DROPPING CONCEPT BOMBS: ARGUING FOR A KNOWLEDGE-FOCUSED INTERVENTION IN SKETCHING TO STIMULATE STUDENT ENGAGEMENT WITH VISUAL THINKING

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Abstract

Sketching is acknowledged as being a crucial tool in both exploring and representing ideas during the engineering design process. Despite this importance design educators experience difficulties in encouraging students to engage in this type of visual thinking. Existent research attempting to improve engagement focuses on building sketching skills. The objective of this paper is to present an argument for a knowledge-focused intervention providing augmented domain knowledge when designing, in addition to increasing sketching skill. The basis for the argument is the consideration of sketching as a reflective design activity requiring a degree of analogous or domain knowledge, where a lack there of forms a barrier to fluent engagement. Observations and reflections on deploying the intervention (the Concept Bomb) over 3 years of teaching provide evidence for the success of the intervention. Successes are manifested in increased momentum in engaging with design projects, and greater time efficiency when sketching. Reflections also lead to a number of opportunities for further research into the causality of preliminary findings and influence of the Concept Bomb on design fixation.

Keywords: Sketching, Design cognition, Design education, Design process, Early design phases

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1 INTRODUCTION

Freehand sketching has long been emphasised as a critical part of the engineering and industrial design process (Tovey 1997, Ullman 2003, Cross 2006, Yang 2009) This is due to the inherently iterative nature of the design process and the need to create visualisations to externalise and explore design options. As such the importance of the activity relates to its use as both a tool for thinking as well as representation/communication. As a communicative tool the design sketch has become an industry standard approach to representing initial concepts and ideas toward the solution of a design brief. With respect to its use as a thinking tool Schön (1983), describes sketching as a conversation between the designer and the drawing (sketch). In stating this Schön further describes the way in which the act of sketching helps designers to develop different types of knowledge relating to the design they are developing. These are described by Goldschmidt (1991), as reflective thinking on the forms and information visualised in the sketch and analogical or re-interpretive thinking that promotes creativity. Thus it is both the action of sketching as well as the outcome of the activity that provides a critical mechanism in the development of a design project.

Engineering design education also recognises the importance of sketching when teaching students about the design process (de Vere et al. 2011, Taborda et al. 2012). Through this understanding there have been various efforts to research and improve engagement with sketching in engineering and industrial design. Many of these focus on sketching skill and fluency in representing ideas but few consider the reflective part of the sketching equation. In this paper we primarily present an argument for a knowledge focused intervention in design education called the Concept Bomb that aims to stimulate reflection in sketching. The implementation of the intervention is described and preliminary reflections on using the pedagogy over a 3-year period are discussed.

2 BACKGROUND

The background section now goes into further detail on the mechanics of sketching in the conext of the design process forming the theoretical foundation for the intervention.

2.1 Sketching activity during the design process

The typical emphasis in the early stages of the product/industrial design process is to explore a wide range of ideas (Ullman et al. 1990, Cross 2006). This initial phase of visual thinking activity is referred to in terms of “lateral” explorations (Goel 1995) or similarly divergent thinking (Cross 2006), and is considered most effective in facilitating creative design solutions (Robertson and Radcliffe 2009, Self 2013).

It follows that emphasis in sketching activities at the beginning of a student design project is in lateral explorations and generating a large quantity of ideas at a lower resolution or detail. As the design process progresses, lateral explorations shift toward what are termed “vertical” explorations (Goel 1995). Vertical explorations describe the type of visual thinking that occurs where refinements are made to existing ideas to add detail. Thus there is a greater emphasis on vertical explorations as a design becomes more resolved towards the final solution.

In a study of different cognitive activities during the process, Goel (1995) sets out a design solution space proposing levels of abstraction in thinking running orthogonally with the levels of detail described during the design process (see Figure 1 below). In studying the paths that designers take in traversing the solution space Goel highlights that the design activity early in the process where lateral translations occur (Problem Structuring and Preliminary Design) requires higher levels of abstraction. This means that the majority of ideas are as a result of drawing on long-term memory calling on solutions often out of context of the design task at hand (abstracted), and thus requiring a degree of modification before they constitute a possible solution. Of crucial relevance to these operations is that less experienced designers are more pre-disposed to vertical or depth-first translations indicating that their capability for abstracting possible solutions from experience is limited (Cross 2006).

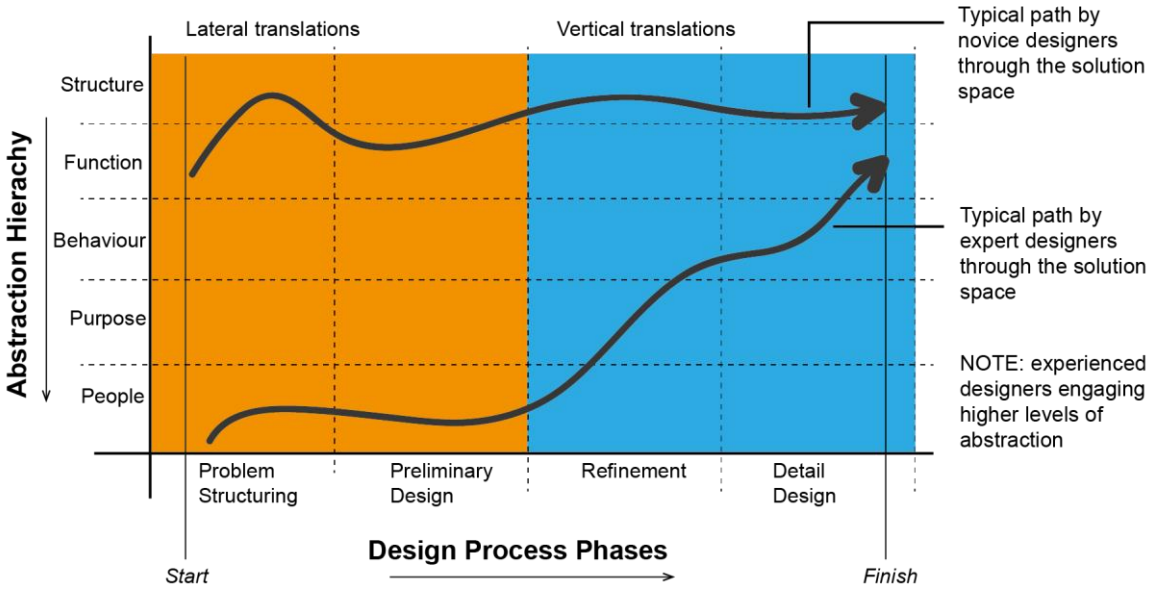

Figure 1 Illustrating Goel's solution space showing levels of abstract thought during sketching against phases of the design process

Ullman (2003) references the importance of sketching during the earlier phases of the design process with respect to expanding knowledge. Specifically Ullman argues that a key the goal of the process of design is learning as much about the evolving design as early as possible while the expense of making changes is low. Hence the affordances of sketching for idea exploration and iteration are of substantial benefit in achieving this goal.

To summarise we show based on arguments by Cross and Goel that one of the difficult components of designing early in the design process with sketching is the requirement to draw on long term memory and abstract possible solutions. Equally, Ullman indicates a need to develop as quickly as possible a knowledge base related to the design problem at hand in order to explore and iterate ideas toward a solution. It is this need for knowledge that is not necessarily present for novice designers, plus the challenges of engaging higher levels abstraction when designing which provides the basis for the argument and intervention presented in this paper.

2.2 Student engagement with Sketching and approaches to improve it

Barriers to engagement with sketching are discussed and methods to improve this are assessed to further frame the intervention within the educational context.

Despite the importance of visual thinking in engineering and design practice, many educators in design experience difficulty in motivating students to fully and “sincerely” become engaged in this activity. The need to encourage students to engage beyond instruction to complete the task is commonly bemoaned by design educators. In a world filled with a selection of digital design tools such as CAD offering opportunities to visualise ideas in 3d at photorealistic detail, the sketch can be seen by students as an archaic inferior practice (Robertson and Radcliffe 2009, Self 2013).

van Passel and Eggink (2013) review some of the barriers causing poor/reduced engagement with sketching. In particular they identify the prevalence and preference of on-screen design tools (specifically CAD tools) in the student design process. They suggest that this widespread use leads to a lack of practice of sketching which leads to a lack of confidence in the said skill. This forms a cycle in which due to decreasing practice and subsequent decreasing confidence the use and value of sketching is lost. Thus a key factor in student engagement with sketching activities becomes the management of

students' self-confidence in their abilities. This preference for CAD and details also evidences novice designers tendency to focus on less abstracted thought during design at the Function and Structure level, (see Figure 1).

de Vere et al. (2011), acknowledging similar issues with engagement proposed a more formalised exercise. In this research the activity "Sketchfest" is introduced whereby students are given sketching assignments, distinct from design projects that are being undertaken, as a means to help students improve their skill level. The approach taken by de Vere et al. (2011), fits with typical skill building exercises that can often be found in studio-based teaching of design. The main difference here is that the exercise is an assessable component of a unit and hence incentivises engagement, as failing to do so would impact student grades. Also fostering and incentivising improved student engagement with visual thinking is the "Concept Bomb" proposed by Chamorro-Koc et al. (2014). Here the addition of a structured peer review stage directly addresses the need to encourage students and increase self confidence as proposed by van Passel and Eggink (2013). Furthermore the Concept Bomb activity is embedded within project work rather than a stand-alone skill-enhancing exercise. The authors contend this integration with major projects also help student engagement in making sketching exercises relevant to overall deliverables.

Focusing on a mechanical engineering context Taborda et al. (2012) introduced a short sketching workshop to supplement CAD education. The emphasis in this intervention was to encourage both divergent and convergent thinking as well as allowing students to explore the affordances of sketching compared with CAD. Distinct from the literature above this intervention also included some consideration of creativity exercises as well as sketch skill building. Findings primarily show improved engagement and development of sketch skills, unsurprising given the intervention is an initial introduction of sketching to the course. Findings do also allude to the success of creating a playful/imaginative atmosphere in addition to delivering sketching exercises.

In summary, all of the approaches adopted above focus on improving skill and thus fluency, speed and confidence while sketching. Some do so through exercises through studio classes, others create exercises separate from the brief at hand. Considering the role of knowledge and predisposition of novice designers to focus on the less abstracted areas of the solution space, the authors contend that a further barrier not yet addressed, relates to the requirement to draw upon knowledge to reflect on sketches/make analogical jumps, and to do so at a more abstracted level of thought than that seen later in the design process. Having evidenced the need (2.1) and this gap in engineering design education literature, we now propose a process focused intervention based on the Concept Bomb which aims to stimulate knowledge base while also providing a sketching exercise. The theoretical intentions of the intervention are now set out followed by the mode of implementation into studio teaching.

3 INTERVENTION: THE CONCEPT BOMB METHOD

Considering the arguments set out above, the primary goals of the intervention is to increase domain knowledge surrounding a given design brief by exposing students to a wide range of potential solutions, and assist students by helping to abstract possible solutions. To achieve these goals we propose the Concept Bomb activity that aims to emulate the design process in a short intensive manner. This is to be executed at the outset of the process such that the learnings can be drawn upon when entering into the project in earnest.

Students must design a single solution using only a limited time period. Hence the first major intervention in using the Concept Bomb at the beginning of projects is that the Concept Bomb requires students to indulge an increased level of vertical thinking alongside lateral thinking. This combined vertical + lateral approach is engendered through the outcome students are challenged to produce during the activity. The "presentation page" that must be presented to peers consists of representing a design in a number of different views to show its overall form (see Figure 2 for examples). Views are rendered to give an indication of materials and manufacturing processes. Thumbnail diagram sketches are encouraged to show internal details or basic moving parts for any given product. It is also expected that

students include details of human factors in supplementary views to illustrate modes of use and interaction.

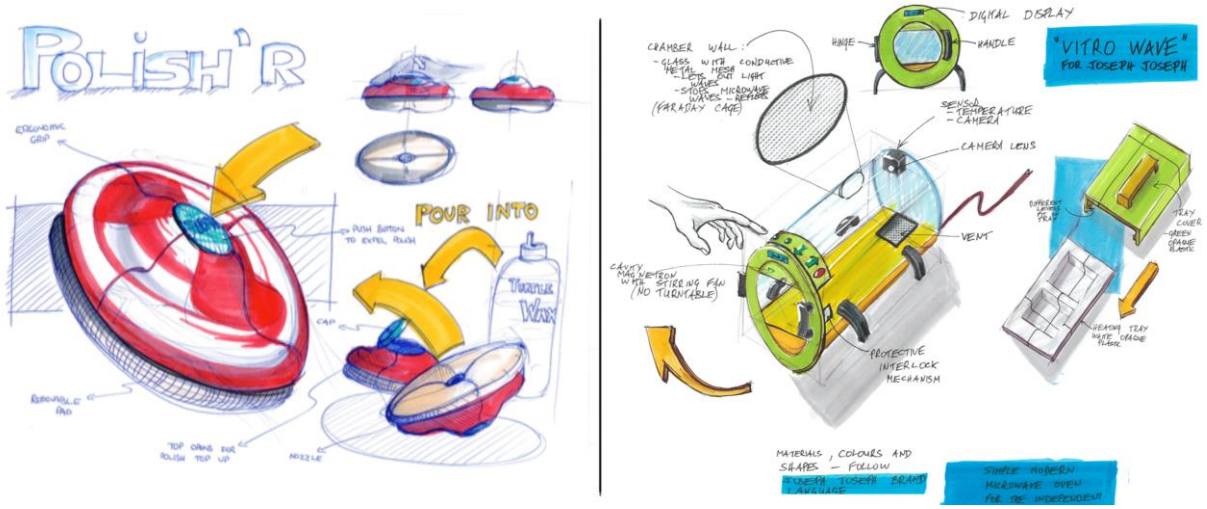

Figure 2 Examples of pages produced by a students during the Concept Bomb exercise.

Figure 3 illustrates the intervention of the concept bomb to a typical design process in terms of lateral and vertical translations. The initial indulgence in vertical transformations is used to breakdown the barrier of a need for abstract knowledge to draw analogies, allowing students to design in their comfort zone. Within Figure 3 this is represented by lower emphasis on lateral exploration and increased emphasis on vertical exploration (highlighted in pink). In doing so students can more fluently sketch out ideas as the thinking aspect of the sketching process is less hindered.

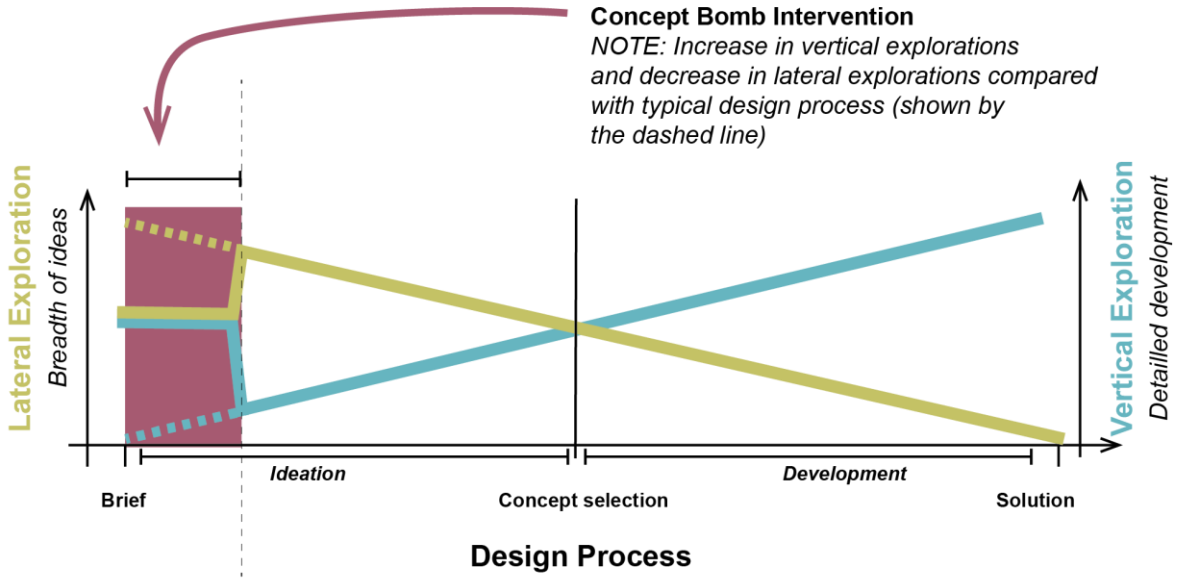

Figure 3 Illustrating the intervention of the Concept Bomb with respect to the shifting levels of lateral and vertical exploration over the course of a typical design process.

In consideration of the abstraction hierarchy and knowledge base, the second and arguably more important phase of the intervention comes in the form of review and synthesis of the class' designs. Following the limited time intensive designing activity a peer review session is held, importantly this forms the mechanism to expose students to a wide breadth of alternatives and hence the crucial knowledge base to take into the design task.

The peer review session is lead and moderated by the educator. Their role as moderator is primarily focused on abstracting/generalising different approaches presented by students with the intention of

leading students to make connections between generalised abstract solutions and the task at hand. In the context of the solution space in Figure 4 the moderator/educator is stepping back from Function and Structure towards Behaviour, Purpose and People levels of abstraction. Thus in addition to exposing students to alternatives, the educator is helping to restructure the design problem as they reverse the direction of the design process phases.

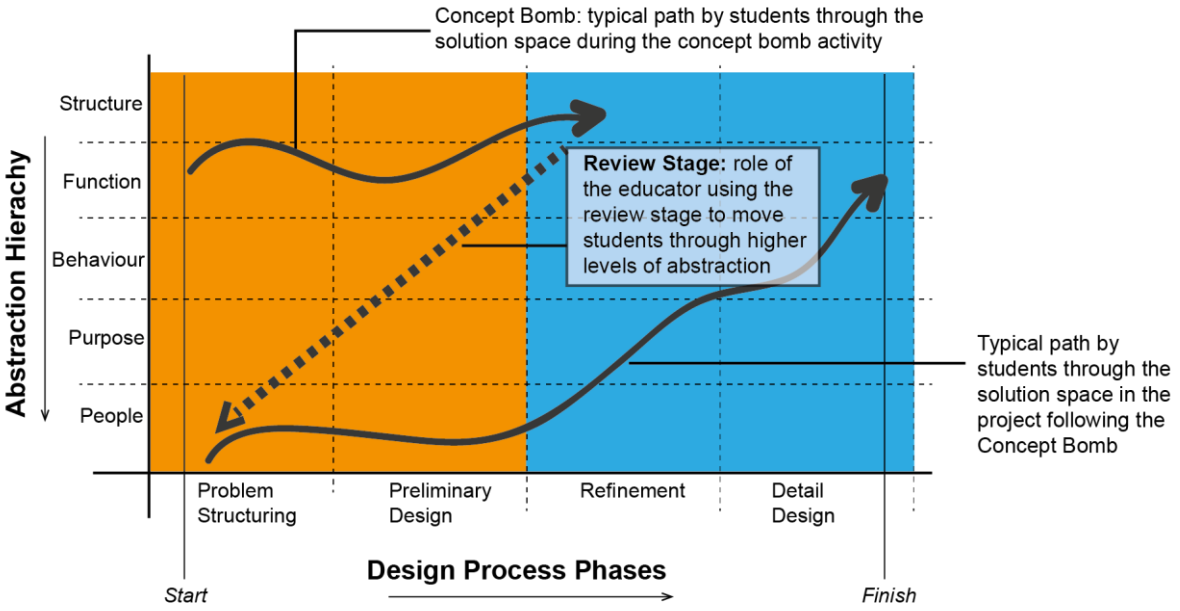

Figure 4 Illustrating the intervention embodied in the review stage of the Concept Bomb.

Following the Concept Bomb and review exercise, the studio teaching structure returns to normal; that is students are urged to explore a wide range of ideas (lateral explorations). As projects progress and students select specific concepts to develop, emphasis is on adding detail to the design (vertical exploration) before presenting a final solution at the end of the project.

4 APPLICATION OF THE CONCEPT BOMB IN TEACHING

The adaptation and application of the Concept Bomb pedagogy is outlined in Figure 5 and discussed in the following five sections as follows.

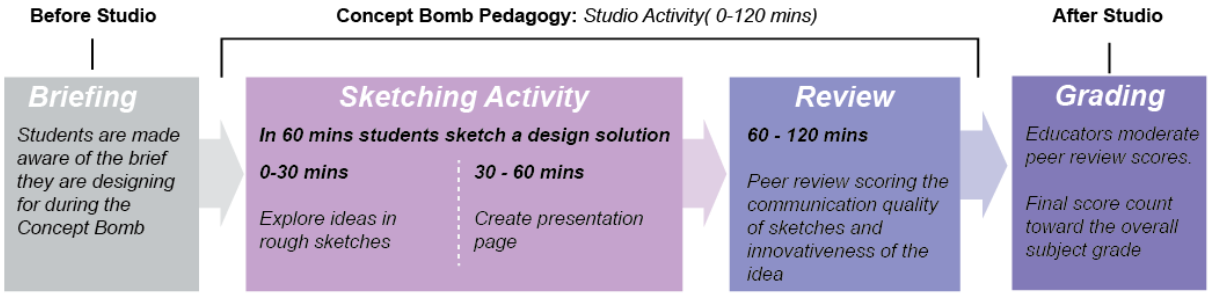

Figure 5 Flow diagram illustrating key stages in implementing the Concept Bomb pedagogy in studio classes

The authors implemented the Concept Bomb within a 4th year (final year) undergraduate Product Design Engineering and 2nd year Industrial Design studios. In both contexts the activity/intervention is initiated as soon as possible after the design brief is given to students.

4.1 Sketching Activity

The complete exercise lasted 2hrs with the first hour dedicated to creating the presentation page/sketch. Students were advised to spend the first 30 minutes exploring ideas and producing rough sketches with the following 30 minutes spent creating the finalised A3 page. The page was to be created using pen and marker rendering including the details set out in section 3 aiming to comprehensively communicate them without the need for additional verbal explanation (see Figure 2 again for an example).

4.2 Review Criteria

Following the completion of the sketch activity students divided into groups of approximately 10. The group along with the educator/moderator first spent time to independently evaluate each page, which is then rated by the rest of the group. To rate their peers each student assessed one another within their group and provided feedback according to the criteria: "innovativeness and appropriateness in solving the brief" and the "quality of communication" of the presented page. These criteria distinguish feedback that relates specifically to the strength of the ideas presented from students' sketching quality and capability. Referring again to van Passel and Eggink (2013), it is contended these criteria mitigate issues associated with confidence and ability in that students can still be rewarded for a good idea regardless of the quality of their sketching.

The quality of communication criteria was set in response to a need to communicate effectively in concept generation. For an idea to be comprehended by a design team and other stakeholders there must be a degree of realism/clarity. While the emphasis in this paper is in the development of knowledge, the need for skill in sketching is still important to develop within the context of teaching the studio. Thus it is important that student's be guided to improve these qualities of their sketches. Crucially, the criteria is named "quality of communication" and not "sketching quality". This naming is done in an attempt to alleviate symptoms of a lack of confidence discussed above, and emphasise communication by any means including annotation, contextual sketches, sequential sketches and captions. Thus, while a good sketch will always be rewarded, weaker sketchers can — with insightful annotation — still communicate well. Hence with these two criteria there was incentive for students to propose innovative ideas as well as work on visual communication skills.

4.3 Review scoring

Students gave 0, 1 or 2 point scores in each of the review criteria to each student in their feedback group (except themselves). This scoring was done by means of giving "thumbs-up", i.e. no thumbs, one thumb-up or two thumbs-up. The moderator then totalled the number of points (thumbs) to give a score in each criterion. In order to encourage discussion and feedback on how the student should progress with their design during the project, the moderator asked the voting students the rationale behind the score they have given. There was particular emphasis on providing explanation where students were giving each other full marks or zero marks. If there was no rationale or the student was plainly giving marks for irrelevant reasons the moderator discounted the mark and educators moderate the resulting score at the end of the session.

Following the formal review the moderator then began the synthesis discussion/phase. The first objective for the moderator was to generalise and group individual solutions together within wider approaches to the brief. This is done primarily by highlighting similarities in the intent and approach set out in each students' design. At this stage educators also add examples from their more extensive knowledge/memory of analogous designs. In doing so the educator leads the group of students through the process of abstracting ideas (see dashed arrow in Figure 4). The review session ended with each student discussing how they intend to proceed with their ideation; whether they intend to pursue completely distinct ideas or to further develop variations of the idea they presented.

5 OBSERVATIONS AND REFLECTIONS

Having delivered this version of the Concept Bomb in 8 design studio classes over 3 years, key observations made by educators are now discussed in order to reflect on the use of this pedagogy and to uncover further opportunities for research on the topic. Initially quantitative analysis was undertaken

investigating the progression of grades awarded for sketching and in the project overall following the intervention. This does show a trend for improvement in sketching ability, the average grade for sketching improved by 8% over the semester). Further Quantitative analysis was not pursued further due to a lack of a suitable control group and the presence of confounding factors such as changing briefs, different student groups making such analysis unreliable. Thus for the objective of this paper in setting out the argument for the intervention and discussing the pedagogy, reflections are drawn from observations by educators and student feedback surveys. These are split first into observations on the successful delivery of the activity, second on the influence on engagement in sketching.

5.1 Reflections on delivery of the activity

Key reflections on the delivery of the concept bomb during class are now discussed summarising student feedback and key observations from educators.

5.1.1 Positive engagement

Feedback from students on the activity is that it provided a constructive experience due to the way that students were able to witness and learn from each other's designs. This is a positive finding as it suggests that the students saw the benefit in being aware of different design options for a given brief, hence saw the benefit of expanding their knowledge base prior to beginning the design task in earnest.

5.1.2 Time management

The second student reflection was that the activity was difficult from a time management perspective. The majority of feedback suggested that this was a positive factor and that the task had helped them to become quicker and more efficient in their ideation. This was not unanimous and there were still a number of voices in each studio indicating that the time constraint was too tight to achieve any kind of helpful outcome. Similarly from the perspective of educators, major observations where first that despite warnings and encouragement, timing was very much challenging for students to complete the exercise. Often failing to deliver a page at the expected level of detail during the first occurrence of the Concept Bomb seemed to be the only way for students to understand how much they could achieve within one session and how quickly time would pass. Consequently, it was observed that the second and third occurrences of the Concept Bomb were far more successful for students completing the task to a suitable level of detail.

5.1.3 Clarifying intentions to develop knowledge and shaeg ideas

The last major observation and point of improvement in delivery of the Concept Bomb was the need to consistently and vehemently remind students of the purpose of the exercise. Specifically, to remind them that the review stage was a means to develop knowledge and reflect for greater benefit of the group rather than a grading task. Over the years of delivery, educators have increased their focus on explaining the rationale behind the task. This was done by using a depiction of Goel's solutions space outlining the intention of the intervention at the outset of the Concept Bomb. Despite these efforts there are still observed to be groups of students where engagement in review and subsequent discussion to synthesise solutions is limited. This was seen to be a symptom of focusing on the exercise as grading (not feedback) or oppositely, for the reason that the exercise was not a graded, thus not requiring effort or engagement.

5.2 Reflections on improved engagement in sketching

Key reflections on the concept bomb's impact on student engagement with sketching is now discussed.

5.2.1 Speed and fluency of sketching

Observations on sketching capability at the outset of the classes compared with those at the end do show improvement. Similar to Taborda et al. (2012) this is of course expected with any sustained engagement/practice, but nevertheless shows a positive outcome. Here the student feedback on the method being difficult in terms of time is pertinent. While it is difficult to prove causality of the benefits of the intervention on sketching skill, the finding that time management has improved is inferred as a consequence of the intervention. Thus, we contend this constitutes an improvement in engagement from the perspective that where the task is perceived as less arduous, it follows that it is more likely to be engaged with.

5.2.2 Generating more ideas quickly

Going beyond sketching skill, there was widespread agreement in student feedback that the Concept Bomb had helped to "kickstart" their projects. We infer from this idea of kick starting projects an improved engagement in sketching from the perspective of greater fluency in lateral and vertical translations after the Concept Bomb. Simply put the increased momentum is interpreted as students generating more ideas (lateral and vertical translations) more fluently. As such we contend that the Concept Bomb has succeeded in expanding knowledge forming the basis to achieve greater fluency in translations, resulting in greater momentum at the outset of projects.

5.2.3 Design fixation

A significant consideration with respect to design exploration is the extent to which the intervention leads to fixation. Again preliminary quantitative analysis was rejected due to a lack of control and variety of briefs addressed by different students in the different studios. A further difficulty was also on-going scholarly debate on how instances of fixation might be defined (Vasconcelos and Crilly 2016). However acknowledging the presence of fixation we argue that the intervention, while contravening some logic on fixation (i.e that early vertical exploration will more likely result in fixation), provides a pro-active mechanism for addressing it. Simply put students are made explicitly aware of flaws in their designs and also exposed to a wide variety of alternatives, alternatives that could well be overlooked if the student were not exposed to. Furthermore considering the concept of sunk-cost (Viswanathan and Linsey 2011), students are less attached to a given idea or concept due to the short amount of time and thus reduced effort expended during the Concept Bomb.

In summary feedback has shown positive impact on student engagement with respect to time management and gaining momentum in the design activity for projects. This in turn has exposed the need to create more experimental conditions in which the intervention can be tested against skill building exercises, and also opportunities to optimise the intervention. Similarly the influence of the intervention on fixation will also form a major topic for further study.

6 CONCLUSION

In this paper, we have contributed primarily in presenting an argument for a knowledge focused intervention in design education that supports the need to expand domain knowledge when designing in addition to increasing skill and fluency in sketching. We then propose the intervention and discuss its application in teaching over the course of 3 years. Through preliminary reflections on student feedback and educators' observations during the application of the intervention, we see evidence of students gaining momentum during early stages of projects as well as becoming more time-efficient in their sketching. Reflections also lead to a number of opportunities for further research into this kind of knowledge focused intervention. Specifically, studies investigating these preliminary findings under experimental conditions to determine causality on which elements of the concept bomb influence improved engagement, and also the need for research into the implications of this intervention on design fixation during student projects.

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