
<th>Analogy S, P</th>
<th>Parallel co-evolution</th>
<th>Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>8: 5 - 18</td>
<td>Interactive watch</td>
<td>Patients with AIDS</td>
<td>Anti Retro Viral (P)</td>
<td>Mother (P) Caregiver (P) Watch (S) Auto off Alarm (S)</td>
<td>P → S</td>
</tr>
<tr>
<td>8: 19 – 30</td>
<td>Interactive watch</td>
<td>Caring for patients with AIDS</td>
<td>Bottle Feeding (P) Mobile phone alarm (S)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8: 70 - 97</td>
<td>Interactive watch</td>
<td>Stakeholders using an alarm</td>
<td>All people (P) Disability (P) Alarm (S)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8: 98 - 113</td>
<td>Interactive watch</td>
<td>Complexity of drug taking</td>
<td>Phone (S)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8: 115 – 130</td>
<td>Phone</td>
<td>Flexibility for a variety of stakeholder</td>
<td>All stakeholders (P) Phone (S) Text (S) Voice (S)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8: 224 - 232</td>
<td>Phone</td>
<td>Flexible for various disabilities</td>
<td>Nurse (P) Language setting (S) Deaf (P) Text (S)</td>
<td></td>
<td></td>
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<tr>
<td>8: 233 - 237</td>
<td>Phone</td>
<td>Flexibility</td>
<td>S → P</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Episodes of co-evolution and analogy use in the framing behaviour of pair 8. A blank cell indicates non-occurrence. P = problem, S = solution. Bridges can go from Problem to Solution (P → S) or reverse S → P.
episodes is shown below in Table 1. Each row in the table 1 represents one unit of analysis.

Finally the individual tables were compiled into one overview table for each cohort – the UK and Botswana – as shown in Tables 2 and 3. Through this analysis we were looking for novice framing practices in both locations and trying to understand the role of analogies and co-evolution episodes in novices’ framing behaviour.

<table>
<thead>
<tr>
<th>P#</th>
<th>Metaphorical theme</th>
<th>Frame</th>
<th>Analogy</th>
<th>Parallel co-evolution</th>
<th>Bridge</th>
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<td></td>
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<td>S P F O C B</td>
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<td>1</td>
<td>The elderly needs</td>
<td>Tablet</td>
<td>Tablet</td>
<td>X X X X X</td>
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<td></td>
<td>are satisfied by</td>
<td>device</td>
<td>Picture</td>
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<td>3</td>
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<td></td>
<td>noepad and doc can</td>
<td>Doc PC</td>
<td>Prescription</td>
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<td></td>
<td>connect to it.</td>
<td></td>
<td>Alarm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Appropriate input</td>
<td>Device</td>
<td>Scanner</td>
<td>X X X X X</td>
<td></td>
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<td></td>
<td>design for</td>
<td></td>
<td>Camera</td>
<td></td>
<td>4</td>
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<td>varying user</td>
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<td>expertise.</td>
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<tr>
<td>4</td>
<td>Universality of</td>
<td>Home</td>
<td>Alarm</td>
<td>X X X X X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>device for</td>
<td>alarm</td>
<td>clock</td>
<td></td>
<td>6</td>
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<tr>
<td></td>
<td>reminding at night</td>
<td>at night</td>
<td>Pager</td>
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<td></td>
<td>and while being</td>
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<td>Text</td>
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<td>out.</td>
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<td>message</td>
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<td>Release</td>
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<td>system</td>
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<td>Alarm</td>
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<td></td>
<td>clock</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Pager</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Complexity of</td>
<td>App</td>
<td>Dataset</td>
<td>X X X X X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>medicine taking</td>
<td></td>
<td>box</td>
<td></td>
<td>5</td>
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<td></td>
<td>requires detailed</td>
<td></td>
<td>Mobile</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>input and output</td>
<td></td>
<td>app</td>
<td></td>
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<td>design.</td>
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<td>iTunes</td>
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<td>Google</td>
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<td>search</td>
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<td>Home</td>
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<td>button</td>
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<td></td>
<td>Snooze</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>button</td>
<td></td>
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<tr>
<td>6</td>
<td>User perception, i.e.</td>
<td>Handheld</td>
<td>Alarm</td>
<td>X X X X X</td>
<td></td>
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<tr>
<td></td>
<td>intrusiveness of</td>
<td></td>
<td>Alarm</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>alarm and ease of</td>
<td></td>
<td>Phone</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>use of guide design.</td>
<td>Watch</td>
<td>Drawer</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Phone</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>alarm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Universal and</td>
<td>System</td>
<td>Alarm</td>
<td>X X X X X</td>
<td></td>
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<tr>
<td></td>
<td>integrated system</td>
<td></td>
<td>clock</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>of PC and watch-like</td>
<td>Doc App</td>
<td>Watch</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>device.</td>
<td></td>
<td>Wristband</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Watch</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 UK novices framing practices where S = solution, P = problem, O = opening of frame, F = in frame C = during co-evolution B = during bridge building. X = observed in this category

Findings
Our main findings are presented in Tables 2 and 3. Column 1 shows the participant or pair number, column 2 displays the overarching theme that is developed and column 3 shows the frames and their names. Column 4 describes several details about the analogies used. To further investigate relationships between co-evolution and analogy use within framing, we have divided it into 7 sub-columns: the name of the analogy; whether a solution (S) or problem (P) analogy was used; whether the analogy was used within a frame (F); whether the analogy ‘opened’ the frame (O); whether the analogy occurred during a co-evolution episode (C); and whether it occurred during a bridge building episode (B). ‘Opening’ a frame means that an analogy was the starting thought around which the thinking was focussed and framed.

Column 5 counts the numbers of parallel co-evolution episodes, and column 6 counts the number of bridge building episodes, and in which direction.

How do novices in the UK and Botswana frame interaction designs?
Columns 2 and 3 in Table 2 give a descriptive summary of
### Table 3: Botswana novice pairs framing practices

<table>
<thead>
<tr>
<th>P</th>
<th>Metaphorical theme</th>
<th>Frame</th>
<th>Analogy</th>
<th>Parallel co-evolution</th>
<th>Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A watch for impaired and less abled.</td>
<td>Watch</td>
<td>Mobile phone</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>Simplicity of use is reached through structured interaction when setting alarm.</td>
<td>Alarm</td>
<td>Mobile phone</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Volunteers remind elderly and the youth is educated to set mobile alarm as reminder.</td>
<td>Volunteering</td>
<td>Mobile phone</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>Wearable object for all environments.</td>
<td>Watch</td>
<td>Bracelet</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>Free Pre-programmed device given to poor.</td>
<td>Mobile</td>
<td>Mother</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>Device needs to be portable to not be forgotten.</td>
<td>Watch</td>
<td>Anti-Virus Scan</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>Pre-programmed and serviced device by doctor.</td>
<td>Watch</td>
<td>Phone</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>8</td>
<td>Flexibility of device for diverse stakeholders.</td>
<td>Interactive watch</td>
<td>Mobile phone</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>9</td>
<td>Designing a Hall of a device to specify it further.</td>
<td>Button device</td>
<td>Mobile phone</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>10</td>
<td>Universal bracelet that is borrowed from and serviced by doctor.</td>
<td>Bracelet</td>
<td>Mobile phone</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>11</td>
<td>Due to complexity a governmental service provider initiates the house alarm.</td>
<td>PA</td>
<td>Watch</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>12</td>
<td>There is a need for training instead of reminding, but the first solution suggests time-saving reminders.</td>
<td>Timetable and</td>
<td>Training</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>13</td>
<td>System housed in a watch-like object that could take over family member's duty of reminding</td>
<td>System</td>
<td>Trigger</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Table 3** Botswana novice pairs framing practices where S = solution, P = problem, O = opening of frame, F = in frame C = during co-evolution B = during bridge building. X = observed in this category.
the framing practices in the UK. UK novices generate between 1 and 3 frames (2.2 on average) in the 1-hour session. Participants 1, 4 and 7 have frames dedicated to parts of an integrated system, e.g. a PC application used by doctors and a handheld device or tablet used by patients. The ideas of Apps and handheld or portable devices are dominant in UK sessions. However, participant 3 and 7 refrain from specifying exactly what kind of device they envisage. Universal usability and appropriate interaction design for the elderly or less-abled users are important framing thoughts throughout, except for participant 5.

Columns 2 and 3 in Table 3 show a descriptive summary of the framing practices in Botswana. Botswana pairs have between 1 and 4 frames with an average of 2. Similarly to the UK, handheld, worn or portable solutions are dominant frames. However, the frames become much more specific in defining the handheld device, e.g. pairs 1, 2, 4, 5, 6, 7 and 8 have ‘watch’ as frame. Likewise, mobile phone is a dominant design, which is used as a frame to stimulate the students’ design process. Universal usability and reducing complexity is a recurrent theme. A recurring metaphorical theme to address complexity is taking away control from the user, e.g. through preprogramming (pairs 5, 7, 10) and putting it in more literate and educated hands, such as doctors. The needs of illiterate and poor users are brought to the fore. We see service design frames and themes in Botswana pairs, such as education, training of users and volunteering aspects. We observe less integrated systems than in the UK.

Both cohorts frame the interaction design problem in similar ways: they suggest handheld devices. Botswana pairs become more specific in defining the handheld device, but both cohorts pay attention to user behaviour in their framing.

**How are analogy, co-evolution and metaphorical theme used in framing designs in novices?**

**Co-evolution**
Both cohorts use co-evolution to develop frames. Columns 5 and 6 in Tables 2 and 3 show the number of parallel and bridging co-evolution episodes for the UK and Botswana respectively. While UK designers have an average of 6 parallel co-evolution episodes, Botswana designer pairs have 5 parallel co-evolution episodes on average. Botswana pairs build on average 4.5 bridges from problem to solution space and 4 from solution to problem space, while UK novices build 2.5 bridges from problem to solution spaces and 1.5 from solution to problem spaces on average.

That means UK designers generally have fewer co-evolution episodes. They co-evolve problems and solutions in parallel more than they bridge between problem and solution spaces. In Botswana, parallel co-evolution and bridging episodes are more balanced.

**Analogies**
Both cohorts use analogies, on average 4.3 in Botswana and 4.5 in the UK. The tables show a dominance of solution analogy in both settings, as was found in expert designers (Wiltschnig et al, 2013). There was an average of around 4 solution analogies in both cohorts, with a slightly higher average in the UK. We can see only a few problem analogies – 5 in Botswana and only 1 in the UK in total. That means novices in both settings draw on analogies to solve rather than to identify problems.

Our novices use more analogies within a frame than outside of a frame. In fact, only a few analogies occur outside of frames - in the UK one on average and in Botswana less than one. We also observed that analogies occurred more often within co-evolution episodes than outside in both the UK and Botswana. In the UK 22 out of all 27 analogies occurred in co-evolution and in Botswana 52 out of all 56 analogies occurred during the co-evolution episodes. This confirms what Wiltschnig et al (2013) found in expert designers. In novices, the occurrence of analogies can be linked to co-evolution and framing.

**Opening analogies and metaphorical themes**
In our data, we found that analogies during co-evolution are often used right at the beginning of a co-evolution episode. In this case the function of the analogy was to open a frame, and we called them ‘opening analogies’. This means that from the moment the designers used a particular analogy, the design thinking was focused around this analogy. We also observed in our data that all designers who did use an opening analogy developed a metaphorical theme around the opening analogy.

Most of the 13 Botswana pairs use opening analogies (not in 4, 8, 13). For example, in Botswana pair 1, the watch is an opening analogy. The metaphorical theme for the frame was “a watch for impaired and less abled”. Likewise in pair 2, the opening analogies alarm and system opened the way for the metaphorical framing theme “Simplicity of use is reached through structured interaction when setting alarm”. Pair 3 is interesting, because they use a solution as well as problem analogy to open a frame – the volunteering frame. The main framing theme to which this leads is “Volunteers remind elderly and the youth is educated to set mobile alarm as reminder”. Although most
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of the opening analogies occur towards the beginning of the design session, some are towards the end too, for example in pair 12, the designers reframed the problem through an opening analogy that saw the problem as training people. Half of the UK participants also used an opening analogy. For example, participant 1 used ‘tablet’ (notepad) as an opening analogy from which she developed a theme around the elderly use of notepads. Opening analogies are a popular tool to frame novices’ thinking in both settings. They offer a quick route into developing metaphorical themes.

Metaphorical themes as bridges
In Dorst and Tomkin’s (2011) argument, metaphorical themes act as bridges between problem and solution spaces. We wanted to see whether this is also the case in our novice designers. Having separated parallel and bridging co-evolution episodes in our analysis, we also wanted to see whether or not analogies in general and opening analogies in particular are associated with bridging episodes.

Previously we have established that opening analogies are linked to metaphorical themes. But are opening analogies also linked to bridges? In the UK 2 out of 3 opening analogies occur during bridging episodes, while in Botswana pairs only 4 out of 15 do. Our data doesn’t seem to support the argument that opening analogies only act as bridges. It rather seems that opening analogies equally support parallel co-evolution. Since opening analogies were related to the development of metaphorical themes, our data suggest that in novices metaphorical themes are developed not only in bridging but also in parallel co-evolution.

Discussion
What implications do our findings have on design pedagogy?
Both cohorts in the UK and in Botswana use co-evolution. But Botswana and UK novices differed in the number of co-evolution episodes (Botswana pairs had more overall) and the types - bridging or parallel co-evolution.

UK sessions include more parallel episodes while bridges lead to reconsidering the problem frame suitability and devising a new solution. Co-evolution episodes evolve problem and solution spaces but don’t shift them ‘radically’. Having more parallel co-evolution episodes means that UK students progress a small number (often one) of ideas in depth but generate fewer ideas. The frame suitability is not questioned, as it would be during bridge building and so UK students remain in a frame.

Botswana pairs reconsider problem criteria in the light of a less than satisfactory solution by building bridges. They question the suitability of a frame and generate alternative ideas, but the new solution does not generate a new frame. Botswana pairs have a similar number of frames on average as UK students.

These differences in co-evolution have implications for design pedagogy in both contexts. To increase reframing and generation of more ideas in the UK, educators would need to increase the number of leaps between problem and solution spaces. This supports Lindner’s (2011) finding that helping students to frame problems leads to more diverse solutions. Conversely, to encourage Botswana pairs to frame ideas and work them through in depth, educators would need to discourage students from building too many bridges. This has not been discussed much before in literature. In addition, co-evolution processes are not much discussed in design education either. Research by Almendra and Christiaans (2011) has shown that students are unaware of these co-evolution processes. A visualisation of the students’ processes was suggested to support reflection and learning.

Both cohorts in Botswana and the UK use opening analogies to develop metaphorical themes and frames. Both cohorts frame their ideas in terms of handheld devices. Botswana pairs are more specific about what kind of handheld device they want to design, often a bracelet, watch or phone. They are specific early on because they show this behaviour.

One implication this has on pedagogy is to encourage the use of opening analogies to help develop metaphorical themes. On the other hand one could also experiment with prohibiting opening analogies to see what other framing behaviours occur. We think of opening analogies like a jump into water, what if we ask students to wade into water slowly?

Opening analogies start the development of a metaphorical theme for a frame quickly. We could also see that the development of a metaphorical theme is not only related to bridging, but also to parallel co-evolution. In the development of metaphorical themes the consideration of users, user behaviour and contextual constraints allowed solutions to evolve. In line with accepted interaction design pedagogy, our novices pay particular attention to user behaviour and requirements. One implication of this for design pedagogy is that by focusing on user behaviour we also develop students’ ability to co-evolve problems and solutions.
**Conclusions**

To summarise, novices in the UK and Botswana develop similar frames — handheld devices. Novices use co-evolution in framing. Analogies are linked to co-evolution also in novices. Opening analogies help students to develop metaphorical themes in framing, but these themes do not only act as bridges, they also support parallel co-evolution in novices. This is important to note because bridges might support big leaps (i.e. reframing) but parallel co-evolution supports incremental progress. Novices need both to develop metaphorical themes in framing.

The study demonstrated that novices show some expert-like behaviour in co-evolution and analogy use in framing. We also found similarities and some differences across our cohorts in Botswana and the UK. We argue that particularly the differences, such as different numbers of co-evolution episodes or opening analogies, have implications for appropriate pedagogy in both settings. We believe that design pedagogy should support but also challenge the natural behaviours in each setting.

We think it is important for educators to know that an emphasis on understanding user behaviour in designing also supports co-evolution in design education. If educators want to encourage ideation of multiple solutions they need to teach bridge building between problem and solution spaces, but if they want to encourage the working through of ideas they need to emphasise parallel co-evolution. Analogies are clearly important to framing, but educators could teach different ways of using analogy, beyond the opening analogy.

Finally we think that studying design behaviours across cultures gives us some valuable insight into how to challenge students’ design learning and design pedagogy in different settings.

**Limitations**

Our goal was to collect high quality data, which meant adjusting the data collection methods for each country. This might have affected the findings and the level to which we can compare them. However we believe the quality of verbalisation can be considered comparable. Comparing a team and a single designer, Goldschmidt (1995) developed the argument that both, think aloud and concurrent interaction, are an equal window into thinking, because thinking is brought into being through words. In addition, our UK participants frequently used social speech (considered responses) rather than internal speech (stumbling, breaks etc.) when thinking aloud, just as the Botswana pairs did in constructive interaction. The rationale for choosing pairs in Botswana and individuals in UK was based on the learning settings that each cohort experience. In the UK, participants study individually at a distance, while in Botswana participants study in face-to-face groups. By choosing pairs in Botswana and singletons in the UK we replicated their normal learning conditions as closely as possible.

The way we constructed our analysis might have had an influence on the results. For example, in some cases it was difficult to determine exactly when a frame starts. We decided to mark a frame when the conceptual object it pertains to is clearly named. But in several UK samples, the designers do not commit to a conceptual object - and hence a frame - right away. They uncover the beginning of a new frame while moving around the conceptual object. Speaking metaphorically, the designers’ waded into water instead of jumping in. We thought that this approach to framing was interesting but it was out of scope to study in-depth here. This would be worthwhile to pick up in a further study.

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Abstract
This paper elaborates on how design judgement can be practiced in design education, as explored in several iterations of an advanced course in interaction design. The students were probed to address four separate design tasks based on distinct high-level intentions, i.e. to 1) take societal responsibility, 2) to generate profit, 3) to explore a new concept, and 4) to trigger reflection and debate. This structure, we found, served as a valuable tool in our context for bringing important topics to discussion in class and for actively practicing design judgement. We discuss what we see as the main qualities of this approach in relation to more conventional course structures in this area, with a focus directed more towards aspects of methodology, specific interaction techniques, and design principles more generally.

Key words
interaction design, design education, design intentions

Introduction
Several scholars have emphasised design judgment as a main trait of skilful designers (see e.g. Lawson, 2006; Nelson & Stolterman, 2003), and which therefore should be acknowledged and practiced in design education. In design schools, this skill is taught for instance through design critique sessions (e.g. Reimer & Douglas, 2003), through critical analysis of existing products and experiences (e.g. Bardzell, 2011), by practicing methods for understanding people and usage (e.g. Dourish & Button, 1998), and through reflective design work using various tools and materials (Schön, 1983). In Fernaeus and Lundström (2014), we introduced an increased focus on design intentions as a complementary approach to guide such activities, and which we have explored in the context of interaction design education. In this article, we extend this work by further elaborating on our experiences in relation to prior work in the field.

The complex issue of intentions in relation to design judgement is likely already well accounted for in existing knowledge practices, for instance in online design forums, in established design practice, or within other similar courses. This especially as designed artefacts, and perhaps especially interactive products, are increasingly reviewed when met by professional as well as amateur critics, and posted publicly, e.g. in online blogs, newspapers and tech-specific forums. However, we recognize a need to engage more specifically with these topics in relation to teaching and education within the design research community. Here, we will further elaborate on our experiences from placing an increased focus on higher-level intentions as a general theme in master level courses in interaction design.

We will begin by outlining the motivations behind this project through an overview of related work, and theory behind the specific implementation that we choose for our course context. Thereafter, we will give a brief descriptive overview of the content and structure of the course, how we have implemented themes and assignments, and a short analysis of how these have played out in practice during the three years we have implemented this setup. We end with a brief discussion based on reflections and learnings from these experiences, in relation to our expectations and experiences from similar courses that use a more methodological course focus.

Background
In an attempt to move beyond simplistic measures of usability, and more seriously address also aspects such as style, experience, value, and purpose of interactive products, there is a need to acknowledge that designers may have different and sometimes conflicting intentions with their work, and through which they may need to be judged and assessed. Making a design that aims to be critical or that explores a new type of technology obviously needs to be judged by different means than one that aims to generate profit or fulfil the needs of a marginalised user group.

However, the relationship between intentions and judgement is not always straightforward, since the intentions of the designers will never be the only measure by which a final product will be judged and evaluated. Jeffrey Bardzell has elegantly discussed this circumstance for the specific case of interaction design, emphasising the cultural context and the varying perspectives as
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represented in the professional tradition of criticism (Bardzell, 2011). As put by Bardzell & Bardzell (2013): “the designer intending to create a critical design can hardly be satisfied with making a design that is critical in her or his opinion only” (p. 10). Matching the higher-level intention of the designer with the interpretation of its potential audience can therefore be an important challenge for designers, and which could be addressed in many ways, e.g. by tuning in with the expectations and desires of the audience, or by through various means being explicit about one’s own intentions (titling, description, context of presentation). In other cases, the core intentions of the designers do not necessarily have to be obvious or visible to the general audience, but still be important to shape the design. As an example, higher-level intentions such as making money by selling information to third parties, as is the case in products like Google and Facebook, might be central in driving and shaping central interactive aspects of a product, but still not be the measure by which one wishes the end users to judge the design.

Concerning the interpretation by the audience or end user, openness for interpretation might also be beneficial to a design as it might appeal to a broader spectrum of people, and a broader range of uses, as highlighted by Sengers and Gaver (2006). However, this should not mean that the designers do not need a good sense of the design intentions with the design. On the contrary, to be able to make decisions of what should be apparent and how to play with the openness for interpretation requires a certain amount of understanding for what is interesting to make and for what purpose.

As put by Bryan Lawson (2006): “Design is a messy kind of business that involves making value judgements between alternatives that may each offer some advantages and disadvantages. There is unlikely to be a correct or even optimal answer in the design process, and we are not all likely to agree about the relative merits of the alternative solutions.” (p. 81)

One basic way of addressing design judgement is from a perspective of design methods. Such a perspective offers many different frameworks and taxonomies for how design work could and should be practiced, from general outlines such as the double diamond process of the British Design Council, to methodological guidelines for specific domains. In Interaction Design course books, we find for instance Dan Saffer (2010) – also quoted in (Sharp, Rogers, & Preece, 2002) – describing five major approaches to designing products: ‘user centred’, ‘activity centred’, ‘data-driven’, ‘systems’, and what is referred to as ‘genius design’. The authors argue that these approaches should not be seen as mutually exclusive, instead they serve the purpose of bringing light to the general observation that successful design work can be executed in different ways. Depending on the task, some approaches may be more suitable than others. An important dilemma put forward by this taxonomy, is that user-centred design methods (UCD), which has been the most actively proposed in Human-Computer Interaction and Interaction Design education, may not always be the most successful method when it comes to real product design cases. The very fact that Saffer’s taxonomy includes different methodological approaches, with UCD as one of many, emphasise that user involvement can in some cases be substituted by the judgments and activities performed by skilled and experienced designers. As an example, a designer or design firm that has worked with a specific domain before has arguably also accumulated knowledge and experience beyond what could be obtained through UCD methods, e.g. general knowledge about what the users want, the market, stakeholders, and other business aspects, to mention a few.

While the focus on methodological approaches is relevant to all design work, we will here instead discuss design judgment on a more conceptual level, and how we have addressed this in our own educational practice. This means that our focus is on frameworks and models that aim to help designers elaborate on what to value and what aspects to consider. In Fernæus, Tholander and Jonsson (2008), we used the notion of shifting ‘ideals’ to discuss the consequences of an increased focus on practice and human experience in the design of interactive products. These ideals represented a fundamental conceptual shift in focus from primarily individual usage, information and cognition, and properties of the technology, towards increased emphasis on collaboration and sharing, engagement in a physical context, and allowing for different parallel practices and interpretations. The framework has later been used as a resource for guiding design work as well as for analysing qualities of the designed interaction (e.g. Tanenbaum et al., 2011). A variety of other models elaborate on what aspects might be considered from a certain perspective, e.g. from a perspective of materiality, crafting or form-giving (Gross, Bardzell, & Bardzell, 2013; Vallgårda, 2013). Other higher-level distinctions has concerned the characterization of design itself, e.g. as the merging of Art, Science and Technology of Bauhaus (Findeli, 2001), or Nigel Cross’ definition of design as Discipline, as opposed to Science (Cross, 2001).

The work presented in this paper is heavily inspired by the ‘four fields of design’ initially articulated in an online article
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by Bruce and Stephanie Tharp (2009). Their framework took its starting point in the profession of industrial design, but has in our case been applied to education in interaction design. The ‘four fields’ comprises a taxonomy for design work focused on different types of higher-level purposes, or intentions:

• Commercial design: with the general intention to generate profit
• Responsible design: intending to do ‘good’ or serve the unserved
• Experimental design: with focus on the process of learning and exploration
• Discursive design: with a higher level goal to generate reflection and discussion

While these different intentions typically overlap in parts, the main argument put forward by Tharp & Tharp was that by articulating them designers could see how intentions might interplay and sometimes even contradict one another. Thereby they could guide discussions and potentially help judging the outcome of a design, although taxonomies such as this will naturally only articulate partial understandings of certain relationships.

The framework was also used to acknowledge the growing terminology of approaches used within the design field. As put by Tharp & Tharp (2009):

‘Just try and make sense of the range of the terms floating around out there: user-centred design, eco-design, design for the other 90%, universal design, sustainable design, interrogative design, task-centered design, reflective design, design for well-being, critical design, speculative design, speculative re-design, emotional design, socially-responsible design, green design, conceptual design, concept design, slow design, dissident design, inclusive design, radical design, design for need, environmental design, contextual design, and transformative design.’ (p.1)

All these terms refer to aspects of importance to design practice, but they also go beyond both the ‘type’ of product being produced (e.g. mobile, tangible, graphic), as well as specific design methods. In addition, the academic discourse has been concerned with similar terms as tools for understanding and shaping design practice, with concepts such as ludic design (Gaver et al., 2004), design for ambiguity (Gaver, Beaver, & Benford, 2003), translucency (Dourish & Botton, 1998), seamlessness (Chalmers & Galani, 2004), among others. It has even been argued that the development of such concepts, so called ‘strong concepts’, is one of the main contributions of design-based research (Höök & Löwgren, 2012). We also found that in the academic discourse, there is often an unclear distinction between discursive design and experimental design. For instance, Daniel Fällman (2008) writes:

“Design exploration often seeks to test ideas and to ask ‘What if?’ – but also to provoke, criticize, and experiment to reveal alternatives to the expected and traditional, to transcend accepted paradigms, to bring matters to a head, and to be proactive and societal in its expression.

(p. 8)

With the focus on higher-level intentions, we found that the four fields managed to articulate important distinctions between design projects that aim primarily to raise discussion or awareness (as discursive design) and projects that are conducted for the sake of learning or exploration (experimental design). Although these often overlap, especially in research settings, articulating this distinction can be important in order to know what qualities to value and on what basis a project should be judged.

With this as a starting point, we wanted to explore how the four fields could be used to guide interaction design projects in a master level course at our university.

Case: Intentions in Interaction Design Education

There are many ways to structure interaction design education. A general challenge is to develop a format that brings in more designerly values to an education traditionally grounded on engineering and social science. A common way in technically oriented contexts, e.g. in computer science schools such as ours, is to provide themes or course modules based on different types of interaction technologies, e.g. graphical interfaces, tangibles, mobile computing, sound and haptics. This is in many ways a logical structure, since it allows students to focus deeply on different technologies and thereby learn about the broad design space that each of these areas provide, which is an important part of becoming a skilled interaction designer in a technical domain. These activities are normally complemented with course content that focus more on theory and exercises related to general methodological issues, such as conducting field studies, engaging users in the design process, and methods for ideation, sketching, and working in a team. However, since there are so many different approaches and settings for the making of interactive systems, our experience is that it is often difficult to cover all the relevant aspects in a structured manner. To address this challenge, the focus in our advanced interaction design course has not been on how to practically conduct design work, but rather on how
to develop and judge design as a central part of the design process, based on its overarching design intentions.

The course has been offered in a similar format during the last three years, covering four smaller design projects, each representing one of the abovementioned ‘four fields’. Each of the four projects lasts 4 weeks and is conducted in pairs, with students working with a different partner in each project. The course ends with a presentation of an individual online portfolio, showcasing all four projects. Important to note is that we have had the privilege to organise this course in an intimate studio format, with a limited number of 16-24 students, running at 50% study speed during 20 study weeks. Which is rather unusual in university context like ours. This naturally allows a structure heavily based on personal supervision, external study visits with the whole group, and weekly design critique sessions. However, since countries and schools have different teaching conditions, our focus in this paper will be on the conceptual content rather than on specific practical arrangements.

It should also be further emphasised that this is an advanced course in the subject, and the students are therefore expected to already know how to independently drive an interaction design process, i.e. knowing how to apply established methods for field studies, ideation, state-of-the-art analysis, user involvement, prototyping, and documentation in the form of video and academic writing. The students are also expected to have an idea of the research front in the field and be familiar with design issues related to different types of interaction technologies. The focus of the course is thereby almost entirely on issues related to intentions and fundamental approaches to practical design work while also conducting practical design work providing cases for discussion. Below is an overview of the four themes as implemented and interpreted in our course.

Experimental or Exploratory Design
Experimental Design or what might also be called exploratory design, refers to design work where the main goal is not necessarily a finished product, based on readily defined briefs with sketches, plans, or requirements. Its primary intention is instead to explore, experiment, and discover within a chosen frame, for instance a specific technology or technique, theme or concept.

Typical examples reside within learning contexts and academic projects following a research-through-design process (Zimmerman, Forlizzi, & Evenson, 2007). Within technically fast paced domains, such interaction design, this is also a relevant design approach outside of academia since emerging interaction technologies, development tools, hardware platforms, to mention a few, constantly require new learning. Experimental or exploratory design work may well result in complete products at a later stage, but the primary intention is much more open – and may even see value in design ‘failures’ (see e.g. Gaver, Bowers, Kerndge, Boucher, & Jarvis, 2009). Thus, these types of design projects value the process almost as much as the resulting product and are motivated and driven primarily by curiosity and an interest in learning.

In our course, this theme starts off with a design brief asking the students to explore a topic, concept or technology beyond what they already know. Previous examples in our case have been to design something based on exploring the functioning of a chosen sensor of a smart phone, or to work hands on with e-textiles. In our latest course round, students got a brief to explore new concepts for interaction at a newly set up museum of dance in our city. The task for the students was to explore possibilities around the general topic of dance in the museum setting, along with testing out different possible technologies (see Figure 1).
This rather specific brief worked well in this case, since the personnel at the museum wanted input on what might be possible or not, rather than solutions. The students were therefore not pressured to develop something fully working, but rather to explore possibilities. The topic of dance in itself also seemed to force the students outside of their own comfort zones and encouraged them to work hands-on with technologies that they were less familiar with from beforehand. Resulting in a range of novel scenarios and setups, including interaction contexts such as the street outside of the museum, visitors waiting in line for the toilets, and the use of a medical stethoscope as an interaction device. In addition, the students explored various ways of interacting in an exhibition space, ranging from mobile applications to physical exhibits, combining experiences from other museums and applying it to the topic of dance. The students were also naturally provided with content and media to engage with as they were encourage building on the existing and upcoming exhibitions.

The staff at the museum, who had initially expected to see a presentation of eight different types of mobile app-based solutions, were excited by the results, and are now considering to implement several of the designs in some form. Indicating that the main intention for conducting explorative design worked well as it led to several new perspectives that not only opened up for new possibilities of installations, but also reinvestigated the very nature of interactive exhibitions in this particular context. In this way the main outcome of the process was to open up a design space, explore possibilities, and for all the involved partners to learn something, which is also from an academic perspective an important purpose of design work at large. The very fact that the students were able to be so successful and explorative also demonstrate that they understood and carefully engaged with the higher-level intentions while not falling for the expectations and pressure perceived among the staff at the museum.

Commercial Design
Commercial design refers to design aimed at the real economic market. Economy is an important component of any design work, so what commercial intentions adds is primarily that the design itself gets grounded much more concretely on what might be desirable on a market, as well as, how the business model of that product would take form and in turn shape the design. The goal is thereby to create attractive, useful, and well functioning products, but with design judgements focusing primarily on potentials for commercial profit. In interaction design specifically, business models are often very deeply intertwined with the design of the interactive product itself, as shown in examples such as streaming media services, ad-sponsored mobile applications, open hardware licensing, and a broad range of electronic currencies and interactive payment systems. Investigating how such systems and models work is therefore a very relevant topic for interaction design students.

In our course, we have let this theme stay as an open brief, placing much focus on the process of ideation, discussion, and grounding design choices in existing use practices. The general task has been to come up with a concept for an interactive product or service that would have a potential of becoming a commercial success. The students are also asked to make the business model a part of the interaction design and to deliver a ‘finished’ design (see Figure 2), personas, realistic scenarios for interaction, and a proposed plan for bringing the product to market. Core to this design challenge is to develop concepts that are well grounded, in technological realities, be it in research or what exists on the market.

Figure 2. Screen designs of commercial design concepts, from left to right: A concept that aims to help customers at a furniture store figure out what furniture would fit in their car. Tool for turning blogs into physical books. Conceptual design for families to stay in touch and privately share pictures and videos.
During the course we invited external lectures that drive businesses to share their experiences and explain how they make money, but also lectures that work with helping researchers and students to develop their ideas into businesses. This is to provide the students with real accounts of business and it is usually are very appreciated by our students as there is often aspects emerging that are surprising or otherwise pointing towards commercial and design aspects never thought of before, e.g. it could be that the profit does not come directly from the end user but from another stakeholder unknown of if just looking at the product as such. In addition to these lectures we have seminars and workshops concentrating on the business model canvas1 and examples of other businesses by using this canvas. In this way the students are encourage to analyse, interpret and discuss various ways of making money in the digital domain.

Our impression is that this has been a tough challenge for the students, but they have also shown much enthusiasm, and some have continued working on their ideas after the project ended, showing that their project has reached some potential for commercialisation and thereby also demonstrating that the students have truly understood and shaped something more commercially viable based on a commercial intention. The serious focus on business models and who might be ready to pay for a particular product or service highlights the complex realities of interaction design oriented businesses. Based on the discussions in class we can only stress the importance of covering such aspects, in particular for interaction design as this is not always as straight forward as for fields more oriented towards selling and making money of physical products, were the profit generating scheme might be more visible. Being able to discuss different types of business models and how each of them relate to interaction design, is a topic that – in our experience – is often overlooked in ordinary interaction design education.

Ironically, this is core to any successful commercially viable interaction design work, independent of other intentions with the design. As a note, even systems designed within other themes during the course and within research have been brought to discussion here, highlighting how the fields often overlap in interesting ways, and the benefits of engaging also with other intentions in commercial contexts to open new spaces for designs that generate profit.

Responsible design
The concept of responsible design refers to design that place ethical and humanitarian aspects at the forefront. The term in itself is broad and invites a variety of topics like designing for people who are ignored by the market, environmentally friendly products, or otherwise to counteract different types of social or physical suffering (see e.g. Papanek, 1972). While commercial products sometimes can and in the best of worlds should take such aspects into accounts, the orientation is fundamentally different as the main measure for success is not framed in economical terms. Rather it is framed in terms of other values, such as if it is helping a group of people or and individual, or if it is more responsible with regards to the environment. This is more in line with what has been referred to as ‘worth’ (Cockton, 2006) or what might be referred to as value in value-sensitive design (Friedman, Kahn Jr, Borning, & Huldgren, 2013).

In this project we let students select and redesign an existing system of their own choice that they would argue are being ‘irresponsibly’ designed in its current form. The definition of responsibility is then left open for the students to discuss, define and motivate, with grounding in literature. Making students start with the existing situation to improve on also reflects a typical interaction design practice, where you would only rarely start out completely from scratch and spend a large part of the process at the ideation stage. This have also resulted in a very broad

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1 http://www.businessmodelgeneration.com/
variety of projects, some examples are to redesign existing services for people with special needs, to make for more sustainable solutions, or to improving poorly working systems in general. This way, the brief also opened up for more general discussions regarding different interpretations and perspectives on what is actually meant by responsibility in design, and how it can be practically addressed.

In addition to the project work we arrange several reading seminars where we discuss academic work discussing various aspects of responsibility, ranging from classic reads as Victor Papanek, to more contemporary critical work that discuss what we should and could do, for instance by using persuasive technology (Purpura, Schwanda, Williams, Stubler, & Sengers, 2011). The main aim with these seminars are generally to face the students with assumptions concerning responsible design, as what could be actually solved with technology and design, and who could solve it, where we for instance discuss problematic aspects of designing for the so called third world while belonging to and judging design from the perspective of the privileged world.

In previous years we have also given more narrow design briefs, e.g. to let students design tools to help foreigners finding their ways through the public transport system in our city, or to design tools for children to manage the situation of living at alternate places due to separated parents (see Figure 3). What we valued in these two design briefs were that they took a perspective of responsible design that focused on ordinary issues where interaction design might actually enhance a currently complex situation. In other projects in similar courses we explored more complex issues, e.g. designing for alone coming teenage refugees, which as such brought in a series of higher level humanitarian and political matters that are difficult to address through the design of interactive systems alone. Although these projects have been extremely interesting, we found that the open briefs on this theme seems more beneficial in terms of keeping the discussion focused on the overarching theme of responsible design.

In terms of learning outcomes and designed results, we have seen a broad variety of exemplars and discussions over the years. One general observation is that the students often initially engage with superficial or almost cliché like topics, but through the process and the design critique sessions the problematic aspects of such framing often gets heavily discussed and critiqued, both by the teachers and the other students, which in turn often leads the students to reframe their problem. We these discussions, observations and from comments by the students, we have come to understand this as an important learning experience, as the students re-conceptualize what it means to take responsibility for something and what they could or should engage with in contrast to stereotypes images of responsible design.

Discursive and Critical Design
The fourth and final of the four fields concerns designs which might not necessarily be oriented towards the market, but rather to trigger reflection and awareness around topics worthy of discussion. Sometimes aiming to make explicit a problematic or ironic issue of some sort, which may be directed towards the society at large or to a specific community. Examples include norm critical or speculative designs, design fictions and provocations, designs that might dwell over into the art scene and where primary measures of success could be to get exhibited in respectable museum settings or to turn viral in social media. Rather than ‘mere’ art projects however, these projects are actively referring to current discourse by focusing on utilitarian objects and function, while at the same time carrying ideas and provoke thought beyond the utility of the artefacts themselves. Much design work within the academic sphere belong in this group (perhaps most notably Dunne & Raby’s Critical Design). Tharp and Tharp (2009) describe critical design as being a form of discursive design, but since critical design is a more well-known term in HCI and interaction design literature, we like to highlight both terms here.

There are many well known examples on this theme within Interaction design, stretching from gimmicky installations such as the Fun Theory experiments of Volkswagen, to dark dystopian designs presented in science fiction, as well as a growing range of examples presented in academia (e.g. Purpura, Schwanda, Williams, Stubler, & Sengers, 2011). Since this type of projects tend to achieve a very broad visibility and popularity, it is reasonable to argue that educated interaction designers should have an informed relationship towards these types of designs, even if it might not represent what most designers get to work with for a living, or what most people will actually get to interact with. Understanding the value of these designs requires an understanding of intentions as beyond use and user experience.

Many of our students have been seriously excited about this theme, although it has also been the part of the course that most have struggled the hardest with. Parts of this difficulty could be due to the brief, which we have let
stay fairly general and open, i.e. to articulate and re-think existing norms in interaction design, questioning what might otherwise be taken for granted. Sometimes they came up with design ideas that were found extremely interesting among the teachers, but that the students dispelled as silly and irrelevant even before they started the actual design. We interpret this partially as a clear indication that our student struggle with understanding the underlying discursive intention, as they seem to fail to make the leap of judging the design against the general purpose of discursive design, rendering it silly in comparison to the established ideas of what design should be. An alternative explanation could also be that they lack the knowledge about the general discourse that we as teachers find them being discursive towards, therefore it does not appear as interesting to them. However, with regards to understanding our students and this behaviour it is important to acknowledge that they all have an engineering background. Therefore, working on a design challenge without a given problem to ‘solve’ requires a slight shift in mindset from what they are used to, and such a shift usually takes time as it challenges deeper ideas of their professional role and identity.

Parts of the difficulties that we have experienced could also be that we on this theme have let the students present their designs in the format of video (see Figure 4 for some snapshots), which in itself has been a new medium of expression to some of the students. Perhaps influenced by the format, many groups chose to present scenarios of what could go wrong, using the storytelling genre of dystopian science fiction. Although this is indeed a perfect way of bringing up discursive matters in the field, our experience has been that the actual interaction designs sometimes lacked a clear focus in favour of higher-level narratives. In other cases, the students focused entirely on the humorous aspects of their scenarios, using irony to such an extent that the point of the discursive message became difficult for an outside person to decode. In some cases the students were even reluctant to include their videos in their public online portfolios, which was a requirement for passing the course. However, it is important to note that we have not seen the use of humor and irony as an issue, as we rather interpret it as a way for the students to deal with this new and unfamiliar situation when they are asked to do something provoking discussion, which is a delicate task to begin with as others might confront such efforts. It is also interesting to note that humor, irony and satire is a common method for social critic, e.g. through political humor. With this in mind, we find it important to be sensitive to the social dimensions and the difficulties involved when engaging with critical design.

Although mixing the theme of discursive design with video scenarios was successful in most cases, it also added extra layers of complexity as it takes time, skill and effort to make a video. To us, the most interesting part of this theme has been the discussions concerning existing examples and literature, and to engage students with strong engineering identities in reflections around more conceptual artistic values.

Student feedback on the four themes
Having four separate design projects requires a lot of creative efforts from the students, and it has been clear from the student evaluations that some had liked more time to be able to make more completed designs, perhaps at the cost of skipping one of the themes. However instead of skipping a theme, we have informed the students about the possibility to continue on one of their projects from the course as an individual course or master thesis project, which several also have chosen to do.
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Still, most students have shown a great understanding and insight regarding the four themes, both as expressed in class discussions and as illustrated in the four student quotes below:

“All projects were good in different ways and I think that all of them contributed to the course in general. I worked very similarly in all these projects but with different goals, themes and angles in each of them, this made all the projects motivating in different ways.”

“Obviously, interaction designers should learn what good design is and how to do great interaction design, this was particularly good with this course, as it challenged what you could actually do as an interaction designer. In this way there was a point of having four such different projects so that we could practically explore as many aspects of interaction design as possible.”

“At times it was even a little frustrating to struggle with the differences within the projects and having to stress the creativity made me feel un inventive, but it has all been a good experience that hopefully strengthened me in the field of interaction design.”

“All in all, the course has been very educational, fun and challenging.”

The first quote, as we interpret it, speaks primarily about the student experience during the course, that he/she found the projects “motivating in different ways”, although the process was otherwise similar in all of the projects. The second student is more directed to the value of getting a chance to explore “as many aspects of interaction design as possible”, and that this is perceived of as an important skill for the future. The two last quotes both reiterate that the fast pace and many projects was a challenge and even at times frustrating, but they also suggest an acceptance of it all as a “good experience”, “fun” and “educational”.

Otherwise, upon the question on what was appreciated in the course, many students highlight one or several of the projects that they had worked on, e.g. “I thought that responsible, experimental and discursive designs were very interesting and rewarding”, “The discursive project was particularly fun as we could be very creative and think about how we could create a discussion”, and “We think our concept turned out really well and we had a lot of fun!” (about a commercial design, eds.). Apart from their own projects, many also appreciated the study visits and guest lectures, which were also tied specifically to the themes. As already mentioned, some students expressed frustration with the many projects and the fast pace, but we have not yet been given any suggestions of a specific theme to omit from the course, or a theme to be replaced by another topic or theme. This, to us, indicates that the students were in general positive to the four themes, although there are areas for improvement in terms of arranging the themes into a course structure and reduce element of stress.

Discussion

In this article we have presented work heavily influenced by the ‘four fields’ of design, as defined and proposed by Tharp and Tharp (2009). There are surely many other concepts that could be valuable for the purpose of articulating intentions in design within educational contexts such as ours. For instance, the four fields have worked as a solid enough base for structuring our course as it has provided both depth and breadth in terms of learning the details that different intentions bring to design and the broad variety of intentions relevant for different design tasks.

In our experience, the four fields have shown to – at least to some extent – help design students to “better understand and focus their projects” (Tharp & Tharp, 2009). First, commercial profit, as an intention commonly overlooked in academic design contexts, proved to spur deep discussions and thereby ensure quality of education in terms of the broad spectrum of issues and solutions connected to designing something commercially viable. Second, by shifting the intentions towards responsible design, students were given the opportunity to discuss and engage with what it really means to be responsible in design projects, discussions that have often turned out incredibly interesting and difficult. Third, the theme of experimental design has proven to be a fruitful tool to trigger deep technological engagement and playful exploration among all students. Rather than working with tools that they already know, which easily gets the case when asking students to deliver working prototypes, the experimental framing invited students to discover new possibilities. Interestingly, the theme of discursive design has turned out to be one of the more problematic themes in the context of our education. Surely, producing a clever and to the point discursive design can be difficult, and the process may not be as straightforward as to have commercial, responsible or experimental intentions. Yet, since it is such an important field in research and art contexts, and also in terms keeping a reflective stance towards innovation, we will continue our struggle on this topic with our students.
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Most clearly, the framework has been effective in structuring our education so that it ensures a broader range of design challenges. Without such a structure, our design briefs and projects have previously tended to get defined in a more ad hoc fashion, based on what seem relevant in terms of scope, technology, and on-going research projects. While not necessarily being a problem in itself, it might result in student projects unintentionally ending up very similar in character, with the risk of missing important points for discussions or aspects of value in a design. The structure of the four fields has also worked as a useful frame for engaging collaborations between students, researchers and partners in industry, as we now know well beforehand what types of projects and perspectives we are looking for.

Apart from being a helpful tool when structuring the course as such and by providing a rich variety of projects, we also feel that the four themes helped the students to channel their focus and concentrate on what is most important for a given design brief. In addition, our implementation also ensures that several groups work on different projects but with similar higher-level intentions, the course also facilitate a breadth within each theme as the students gets to dig deeper into and share different problems, designs and areas for investigation. Of course, this is a natural effect from any project-based course; however, in our case we know for sure that the students will get this benefit for each of the four intentions.

Another experience from this thematic format has to do with the structure of intellectual discussions in the classroom. Seeing that interaction design can be driven by different high-level intentions also means that the students need to acknowledge that success can be measured in several different ways, and that a design task is not always as straightforward as solving a technical or conceptual problem. This brings up interesting questions for discussion, regarding what we value and take for granted as desired, good quality, or successful in a specific design process.

The extent to which the students have been willing to discuss such matters is in our case is obviously affected by the intimate course size, but it also seem heavily influenced by the varying focus of the four themes, which helped guiding discussions in new interesting ways. The commercial theme brings focus to personal experiences of products, trends, and markets. The experimental theme brings more focus to what is known about research and new technologies. The responsible design theme brings in aspects of ethics and how to approach people and their values. Finally, the discursive theme brings to debate a discussion around current design norms and political perspectives around the field as a whole. Without the four themes, these discussions would, again, probably become structured in a much more ad hoc fashion, driven by specific research interests of the teachers or topics brought up freely by the students. This is not to say that such discussions would necessarily be any less interesting, but probably less varied and dynamic. For instance, and from our experiences of other HCI courses at our school where students do one project that changes each year without considering underlying intentions in the topic selection process, the discussions, learning outcomes and even the quality, also varies from year to year. To conclude, we find it interesting how these themes open for reflections concerning the relationship between education and research, and how we can develop this relationship so that research and education could benefit – as naturally as possible – from each other.

Relevant to our specific experience is also that the students that we work with have undergone a long education that has a strong thread of classical sciences and engineering, in contrast to design students with more artistic backgrounds. In comparison to traditional engineering education, we believe that discursive design especially might have a similar role as mathematics traditionally has had, namely, as an intellectual exercise with qualities to expand thought. Here, instead of practicing logical thinking, students are confronted with the challenge of engaging in more conceptual design thinking. From this perspective of practicing thought, discursive or critical design could be argued to deserve a strong and natural place in design education, just because it is difficult and entails so many conceptual challenges.

Finally, our approach and the implementation of the four themes in the course have been slightly different each year, and we see many potential ways that this could be structured differently. One interesting approach, which we are testing in the writing of this article, is to connect the four themes more concretely, e.g. by having the same overarching design brief stretched over the entire course and then approached using the four intentions. The main benefit that we have discussed with modifying the implementation in that direction, is that less time would be needed for ideation after the first theme, as the students then already have explored the topic quite a bit and could instead continue to redesign and reformulate with regards to the changed intention. This would also potentially provide additional room for other activities such as reading seminars, lectures, further discussion, and more finished projects. In such efforts, starting with the exploratory and experimental theme might be a natural way to open up the design space in favour for the following themes.
Concluding Remarks
In this paper we have discussed our explicit focus on design intentions in the last three instances of an advanced course in interaction design and described what we see as the main qualities with such course structure. The work is originally inspired by a framework that suggests that design is normally driven by one of four major types of intentions: to serve users, to generate profit, to learn, or to trigger reflection and debate. In general, the course structure and the amount of time spent on reasoning and talking about complicated issues seems appreciated by our students. Although the framework was originally presented as a resource for practicing industrial designers, it seems to have some value also in the education of interaction design, and probably in other design fields as well. In particular, we see clearly how this approach aids the student in mapping the landscape of underlying intentions, something that in turn helps to shape and guide their design processes.

References


Practicing Design Judgement through Intention-Focused Course Curricula


Complexity in Design-Driven Innovation: A case study of knowledge transfer flow in subsea seismic sensor technology and design education

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Abstract
To the extent previously claimed, concept exploration is not the key to product innovation. However, companies that are design-focused are twice as innovative as those that are not. To study design-driven innovation and its occurrence in design education, two case studies are conducted. The first is an example of design practice which includes observation and cooperation process maps in an offshore project. The second is an example of product design education which includes observations of teamwork, team member interviews and archival studies. While the first case study demonstrates how a company innovates through a design-driven process with complex knowledge transfer and systematic planning and improvisation, the second case study shows students managing their design processes through concept generation in a less complex trial and error process. Knowledge exploration as a part of design activity was analyzed through the criteria of network paradoxes. A pedagogic concept has been synthesized and validated internally based on the case study, and externally based on other design practices and design research. The pedagogic concept synthesized was Knowledge Transfer Flow [KTF]. The KTF concept can help to orient design students within the information-saturated design processes integrated within complex innovation systems.

Key words
knowledge transfer flow; design thinking; network paradoxes; professional practice in design education

The skill of generating ideas in a variety of ways relates to design practice, but this skill is transferrable to other fields of product development that can result in design-driven innovation. This is why general competence in design thinking has gradually influenced several professional fields (Stamm, 2008, Brown, 2009). According to Stamm, this could happen because design activity includes processes of expertise, which do not necessarily include any particular technological or system knowledge. These processes can be used for encounters with professional practices across technological and social traditions. This can be done by generating, manipulating or combining product and system design features through the generative process of concept exploration. Design-focused companies in Norway are twice as innovative as those that are not, according to Skule Storheil, speaking at the "Inspiration-Innovation" seminar at the Norwegian Design Council in Oslo on April 17th, 2013. If companies already have the necessary knowledge but lack the ability to explore concepts, which is the key to design-driven innovation, then this should reflect on design education as well. However, researchers aim for the skill of "connecting the right dots" (Nussbaum, 2013, p. 58) rather than exploring concepts in multiple directions (Nussbaum, 2013). Therefore, the following question should be critically explored: How does concept exploration lead to increased innovation? The following elements seem relevant in this process:

Problem setting is one of the core values of the creative design process (Schön, 1983). This value emerges from discussing and interpreting a design problem. In educational and professional practice problem setting and concept development have been intensively adopted and methods have been developed (Micheli et al., 2012), while overlooking other methods of gathering and choosing design aspects that have been similarly effective in innovative processes (Gillier et al., 2010). According to Concept-Knowledge theory innovative and creative work happens in a concept space (Hatchuel et al., 2011). Once concepts are affirmed, they pass on to knowledge space; thus, they describe how knowledge is systematized and used again as an essential design factor in creative methods that can lead to new concept generations. Concept space is where many creative methods take place, from combining design aspects to formulating design problems (Lawson, 2006). Thus, in design practices, both associative and cognitive creative methods operate while exploring possibilities within a specific design field (Stamm, 2008). This approach seems too fixated on generating new solutions from existing knowledge, so some researchers propose that these approaches could be developed further from a creative perspective by including a greater exploration of possibilities, which happens by actively using phases of divergent and convergent thinking (Baregheh et al., 2009). This idea that possibilities can emerge from complexity is
connected to system-oriented design theories, and this is what some design educators frequently aim to achieve in practical design projects (Sevaldson, 2011). However, this is not obtainable without the richness of data to combine and the opportunity to explore the topic in a complex environment. Such a complex environment can be identified in product design practice today, a profession that has evolved from product branding in the 1980s to being part of New Product Development (Perks et al., 2005).

With a lot of suppliers and collaborators in this complex innovation environment there is a need for the skill of choosing what is most relevant in each situation, and what can contribute to innovation. It has been demonstrated that a design team has to be able to explore knowledge space and to generate concepts at the same time (Valtonen, 2007). Another factor for successfully implementing concept generation methods in NPD practice is the ability to handle the increased complexity of knowledge space content and its interconnections to relevant fields (Visser et al., 2007). Despite these studies in design-driven innovation and industrial technology, there still seems to be a knowledge gap concerning the complexity of design-driven innovation in product design education. There is a need to expand knowledge about this design practice, reflected in a pedagogic model that includes practice in complex design work. The research question therefore is: how can network paradoxes in practice contribute to education for design-driven innovation? This question will be discussed in relation to what extent the product designer can be situated in the creative process through a methodical choice of relevant knowledge. The aim is to find a pedagogic tool for design education.

**Method**

According to Concept-Knowledge theory creative work happens in a concept space through the combination and manipulation of existing knowledge (Hatchuel, Le Masson, & Weil, 2011). This process is termed disjunction, or knowledge transfer. Once concepts are affirmed, they pass on to knowledge space. This process is termed conjunction, or concept transfer. Knowledge is then systematized and reused as an essential concept-generating factor in a new disjunction cycle. Concept-knowledge theory has been useful from a theoretical perspective that allowed for framing research. By tracing conjunctions and disjunctions in different design processes it might be possible to understand how concept exploration and knowledge transfer can induce design-driven innovation. Concept mapping was chosen to record the findings because it presents processes in a visual way, which allows for the comparison of concept and knowledge exploration (Maxwell, 2005).
A case study was chosen because there was a need to exemplify theory in the field—such as, in this study, network paradoxes—in relation to practice (Yin, 2009). In order to understand how complex design problems and innovations are managed in practice, problems such as network paradoxes (Håkansson and Ford, 2001), a relevant design project from the offshore industry was chosen for the case study. A participatory design approach (Asaro, 2000) was used to gather the documentation from offshore field work in order to examine the organizational structure and dynamics of cooperation between participants in the process. The aim was to collect material about learning outcomes that enhance understanding, skills, and general competence related to complexity in design-driven innovation. The case study contains observations of two student groups doing their projects to gain direct information about their everyday practices and perspectives concerning the design process (Powell and Steele, 1996). Archival studies of their project reports were used to analyze their reflections on the accomplished projects. As both innovation and knowledge transfer flow occur in certain environments defined by relationships and networks, both case studies are described and questioned by mapping these relationships between participants (called “nodes”). The results have been analyzed and selected through the identification of network paradoxes in organizations to understand how design students become more conscious of how to integrate knowledge space and how to handle complexity in practice (Håkansson and Ford, 2001).

Results from Practice and Design Education

A case study of complexity in design-driven innovation in subsea technology

The case study for illustrating a new practice in product design is from the offshore exploration industry. The design task was to commercialize seismic sensor technology (Figure 1) and explore the possibility of big scale data production. Technology gave far richer 4D data (Derfoul et al., 2013) that enabled easy oil and gas detection. By compressing the seismic sensor unit size and optimizing the handling system, the amount of sensor units per vessel was doubled and the operating time of the planting of a sensor unit was reduced to one minute.

The organizational context of the case study was the offshore company Seabed, now Seabird. The company, the owner of the technology, and a seismic vessel recruited possible suppliers through a series of pilot projects (Figure 2a). These pilot projects were time-consuming processes that the administrative leadership frequently opposed. On the other hand, the practitioners in the engineering team gained from them.

The onboard handling system, including trolleys and elevators for automatic transport of the seismic sensor units, was designed by a company that specializes in airport baggage belts for passenger self-service; thus, the system was based on engineering skills and knowledge of logistics. The subsea sensor unit handling (Figure 1) was executed by a company that specializes in remotely operated vehicle [ROV] navigation. This company provided the whole subsea navigation service and was a source of knowledge that enabled the core team to define design demands for the seismic sensor unit and the ROV tool. The sensor unit deployment system and ROV tool that handled subsea loads and placement of the sensor units was fully outsourced to the engineering company that handled high-quality mechatronics to sustain active deep-water use. The construction of the sensor unit components was also outsourced to these companies. A metal frame and some metal vessels were outsourced to
A company specializing in metal processes, and this knowledge transfer influenced the frame design and handling procedures. The sensor unit shell production was executed by a company specializing in rotational molding that allowed for the design of numerous multipurpose sensor unit features for both onboard and subsea handling, maintenance, and human interfacing. Logistics and design were outsourced to a company that suggested including a product designer as a permanent member of the team. Software and electronics were designed in a separate division of the home company that housed the core of the new technology. The team leader stated that: “The crucial factor for innovation success was early, initial involvement of suppliers through pilot projects. This allowed the team members not only to pick and choose partners but to learn new practices they were not familiar with.” J.F. Naes (personal communication, February 21, 2009), (Figure 2a).

The Seabed team featured two chief operators who worked on development in the laboratory and offshore operating seismic procedures on the vessel. Other team members included an engineer, a chief developer, and a product designer who was outsourced from another company. The designer’s role was to design systems and product features, and to facilitate discussions through knowing how to visualize animations and to rapidly generate solutions by exploring suppliers’ competencies (Figure 2b). The product designer worked daily with chief operators on human aspects through participatory design. Daily decisions were made through discussions and operation simulations. This understanding enabled the designer to facilitate assembly and operating systems through manuals and user interfaces. The product designer worked intensively with an engineering team but also communicated on a daily basis with suppliers about solutions and relevant discussion topics.

A lot of testing of the sensor unit handling system was required. The tests demonstrated that the results were not only merely good but also that the system needed improvement. When the practical operation had started, improvements were still made in the process. When an average sensor unit planting operation took only one minute, the commercial goal was achieved. At that point, it was not just technology but also a relevant service. The process was generative and the participants were expanding their knowledge as well as making solutions. In this approach, people adjusted to the system and the system adjusted to the people.

The design project won an Honors Award for Design Excellence at the annual evaluation of the Norwegian Design Council. It was also nominated for Best Design in British Design of the Year 2010. The concept was characterized as innovative, and its benefits were identified to contribute to functionality in terms of logistics, timing, and branding. It changed the perceptions of the clients of the data sales service.

**A case study of complexity in design-driven innovation in design education**

Experiences in a subsea technology context and approaches from this practice were used in an analysis of the practical approaches of product design students. The documentation from this student project included direct observation, archival studies, and interviews that would demonstrate students’ reflections during design education. The reflections were related to function, performance, originality, and product appeal. Two groups of ten and twelve students each were observed and interviewed during a six-week period in November and December 2012. They were told that observations and interviews were conducted as part of the module evaluation. The goal of the second case study was to exemplify a student...
project in the context of an educational setting similar to a
start-up company where students are set up to form and use
network connections to develop a commercially viable
design concept. Prior to this subject module, students
were trained for two weeks in different skills: third-year
students in dynamic project leadership; second-year
students in branding, presentation, and communication;
and first-year students in mock-up building and workshop
equipment. The design students were then merged with
several groups of up to twelve students across the three
years of the bachelor’s program. They were instructed to
form and self-manage a design team using the knowledge
they had gained in the previous two weeks. The first
chosen group for this case study was involved in a realistic
project with Akershus Energy, a local hydroelectric plant
providing home heating. In order to stay competitive, the
plant has to implement new technologies and widen
harvesting capacities to be able to reduce prices.
Therefore, the plant was seeking the opportunity to
expose itself to the local community, raise awareness of its
benefits to the environment, and create goodwill and
increase satisfaction among its customers. The second
group responded to a furniture design competition for
Bolia, an interior design chain and producer. The company
was seeking a new set of products that would fit in with
their portfolio: a specific aesthetic expression with the
topic 'nature in the city.' The first interview with members
of both groups was conducted at the end of design
research and the problem formulation phase, and the
second interview was conducted at the end of the six-
week period.

The results for the problem definition period showed that
the first group hadn’t considered any other design aspects
than those that were discussed with the client, that the
client had pointed out, or that they had discovered
themselves through concept generation (Figure 3a).

Students had a weekly review with the client in addition to
e-mail communication. The leader stated: “We have tight
cooperaion with the client and they are providing us with
relevant information that we need to know.” I. Ryland
Hasle (personal communication, November 23, 2012)
The group had spent a great portion of their project on
finding and defining a concept that would promote
company values.

The second group didn’t establish any contact outside the
group and defined their design problem through the
interpretation of competition propositions (Figure 4a).
When asked how they decided on the most important
design aspects to address in their project and how they
collected relevant information, the students claimed that
they focused on the ideation process. “Since we don’t
have direct communication with the client, we are
focusing on gathering ideas and then deciding how they
could fare in the competition”; “We have the specifications
from the competition entry, but we have mostly discussed
on our own how these ideas could be commercialized.”
M.C Torgimsen (personal communication, November 20,
2012). After the first round, students were encouraged to
observe or interview users. The first group conducted
interviews with several users within their target group and
adopted their insights as a valid design aspect when
generating final solutions (Figure 3b). The second group
focused on finishing a functional prototype without
previously interviewing or observing any users. The final
prototype was presented to a user and an interview was
conducted where the user reflected on the prototype
design (Figure 4b). These insights were then delivered in
the group report.
Complexity in Design-Driven Innovation: A case study of knowledge transfer flow in subsea seismic sensor technology and design education

Discussion on Network Paradoxes
Network connections have been defined by the opportunities and restrictions they give to participants; these network connections have been called “nodes” (Håkansson and Ford, 2001). This research describes three paradoxes in the nature of node relationships. The first paradox explains that “The stronger the threads are—the more content there is within them—the more important they will be in giving life to the node, but the more they will also restrict the freedom of the node to change.” The second paradox describes how the nodes and the threads are interdependent, meaning that companies build relationships that are in their own interest, after which relationships start defining companies. The third paradox describes how relationships influence a company by putting companies under the influence of their partners. Controlling these relationships is crucial for a company, but at the same time the dynamics of the relationships bring change and new ideas which tend to happen due to a lack of control (Håkansson and Ford, 2001).

As shown in the offshore case study, similar opportunities and threats could be applied to knowledge transfer flow within a network relationship. The study showed how pilot projects were used in establishing new relationships as effective managerial moves in order to minimize restrictions, stimulate opportunities, and gain knowledge transfer while establishing connections with component suppliers who saw a relevant professional challenge for themselves. Pilot projects were a form of establishing cooperation and also an establishment of a policy and company culture that made the company less inert and more innovative. In the case study, a pilot project was a good method to diminish paradoxes to a certain extent. In the case of the first paradox, healthy threads were established through trial and error. In the case of the second paradox, healthy threads were created by defining the scope of action. Finally, the third paradox was partly diminished by focusing on the goal rather than on a way to achieve it.

In the case study of the first student group, the project was strongly affected by the first paradox as they had only one connection established over a longer period of time, analyzed and visualized through concept mapping (Figure 3a) (Maxwell, 2005). As soon as they had established the link with the third node—the user—the knowledge transfer flow gained new meaning for them and the first node, and this enabled the second paradox (Figure 3b). The knowledge they gained by interviewing users influenced the client’s knowledge space as well. In contrast, the second group of students minimized the amount of knowledge in their concept space by not developing any network outside their own group task sharing. This reduced the opportunity for commercial refinement and further detailing of their concept. In this case study, the initial knowledge transfer (Figure 2a) seemed to enable the most effective innovation process.

A pedagogical concept in network paradoxes
The results shown indicate that it is difficult and unlikely for design-driven innovation to occur in educational settings. Design can play an important role in innovation, but, for this to happen, design has to be present in the commercialization process, not just in concept generation (Stamm, 2008). This is not yet common practice in randomly chosen design education problem-based learning settings. Studies also show significant knowledge transfer activity in the innovative offshore project, which is absent in studies of student projects, indicating that education is not preparing designers for using design as a tool for innovation. The study of design in a subsea technology context showed that extensive collaboration created the opportunity for the knowledge transfer flow to emerge. This was analyzed, visualized, and categorized by concept mapping (Maxwell, 2005) into a pedagogical concept: Knowledge Transfer Flow (KTF) (Figure 2b). Furthermore, the case study demonstrated an example of how complexity can be demanded in professional practice and how certain design competencies are essential in order to manage and organize problem complexity. However, it also revealed that complexity cannot be obtained without a thorough examination of knowledge space in practice. This complexity consists of many highly advanced professions within a dynamic interplay, and these premises are crucial for design-driven innovation.

The complexity demonstrated in the subsea technology context was not reflected in the design education. Although the problem-based learning process demonstrated how design students were motivated to choose their own problem perspectives, how they discovered it, and how many aspects of the problem were considered before or during the design activity, the implication of the study was that design education should be viewed from a wider perspective than only as a concept-focused process method (Aagaard Nielsen and Svensson, 2006).

The study exemplify in practice how knowledge space can be explored in network paradoxes. The case studies showed that in real-world projects the design process relies intensely on knowledge space exploration and knowledge transfer than design subjects conducted in cooperation with external factors. The case study of the
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design education, contrary to the design process, relied on massive concept generation that was later analyzed and from which conclusions were drawn. The second group of students used most of their time to build a propositional model that needed validation in reality. They learned how to explore concepts but seemed to fail in directing their knowledge into a broader implementation and commercialization context, and they did not implement their work into a complex network setting. Such an implementation is crucial for innovation (Figure 3a). Therefore, it can be useful in design education to expand student activity into more complex contexts. Design education should teach students to design and innovate in specific real-world settings (Figure 2a).

The knowledge transfer flow that might happen in network paradoxes was exemplified. It was shown how it was necessary to experience problems in practice in order to understand them from the design studio. In one anthropological study an architect bureau was observed (Rudningen and Hagen, 2009). According to this study, the professional design practitioners working in the group had the tendency to be confined by their materials, and extended their work in their studios. This is quite opposite to openness to new experiences and communication which was stimulating for creative processes, (McCrae, 1987). It was essential to learn and try to design elements outside the knowledge field. The more unknown, the richer the solution, so ambiguity was crucial in the design process even though it could break the experience of the flow (Csikszentmihalyi, 2008). Complexity and generative processes were inevitable for creative solutions. It has been argued (Buur and Jakobsen, 1991) that design is a process method and that designers need to master design as a process tool. This is a valid view, but it is also crucial to acquire the ability to immerse oneself in a problem and to obtain any necessary knowledge in one’s chosen field (Csikszentmihalyi, 2008). The second case study demonstrated that, while students were able to generate valid concepts, they were not aware of the necessity of immersing themselves in relevant knowledge space, possibly because they had not learned to do so. If designers are to master and handle design process, they would gain from knowing how to facilitate the knowledge transfer flow as a substantial source of creative provocation. It would be a good preparation for professional practice if design teachers made students experience how to enable knowledge transfer flow in an academic and practical way. Design education can contribute to this by enabling interdisciplinary environments for problem-based learning.

Implication for Design Education and Design-Driven Innovation

The result from the two case studies documented that concept exploration can be enhanced through knowledge transfer flow, especially in the incubation of the creativity phase. The design approaches have been developed through a case study of subsea seismic technology to enhance commercially-based innovation in design education. The educational goal has been to prepare students to tackle complex design processes and elements in their future jobs. The theory of flow could help explain the psychological mechanics of dealing with complexity. According to that theory, a problem-solver’s experience of a problem-solving process depends on the relation between problem complexity and the problem-solver’s skills (Csikszentmihalyi, 2008). Flow is defined as the opposite state of apathy where the problem-solver experiences enough difficulty to be stimulated and enough mastery to be able to handle working on the problem. Csikszentmihalyi's subjects have reported that they tend to lose track of time and experience a sense of satisfaction by working on a problem. These subjects had long-time experience working with these problems, which means that they have mastered problem aspects of knowledge space. Reflecting on this, it would be reasonable to consider that, by limiting the amount of design aspects, students are making it easier for themselves to achieve the flow. This might make it easier for students to adopt concept exploration mechanics, but they would miss the complex settings in which innovation tends to happen. From a pedagogical perspective it might be equally important to teach students to generate creative ideas as it is to allow and manage complexity. It should therefore be carefully considered how to provide students with intuitive methods for accessing and assessing knowledge space to create network settings that simulate the complex environments in which innovation occurs. Pilot projects seem to be a good method for establishing relationships in business settings, but further research is needed about their implications in educational settings.

It is in human nature to solve puzzles, which gives a sense of purpose and, once solved, a sense of achievement (Lawson, 2006). He warns that designers need to delay this sense of achievement as part of the design, unlike puzzle games, which almost always lead to multiple solutions. Choosing the acceptable solution is then part of the convergent creativity phase. In newer creative personality theories, one of the properties of a creative personality is tolerance of ambiguity (Stamm, 2008). It is argued that designers have to be flexible enough to keep the problem open while at the same time having enough
confidence to choose paths in convergent phases of creative processes. Some researchers would see the tolerance of ambiguity as essential for the innovative results that emerge from complexity (Sevaldson, 2011).

Product development activity should, according to the requirements from the Bologna process, reflect a more holistic and complex view similar to business practice. The discussion is about how complex methods have to be modified to integrate large amounts of data throughout the whole commercialization process, not only in concept development, which demands that designers learn even more rapidly. The new pedagogical concept of knowledge transfer flow based on complexity in design-driven innovation (Figure 2b) can enhance this design practice. In the aim of solving complex problems it is not valuable to convert design education to a total integration of designers into the company workflow as there is a danger that valuable perspectives can be lost. Instead, most design education has intrinsic qualities that can be enhanced through the extension of design activity rather than changing the designer’s role. Further research should be executed on how design practitioners allow and manage complexity in engineering and in complex institutions such as hospitals and other contexts. Designers must often search for relevant design aspects from knowledge space in a very short period of time. It would contribute to the culture of innovation if designers worked with knowledge sharing to a larger extent in complex situations. The effort should be put into researching how successful designers manage their knowledge space exploration process. Students who experience more complex situations in their design education thus could become more independent in organizing design processes. Learning to experience and tolerate ambiguity in practice could contribute to strengthening designers’ identities and the creative qualities needed for knowledge-based innovation.

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I’m sure most of us have read a lot about STEM (Science, Technology, Engineering and Mathematics) in documents such as research papers, journal articles, government documents and the media, but this book is different. While it draws on the authors’ undoubted knowledge of STEM on an international front, with references to documents from numerous international sources, this book is more down to earth and is about STEM as it is in UK schools, with the added vision of how it could be if the opportunities were fully explored. The book is not written in the usual academic prose normally used for education books, it is written in what is best described as a ‘conversational style’; at times I found myself asking questions such as ’what if?’ and ’but can’t we do that?’ and, on several occasions, disagreeing with the authors by thinking ‘no that can’t be right!’ Occasionally there is an element of humour which adds to the enjoyment of reading this book. This style of writing an educational text book is particularly welcome at a time when teachers and trainee teachers have become used to the usual list of bullet points and tick boxes. Part of this readability is achieved by the authors using case studies, cameos and examples thus ensuring the book is a realistic view of STEM in schools.

Who is this book for?
The text on the cover says ‘essential reading for trainee and practicing teachers’ however I suggest that this book is also essential reading for senior leaders in schools such as head teachers and curriculum deputies who need to gain a very clear understanding about the educational opportunities available within STEM subjects.

Format of the book
In the introductory chapter about the nature of STEM the authors raise issues such as the relationship between science and technology, a topic that seems to recur periodically in the book and is not fully resolved. It is chapter two, where they start to show the way they think about STEM, the title ‘A curriculum for STEM – ‘looking sideways’ (page 25) says it all; numerous examples of good practice mainly from schools that introduce the reader to a range of educational initiatives that have, and are still influencing STEM implementation in schools. A section headed ‘Sharing teachers’ professional knowledge’ (page 33) includes a theoretical example of how STEM can help teachers gain an understanding of sharing the curriculum and yet establish a personal construct to inform their pedagogical practice. This is encapsulated in a simple but very effective diagram (page 34) that must be useful to anyone involved in teacher education.

It is in this chapter that an element of confusion creeps in as the previously discussed relationship between science and technology is exacerbated by the statement ‘science and design & technology are so significantly different from one another that to subsume them under a ‘science and technology’ label is highly dangerous.’ (page 41). Perhaps this clarifies the confusion! At several points in this book I thought the authors, both with a science background, were talking themselves out of being scientists and into being technologists, but then the old problem of what design & technology is compared with technology (as used by many countries) raised its head. The authors, both with a thorough understanding of D&T through their international curriculum development activities and teacher education responsibilities, make a good job of trying to rationalise this but it remains an unresolved issue. This curriculum analysis chapter concludes with a statement that we could all take to heart. ‘If teachers ‘look sideways’ pupil learning can enhanced.’ (page 46). A very true statement.
Analysis of the each of the STEM subjects
As expected each of the subjects contributing to STEM is allocated a separate chapter each with an analysis using quotes from distinguished authors and published texts however what makes this book so useful is the inclusion of numerous examples of how the subjects can capitalise on STEM. These examples are realistic and achievable the theme being subjects cooperating in the development of teaching and learning materials. In the chapter ‘Teaching Science in the light of STEM’ (page 48) the authors introduce the notion of teachers talking to each other. This becomes a strong thread in the book binding each section together. A second, but equally valid thread, is the importance of project work and project based learning (PBL) as these features in virtually every chapter. The science chapter starts with a short historical review with quotes from eminent authors and curriculum developers identifying the strengths and weaknesses of the way science is approached in UK schools. The possible relationship with D&T is a strong element in this analysis particularly with a recognition of the work by David Layton to the point of quoting the controversial statement ‘the acquisition of scientific knowledge is inescapably tinged with dogmatism’ (Layton D, 1975) (page 50). Inevitably the examples given for consideration by teachers, and particularly suitable as STEM curriculum development, have a science base but are presented as being ideal for discussion with other STEM teachers thus demonstrating how ‘dogmatism’ can be broken down. In the chapter dealing with D&T the subject is dealt with in a similar way with the addition of how D&T, through the D&T Association supported by higher education, design, engineering and manufacturing industries dealt with recent negative political interventions. Unfortunately the authors consider the starting point for D&T was in 1988 with the introduction of the UK national curriculum ignoring the fact that much of D&T curriculum development occurred prior to this in the 1970’s and 80’s supported by projects such as the Schools Council funded Modular Technology, Microelectronics For All (MFA) and Design & Craft. Similarly, more recent curriculum development initiatives such as the Digital D&T programme are not included although the Technology Enhancement Programme (TEP) gets a brief mention (page 161). Torben Steeg, an experienced educational researcher and consultant, (page 77) uses his in-depth knowledge of both science and D&T to provide an illuminating interview promoting interesting practical ideas for co-operation between D&T, science and mathematics. As with science the D&T curriculum development examples provide exciting opportunities for teachers and their pupils with no fewer than seven realistic examples of how D&T and maths could work together. While the text of this chapter, with the examples, encapsulates the learning embedded in pupil research and designing activities there seems to be a lack of recognition that making processes require similar levels of intellectual engagement as pupils use materials, tools, equipment and machinery to turn their ideas into reality.

I expected ‘E’ for engineering to follow next only to find it is ‘M’ for mathematics! (page 100) Engineering seems to be relegated to a later chapter titled ‘Enabling the ‘E’ in engineering’ (page 151). The opportunities for mathematics within STEM are introduced using an amusing, but serious analogy, and then are dealt with in the same way as science and technology (D&T). The authors cite OFSTED reports and several eminent experts such Vorderman and P orkress (page 103) who paint a picture of concern about the lack of popularity of mathematics in schools and express major anxieties about the way it is taught. This is balanced by a discussion about initiatives such as the case study approach developed by the National Centre for Excellence in the Teaching of Mathematics (NCETM) until recently directed by Professor Celia Hoyles whose interview with the authors provides ideas for capitalising on the relationship between technology (D&T) and mathematics identified in an earlier chapter. As in previous chapters this is followed by examples of collaborative ventures between subjects although these seem to have a more scientific focus, this is recognised by the authors with the comment that science and D&T teachers ‘will be able to identify many more examples’ (page 133). Surprisingly ventures such as Class Of Your Own (COYO), an emerging UK initiative, that focuses on mathematics in real life situations such as surveying in civil engineering and the construction industries is not included.

(http://designengineerconstruct.com/)

Eventually I came to the ‘E’ for engineering in STEM and this chapter is in an entirely different format. A major part of is a presentation by Professor Mathew Harrison, until recently Director of Education at the Royal Academy of Engineering, in which he presents a convincing case for engineering being a school subject backed up by recent facts and figures with quotes from numerous published reports. His main thrust can be summed up as engineering is the one subject in the STEM agenda that pulls together all of the subjects and these link into manufacturing and engineering industry. This is an impressive report on the recent history and successes of engineering in UK schools however it does raise the, controversial in the UK, question of whether engineering is a vocational subject. This is followed by the authors’ discussion dealing with issues raised by Mathew Harrison,
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again using their questioning style that effectively thus puts the reader in the position of decision maker. The USA STEM model, where engineering is seen as part of science, is explored with considerable detail and the authors make a convincing case that this model is unlikely to work in the UK and a collaborative model is more appropriate. A figure of ‘more than 5,000 teachers’ (page 166) with engineering degrees is given as being the number employed in UK secondary schools mostly engaged in teaching STEM subjects. Surely they are ideal people to initiate or take part in discussion of this type at school level. The authors well balanced debate concludes that if engineering is to be a successful part of the school curriculum it will require considerable co-operation between science, D&T and mathematics teachers reinforcing, once again, teachers talking to each other. Unfortunately the authors deviate from their established format by not including examples of engineering project work and exemplary teaching and learning opportunities. Bearing in mind that until recently the UK had 70+ engineering schools under the Specialist Schools and Academies Trust (SSAT) scheme many developing outstanding STEM teaching and learning materials that are worthy of inclusion in this book.

A message that permeates the four chapters dealing with each of the STEM subjects is that curriculum development in the UK seems to be rather haphazard. For example in the mathematics chapter the authors enthuse about D&T project opportunities using four bar linkages as part of animated toy projects (pages 122, 123). This knowledge was part of geometric and engineering drawing (GED) some 40 years ago and did result in well motivated pupils engaging with interesting paper based design activities. Why was this abandoned? The authors are right - the four bar linkage with a mathematical analysis is an ideal opportunity for toy design in D&T providing it is updated to a computer aided design (CAD) based activity. To underpin this notion of updating important aspects of the curriculum the authors recount working with a group of science trainee teachers on acceleration using Fletcher’s trolley which many readers may remember from their physics lessons. The task was to update this using data logging and IT to retain the learning but make it more accessible to pupils (pages 201,202). So science teachers were able to reinvigorate this essential learning. There is an interesting message in the chapter on IT that, in the light of STEM, the contributing subjects could revisit essential parts of their curriculum and update in a similar way.

Project based learning
The project based pedagogical thread mentioned previously is aligned with problem based learning (PBL) and brought together in a chapter (page 135) set out in an accessible format of question based headings such as ‘How are successful project-based learning and related tasks organised?’ (page 144) and, important to the D&T teacher, ‘Teaching knowledge when needed, or as structured development and the relative importance of skills’ (page 145). This chapter is particularly relevant to D&T trainee and practicing D&T teachers as it provides considerable detail about how to plan and manage design and make assignments, including assessment. The authors draw on the recommendations of the D&T Association to consider planning a programme of study using ‘small tasks’ and ‘big tasks’ (page 145) to ensure coherence in the learners experience. It is a comprehensive chapter concluding once again with the all important thread ‘regular conversations with colleagues’ and the additional recommendation of ‘teamwork’.

Making STEM work
Several shorter chapters provide insight into how STEM can be pulled together in schools. The chapter titled ‘The role of STEM enhancement and enrichment activities’ (page 175) is packed with fascinating information covering numerous examples of competitions and after school activities, many from overseas providing an international perspective about what is possible. The authors have done considerable research into this aspect of their book the result being a sort of directory of ‘a good fun guide to STEM. Particularly pleasing is the detail of more local initiative developed by a UK based D&T teacher who puts a ‘D’ into STEM providing design days and design camps for students. As a result of reading this chapter I found myself following up many of the initiatives searching for further information on the internet, I’m sure most STEM teachers would find doing this an inspirational experience as there are so many worthwhile schemes. The chapter finishes with a questioning conclusion of ‘Why is the school experience so impoverished that stakeholders feel the need to initiate enrichment activities outside the mainstream school provision’ (page194). I’m certainly not sure about the answer but it is a question that teachers involved in STEM subjects could seek their answer. It is a point well made.

Similarly the chapter ‘Computing and digital literacy, IT, computer science, TEL and STEM’ (page 197) is invigorating as it presents the reader with ideas for development. Headings such as ‘IT and science’ (page 201) and ‘IT and mathematics’ (page 207) are obvious but are supported by examples and cameos suitable for schools thus demonstrating the opportunities IT provides for teachers to develop creative teaching and learning situations for their pupils. For D&T and engineering the inclusion of ‘systems for controlling artefacts’ (page 206)
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is a comprehensive list of suitable soft and hardware followed a list of eight projects each starting with ‘design and make’ underlining the importance of the making activity. A feature of these seems to be how systems and control can be harnessed by the ‘pupil designer’ rather than just learning about control systems and software.

Concluding chapters
While these chapters, ‘Creating and environment for sustaining STEM’ (page 216) and ‘Future vision for STEM’ (page 238), are important to all readers they are particularly relevant to school leadership teams as they provide insight to how STEM can provide a balanced curriculum. By presenting ideas such as ‘considering mathematics’ and ‘considering technology’ the authors précis the previous in depth commentary with additional material drawn from international sources. Amongst many examples I found two that are particularly noteworthy. The first is a long quote from David Hargreaves (page 233) who uses a gardening metaphor in a discussion about generating ideas and managing knowledge creation. This is particularly relevant to senior management teams in schools. The second is the STEAM (Science, Technology, Engineering, Arts, Mathematics) (page 252) movement in the USA which is likely to be of interest to some D&T departments in UK schools. (http://www.stamedu.com/). It would be easy for the authors to impose their vision for STEM but they steadfastly resist this saying ‘Clearly we, as authors of the book, cannot and should not define the future vision for STEM. Any attempt would be futile and the fact is that it is your vision in your school that is important and only you can decide on and work towards that.’ (page 254)

Conclusion
This is the most comprehensive and interesting book about STEM in schools I have read. The style of writing ensures the wealth of research, information, ideas, and examples of good practice are accessible to teachers, trainee teachers and any educationalist involved in these subjects including those in education management positions. This book is a leap forward for STEM in schools. Enjoy reading this book and then heed the authors’ advice and talk to colleagues about it.

Available from the D&T Association.
www.data.org.uk
Guidelines for Contributors

Journal overview
The mission of the new international Journal is to publish high quality research, scholarly and review papers relating to design and technology education. There will be three issues each year and five or six substantial articles in each issue. Submissions are welcomed relating to the primary, secondary and higher education sectors, initial teacher education (ITE) and continuous professional development (CPD). Contributions to the on-going research debate are encouraged from any country. The expectation is that the new Journal will publish articles at the leading edge of the worldwide development of the subject area. The final edition each year will include published versions of the keynotes from the D&T Association’s International Research Conference.

The normal word limit for articles is 5000 words, although up to 8000 words will be permitted in exceptional circumstances. Visual illustrations are encouraged in keeping with design and technology’s ethos and practice. It is the Journal’s policy to positively encourage the submission of articles based on action research by practitioners, which has been the bedrock of the subject’s development for several decades. The Journal would also welcome the opportunity to publish substantial literature reviews in order to consolidate contributions which have been made to the subject, and ensure that they are accessible to current researchers and teachers.

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Guidelines for Contributors

Developing conference papers for submission to the Journal

The conference paper, such as one written for the D&T Association International Research Conference, would have been subject to a word count restriction (typically 2500 words) in order to ensure that it is possible to present its content in 15-20 minutes. Clearly, this constraint is removed for a Journal article, and replaced by a larger word limit. The word count restriction on a conference paper normally means that the agenda it addresses has been correspondingly restricted and the paper has perhaps also been deliberately slanted towards the conference theme. For a Journal article, it might be possible to put the research more firmly into context by looking more extensively at prior research by others on the topic, or by looking at wider implications of the research work completed (beyond the conference theme). This might involve some further literature-based research, but it does not necessarily mean that any further data collection needs to be carried out. Conference delegates might have suggested other authors whose work the researcher should review.

A further area that can be developed within a Journal article is a discussion of the research methods employed. It is possible that other methods were considered and rejected (but not reported). The methods chosen might have known strengths and weaknesses which have not been fully explored in the conference paper. It may be possible to make comparisons with studies which use similar research methods, but which were not discussed in the conference paper, perhaps because they were too loosely related to the conference theme. Again, conference delegates may have suggested other studies with which the author might compare their work.

It is likely that the discussion at the conference will, in any case, have moved the research thinking on and this can be captured, or the data re-examined in the light of new suggestions.

The intention is obviously not to republish the conference paper, but to consider the possibility of publishing a related ‘deeper, richer’ account of the developing research. Conference papers are often thought of as ‘stepping stones’ towards more thorough research accounts, and perhaps the process is best thought of in that light. The author could consider how the subject matter has revealed itself during the process, their aims and how close they are to realising them. It is hoped that the conference paper presentation and subsequent discussion with delegates might contribute some new understanding.

Developing research assignments for submission to the Journal

Many teachers undertake CPD programmes that incorporate research elements such as literature reviews or action research studies. Some teachers also undertake MPhil and PhD degrees or other higher qualifications, such as EdD. Although assignments undertaken for such programmes will initially be formatted in accordance with the submission requirements, such postgraduate students might consider the possibility of submitting their work to a research conference or journal. A poster or PowerPoint presentation at the D&T Association’s International Research Conference provides the most straightforward first step to getting feedback on your work from the research community; however conference papers have been successfully written based on such action research programmes (e.g. Alison Hardy’s Questioning Styles: observations of differences in practice at Key Stage 2 and Key Stage 3 at the 2004 International Research Conference. A copy of this paper can be downloaded from the members section of the D&T Association website: www.data.org.uk).

Of course, it might also be appropriate to submit an article to the Journal based on the research undertaken and such submissions would be welcomed.

Some detailed notes on research articles

Research articles would be expected to make an original contribution to design and technology education research. Such contributions should be based on evidence (e.g. newly acquired data, historical records, published work).

The article should have a title, name(s) of author(s), their titles and affiliations. It should have an abstract of between 200 and 250 words. It should have six keywords for reference purposes. The paper should not be more than 5000 words in length, unless there are exceptional circumstances. All submissions must be typed in good English, they must have been spell-checked and include a word count (excluding the abstract and title). All pages must be numbered and double-spaced in order to facilitate the refereeing process. All references should use the Harvard Method of referencing and details of this are given in the following section. Any information relating to authorship including affiliations should be confined to a removable front page and should be free of clues such as self-citations, e.g: ‘in our previous work…’
Example of an Abstract
The teaching and learning of technology for design

Eddie Norman, Senior Lecturer, Department of Design and Technology, Loughborough University, Co-Director IDATER

Abstract
This paper presents a non-linear model of design and technology that illustrates the concept of technology for design (or technology for the purposes of those engaged in designing). The model shows technology for design as the summation of the knowledge, skills and values employed in design decision-making. Technology’s relationship with science is discussed and research evidence concerning the emergence of new technology for a polymer acoustic guitar is described. This is a fully-documented case study, which demonstrates the existence of knowledge, skills and values that are derived from designing and making rather than science. Learning ‘by doing’ and teaching ‘by showing’ and their pedagogical implications are discussed. Examples are given from the author’s teaching of undergraduates, which demonstrate the teaching of technology for design through designing i.e. where design activities are a teaching and learning strategy (e.g. injection moulding and the use of recycled materials). Examples are also given of technologies for which research evidence has indicated that there is a need for them to be taught prior to designing if they are going to be employed effectively (e.g. structures). These ideas are further illustrated using examples from a resource pack on kite design and technology for KS3. The paper shows the importance of sustaining designing and making as a teaching and learning strategy in order to promote innovative and creative designs in the next century.

(226 words)

Key words
models, technology, design, teaching, learning, guitar

The Harvard method of referencing
The work is referred to in the text by stating its author’s name and the year e.g. (Pacey, 1983). If there are two authors, then both their names should be given e.g. (Roberts and Archer, 1979). If there are more than two authors, the surname of the first author should be given, followed by ‘et al’ e.g. (Benson et al, 2002) If there is a need to be more specific, then the page number should be stated immediately after the year e.g. (Mockford and Torrens, 1997:164). Some examples of references using the Harvard method are given below.

Books: the author(s) and year of publication should be given followed by the publisher e.g. Eggleston, John (ed) (2000), Teaching and learning design and technology: a guide to recent research and its applications, Continuum, London.

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Papers within conference proceedings or collected work with editor: the title of the proceedings or the whole book is in italic followed by the publisher e.g. Norman, Eddie (2000) ‘The teaching of technology for design’. In Richard Kimbell (ed), Design and Technology International Millennium Conference 2000, The Design and Technology Association, Wellesbourne, 128-134.

Hope, Gill (2001), ‘Participant research in design and technology education from the perspective of a design and technology participant researcher’. In E.W.L.Norman and P.H.Roberts (eds), IDATER 2001, Department of Design and Technology, Loughborough University, 47-51.

When referring to more than one document published by an author in the same year, these are distinguished by adding lower case letters (a, b, c...). At the end of your paper the references should be given in alphabetical order (‘a’ will refer to the first source quoted, ‘b’ to the second etc.).

Deadline dates for Volumes 20.2, 20.3 & 21.1

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Submissions to Design and Technology Education: An International Journal are accepted throughout the year, however, the copy deadline dates for Volume 20.2-21.1 (2015-16) are as follows:

Response to papers
The key purpose of the journal is to support the on-going conversation which will be the foundation of future progress in design and technology education. To this end, the Editors will consider publishing in subsequent issues, short responses to any of the points raised in this issue. However, please bear in mind that more substantial responses would be better submitted as papers for publication in the journal in their own right.