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

Dr Marianella Chamorro-Koc, Queensland University of Technology, Australia

Mr Andrew Scott, Queensland University of Technology, Australia

Dr Gretchen Coombs, Queensland University of Technology, Australia

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

studio tradition where the act of designing – generating, evaluating, and developing alternatives – is learned and practiced (Gross et al. 1997). The literature refers to a variety of well-established pedagogies that are employed in design studios where the student's individual designing process during the studio is the central activity. Some of these pedagogies are: field trips, expert lectures and panel discussions, pin up sessions, desk critique sessions, formal juries, consultation during class work time, and a propose-critique-iterate stance (Broccato 2009).

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.

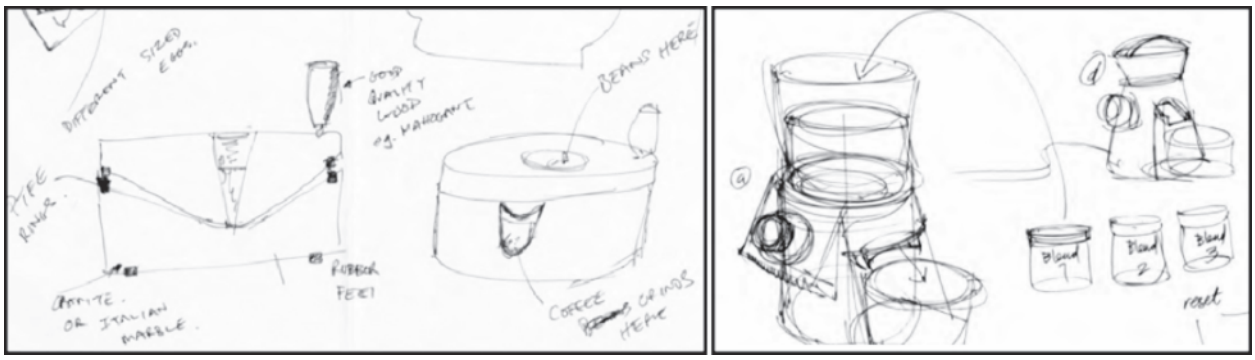
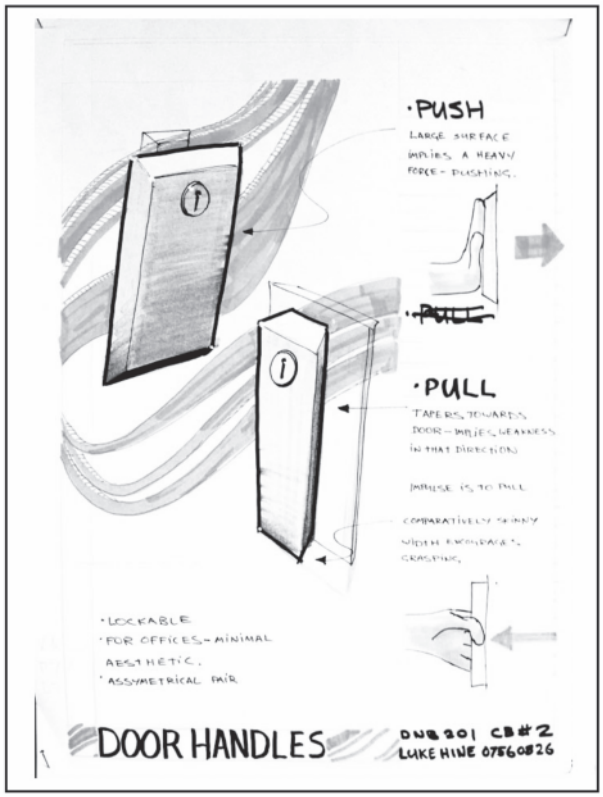


Figure 1. Segments from a novice (left) and expert (right) designer sketches

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



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

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

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

Figure 3. Concept bombs punctuate the First Year semester and provide a change of pace from long projects.

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.

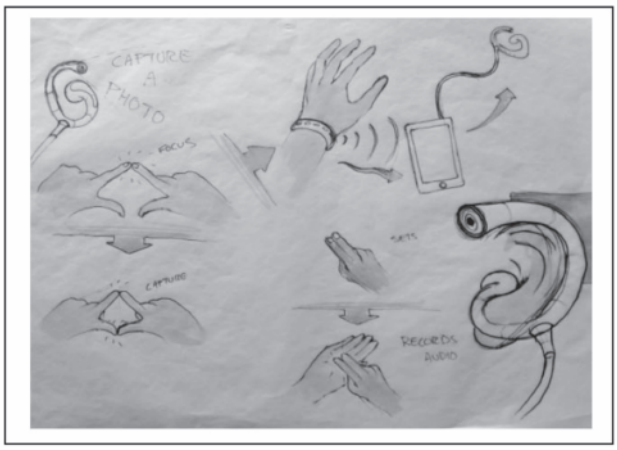
Rapid feedback: Concept Bombs enhance learning by closing the feedback loop. As there is little pause between doing the sketches and getting feedback and assessment they provide 'instant gratification' to students. Staff moderated peer feedback also encourages student engagement with assessment criteria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

Figure 4: First Year students during concept bomb activity

RESEARCH



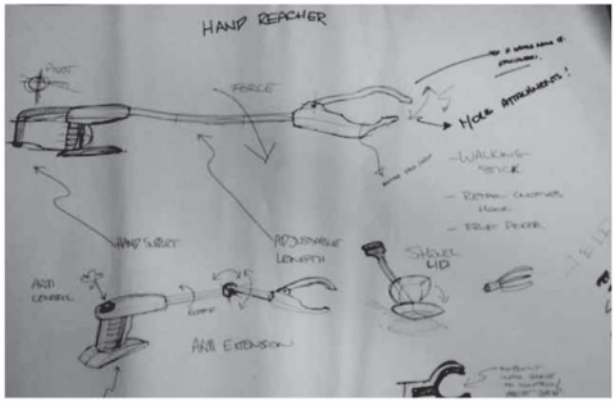
CONCEPT BOMB #1: "Collecting information on the go"
Your client is a high-tech product developer and is planning the next generation of wearable devices the techno-savvy group of users. This market niche is comprised of people who 'collect information on the go' in their lives with the goal of selling 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 5. A Third Year design student's Concept Bomb sketch (left) and the design brief

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.



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.

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

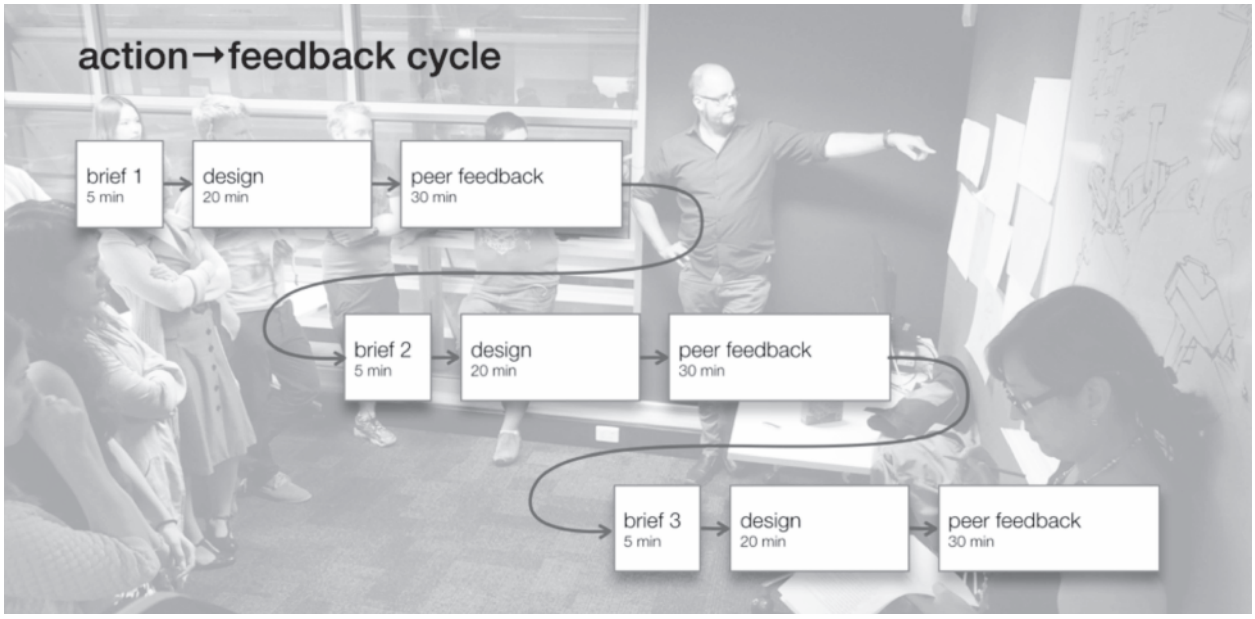


Figure 7. A Third Year industry-led session format

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

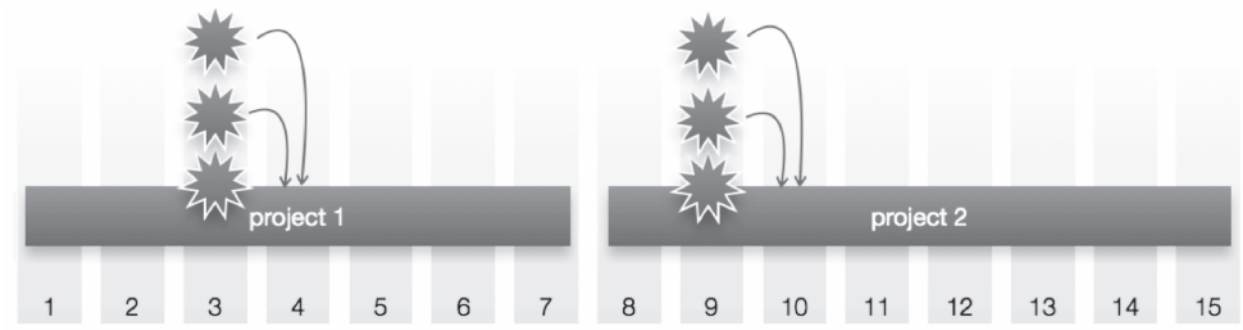


Figure 8. Third Year concept bombs stimulate the early phases of larger design projects.

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.

Categories	Subcategories	Codes
Experience	Features with indication of usage	FE
	Individual experience within context	IEC
	Episodic data	ED
Knowledge	Principle-based concept	PBC
	Description-based concept	DBC
Context-of-use	Intended use	IU
	Situation	ST

Table 1: Coding system

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

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

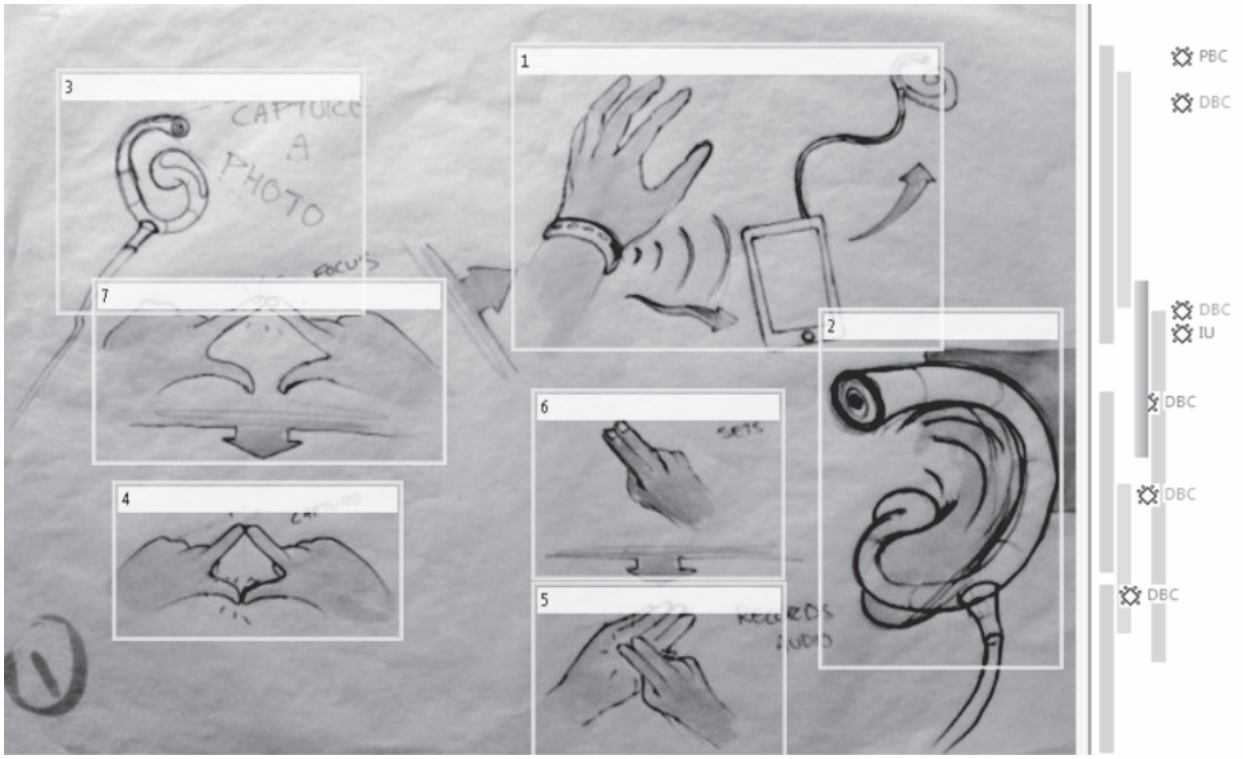


Figure 9: Exemplar of a coded Concept Bomb

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:

Characteristic	First Year Students	Third Year Students
Pace and Focus	Three to four times during semester. Object oriented. Promotes engagement with fundamental design process.	Enabled twice or thrice in the same session, several times during the semester. It focuses on people's relationship with objects in everyday life practices. Use of scenarios allows quick engagement with new theory.
Rapid Feedback	Staff-moderated peer assessment (formative and summative). Instant gratification.	Peer assessment (formative). Promotes engagement with the larger design project.
Ideation Technique	Promotes rapid ideation skills	Refines rapid ideation skills
Repetition	Promotes skill development and confidence Best-three-out-of-four assessment reduces student stress.	Single-session repetition refines skill development and confidence

Table 2: Comparison of characteristics of Concept Bombs in First and Third Year design studios

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.

RESEARCH

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 were 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 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 (Benntt 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

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.

References

Australian Learning and Teaching Council (ALTC) 2011, '*The Studio Teaching Project report*', University of New South Wales, University of Queensland, RMIT University, University of Tasmania, viewed October 12 2013, http://www.studioteaching.org/index.php

Benntt, R 2001, 'Omnium: A research initiative proposing strategies fo quality, callaborative on-line teaching and learning'. *The ECI E-papers*, vol. 1, no.1.

Beswick, N 1990, *Resource-base learning*, Heinemann Educational Books, London.

Breslin, M & Buchanan, R 2008 'On the Case Study Method of Research and Teaching in Design'. *Design Issues*, vol 24 no.1. pp. 36-40.

Brocato K 2009, 'Studio Based Learning: Proposing, Critiquing, Iterating Our Way to Person-Centeredness for Better Classroom Management', *Theory into Practice*, vol. 48, no.2, pp. 138-146.

Broadfoot, O & Bennett, R 2003, '*Design Studios: Online? Comparing traditional face-to-face Design Studio education with modern internet-based design studios*', viewed October 12 2013 http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.124.3548

Brown, J S 2001, Learning in the Digital Age, *The Internet and the University: Forum*, pp. 71-72.

Carey, G, Bridgstock, R, Taylor, P, McWilliam, E & Grant, C 2013, Characterising one-to-one conservatoire teaching: some implications of a quantitative analysis. *Music Education Research*, vol.15 no.3, pp. 375-368.

Cartier, P 2011 'Most valuable aspects of educational expectations of the students in design education'. *Procedia-Social and Behavioral Sciences*, vol. 15, pp. 2187-2191.

Chamorro-Koc, M, Popovic, V & Emmison, M 2008, 'Using visual representation of concepts to explore users and designers' concepts of everyday products'. *Design Studies*, vol. 29 no. 2, pp. 142-159.

Chamorro-Koc, M & Popovic, V 2009, 'Experiential Knowledge representation and the design of product usability', in *Proceedings of EKSIG 2009: Experiential Knowledge, Method & Methodology*, eds. K Niedderer, L Reilly, S Roworth-Stokes & C Smith, London, UK: London Metropolitan University, pp. 41-55.

Chamorro-Koc, M & Scott A 2012, 'First year ID studio-based teaching pedagogies and students' engagement' *ID Educators Network (IDEN) Journal*, issue 1.

Cross, N 1982, 'Designerly way of knowing' *Design Studies*, vol. 3 no. 4, pp. 221–227.

Cross, N 1998, 'Natural intelligence in design' *Design Studies*, vol. 20, no. 1, pp. 25–39.

Do, EYL & Gross, MD 1996, '*Drawing as a means to design reasoning*', Artificial Intelligence in Design '96 Workshop on Visual Representation, Reasoning and Interaction in Design, viewed 30 September 2013, http://depts.washington.edu/dmgftp/publications/pdfs/aid96-mdg.pdf

Dorta, T, Perez, E, & Lesage, A 2008, 'The ideation gap: hybrid tools, design flow and practice', *Design Studies*, vol. 29, no.2. pp. 121-141.

Dutton, T A 1987, 'Design and Studio Pedagogy', *Journal of Architectural Education* vol. 41, no. 1, pp. 16-25.

Fisher, K 2010, 'Technology-enabled active learning environments, an appraisal', *CELW Exchange. Centre for Effective Learning Environments*, pp. 6-10.

Goldschmidt, G. (1991) The dialectics of sketching. *Creativity research journal, vol. 4*, no. 2, pp. 123-143.

Gross M & Do YL 1997, 'The Design Studio Approach: Learning Design in Architecture Education' in Proceedings from Design Education Workshop, eds. J Kolodner & M Guzdial, viewed 30 September 2013 http://depts.washington.edu/dmgftp/publications/pdfs/edutech97-eyd.pdf

Hill, JR & Hannafin, MJ 2001, Teaching and learning in digital environments: The resurgence of resource-based learning, *Educational Technology Research and Development*, vol. 49 no. 3, pp. 37-52.

Krause, K & Coates, H 2008, 'Students' engagement in first-year university' *Assessment & Evaluation in Higher Education, vol. 33* no. 5, pp. 493–505.

Kvan, T 2001, 'The pedagogy of virtual design studios' *Automation in Construction*, vol. 10 no.3, pp. 345-353.

Lockett, DR 2008, *The scholar/performer: a new dimension in music research*, Paper presented at Australasian Piano Pedagogy Conference,Canberra, viewed 30 September 2013 http://www.appca.com.au/2007 proceedings.php

Menezes, A & Lawson, B 2006, How designers perceive sketches. *Design Studies*, vol. 27, no. 5, pp. 571-585.

Oxman, R 2004. 'Think-maps: teaching design thinking in design education' *Design Studies*, vol. 25, no.1, pp. 63–91.

Oxman, R 1999, 'Educating the designerly thinker' *Design Studies*, vol. 20, no. 2, pp. 105–122.

Shao, YJ, Daley, L & Vaughan, L 2007, *Exploring Web 2.0 for virtual design studio teaching*, in eds. Roger Atkinson, Clare McBeath, Elvin Chua Chee Peng, Alan Soong Swee Kit, Chris Cheers, ICT: Providing Choices for Learners and Learning, Singapore, 2-5 December 2007, pp. 918-922.

Schön, DA 1983, '*The reflective practitioner how professionals think in action*', Basic Books, New York.

Schön, DA & Wiggins, G 1992, 'Kinds of seeing and their functions in designing' *Design studies*, vol. 13, no. 2, pp. 135-156.

Taboada, M & Coombs, G 2013, 'Liminal moments: designing, thinking and learning' in DRS Cumulus 2013: *Design Learning for Tomorrow – Design Education from Kindergarten to PhD*, in eds. Reitan, JB, Digranes, I & Nielsen, LM, Oslo.

Zehner, R 2008, '*Studio teaching in Australia, from art and architecture to urban design and planning*', Paper prepared for presentation at the ACSP – AESOP Joint Congress Chicago, Illinois