MANAGING CONSTRAINTS IN DESIGN PROJECTS TO ENCOURAGE MAKING, ITERATIVE DESIGN AND A DEEPER LEARNING EXPERIENCE

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Abstract
Design education has been challenged by the need to teach students design, when being a designer has proved difficult to define and articulate. The solution adopted by design educators has been to dismantle the design process into smaller, easily managed segments, such as manufacturing and ergonomics. This approach has largely been successful and graduates make the transition from academia to professional practice with relative ease. Recently however, design has expanded beyond its traditional borders into new areas such as experience design and digital manufacturing, this requires new learning products to be delivered into what is an already overcrowded curriculum. Furthermore, increased student numbers in programs like Integrated Product Design, where model-making in workshops is fundamental, is placing additional pressure on delivering efficient and effective learning experiences. This paper will present a pedagogical reflection from the perspective of an integrated product design program where two subjects were re-structured in response to these pressures. The subjects involve the design of an object and the making of functional prototypes using analogue and digital technologies located both internal and external to the university. Central to this re-structure was the management of contextual factors to facilitate high level design outcomes and deep learning.

Introduction
Many university courses including integrated product design (IPD) are experiencing pressures that include; increasing student numbers, crowding of the curriculum, reduced face-to-face teaching and the need to develop online products. The removal of student quota limits for university courses has seen enrolment numbers significantly increase (Coaldrake and Stedman 2016), yet staffing numbers have remained stable. In this period of considerable technological change IPD has absorbed new material into the existing curriculum, such as additive manufacturing (AM). AM refers to a new method of production and it is now taught alongside other traditional methods such as moulding and fabricating. The inclusion of AM has placed added pressure on IPD teaching staff to properly cover all necessary content. Additionally, the teaching semester has reduced in some cases from 14 weeks to 11 weeks, which results in less face-to-face time between students and teachers. This decrease requires subjects to be restructured in order for material to be either eliminated or reconfigured. The impact on courses such as IPD is considerable, time taken away from studio or workshop practical exercises are not adequately satisfied by online substitutes as many of the technologies are only available within industry or in dedicated workshops. Operating exclusively in the digital realm for IPD is problematic, notwithstanding the huge impact the digital revolution has made, our world is still inhabited by things (Anderson 2012) and for IPD addressing tangible objects remains a key focus.

Given the challenges placed on teaching and the negative repercussions on a student's ability to make sketch models, appearance models, prototypes etc., a strategy was developed to address how IPD students might successfully engage with the making process in this modified context. Making is one of many steps in the design process and although the expectation, like drawing or rendering, that a student will repeatedly make a model or prototype until the design question is appropriately resolved, is that factors such as time doesn't allow for this. What changes then would allow for a focused attention on making and the quality of tangible outcomes in an IPD student project?

Project-Based Learning

The central motivation behind this question was to encourage more critical making by IPD students. By repeatedly making and testing, students are encouraged to redefine their project at every iteration, they develop a profound understanding of the subject matter which then locates them in a situation not dissimilar to professional practice. This function of a loosely structured problem setting and the realisation of high calibre objects align with the notion of Project-Based Learning (PBL).

PBL is a constructivist approach to learning, it originates from a theory that suggests effective learning is achieved through the restructuring of knowledge a learner already possesses via a real-world project and that outcomes are discussed and shared in a group setting. An underlying theme of PBL is students become active participants in the learning process (Wurdinger 2016) which results in learning that is deeper and more meaningful (Rodriguez 2013) and they are more motivated (Boss and Krauss 2007). PBL is a more intensive learning process compared to memorising information and it assists students to develop what business call the twenty first century skills of creativity, adaptiveness, communication and collaboration (Werberger 2016).

The first of two key characteristic that constitutes PBL is the presence of an authentic and complex question that drives the activity (Blumenfeld, Soloway et al. 1991). The nature of this type of problem means there is no unique solution, following each iteration the new solution provides new information, impacting and modifying the problem and solution in an evolving manner. The nature of the authentic question is important because it needs to replicate the complexity and vagaries of the real-world. Connection to the real-world, allows the student to establish connections between abstract phenomena learned in class and real life experiences.

The second characteristic of PBL is a series of objects that result from the activity and address the first characteristic (Blumenfeld, Soloway et al. 1991). The creation of solutions in the form of tangible and observable objects that are concrete and explicit facilitates a student's' ability to share their ideas and findings with others; discuss solutions, ask new questions and importantly propose new solutions. Continually addressing the project question through the production of tangible outcomes in the context of a student project involves engaging with materiality (making) and the iterative process.

Literature Review

Making prototypes and iterating are functions of the design process, yet for an IPD student they are not always used. For example, a student designer makes a model or prototype as it represents observable evidence of their design, yet iterative making, which is equally important can be a challenge due mostly to limitations on time.

Making

Making has the ability to generate ideas (Dobson 2013) and produce proprietary knowledge (Fingleton 1999). Three dimensional outcomes generated in student projects are limited to sketch models sometimes followed by an appearance model or a proof of concept prototype. Making beyond these early stages of a design project, such as the detail design stage, are rarely seen in student projects possibly because it is the most time consuming stage of a design process (Pugh 1991). Detail design is a function that commonly occurs towards the latter stages of the design process as it addresses the micro and final elements of the design. Detail design can be generated using 3D modelling or technical drawing, which is useful and valuable, however they are not a definitive indicator of performance (Lawson 2006), a complete understanding of a design is achieved through making (Crawford 2009) and making must be accompanied by the iterative process for resolved designs to emerge.

Iteration

Stages of the design process are connected via recurring or repetitive loops, suggesting that design is inherently iterative. Therefore, to iterate is to properly engage with the design process. Student designers often fail to acknowledge this and embark on projects utilizing the design process in a linear manner, that is, they address a problem, develop a solution and remain fixated (Cross 2008). This is understandable, the complex nature of IPD projects requires designers address a variety of issues and having to stop the process, reflect and return to repeat a step seems illogical and a waste of time, especially for a design student. But, the notion of pausing, reflecting, re-evaluating and re-proposing is a necessary requirement to better understand the problem and solution situation, it also allows new opportunities and solutions to emerge which can positively contribute to the project as well as enable rapid learning (Berends, Reymen et al. 2011).

Iterating operates on two levels; divergent thinking, which is crucial to exploring new ideas, and convergent thinking, which narrows and selects from the available options (Yilmaz and Daly 2016). The iterative function is applicable at any stage of the design process, yet some stages are more open than others, for example, hand sketching which continues to underpin design activity (Page 2016) is an example of divergent thinking that easily accommodates iteration, yet iterating models and prototypes due to its complexity is more difficult. Iteration is about action and perception which is important to learned experience (El-Zanfaly 2015). It is not enough that students are presented examples of iterative design such as the more than 5000 prototypes James Dyson constructed in resolving the first bagless vacuum cleaner (Dyson 1998), for students to actively engage with the iterative process the way a project is structured becomes fundamental. Elements of a project that impact on what a student can and should not do are those associated with constraints.

Constraints

Constraints provide a project with a starting point and the building blocks to work with (Sturt 2013), without constraints a project is without purpose (Potter 2002). Constraints are commonly listed within a design brief, some designers see value in being involved in the project even before the brief has been created (Lawson and Dorst 2009), others prefer to work on projects that have very tight briefs, believing that constraints stimulate creativity (Ambrose and Harris 2015). A brief is a mechanism to encourage a level of understanding and certainty between stakeholders (Mcvicar 2012). A well-executed design brief enables designers to work confidently, however by their very nature designers will challenge design briefs in order to gain the control or freedom over the project (Dorst 2003).

At any stage in a design project, a number of constraints exist (Onarheim 2012) and depending on the complexity of the situation, adhering to the constraints can become an onerous undertaking and it is easily seen how they can be viewed as restrictive and unpleasant. Not only, projects that contain large numbers of constraints indicate that the problem area is well-structured and that little potential for variability exists, but, creativity depends on a context of high variability (Stokes 2008) this establishes that creativity and constraints are inevitably related (Onarheim 2012).

Sometimes designers impose constraints without realizing it, which results in constraints performing like an artificial bias that limit possibilities rather than expanding them (Lopez 2012). Student designers are also susceptible to this, for fear of running out of time, or lack of self-belief in their ability to find a better solution which reinforces the conviction that their first solution is the best one, are limiting their project options. This lack of extended exploration at both macro and micro levels impacts significantly on their ability to fully exploit the design process

Methodology

Two subjects were selected to address the making and iterative design shortcoming, the first is an undergraduate subject with a focus on furniture design and the second is a postgraduate subject with a focus on object design for small batch production. Both subjects were located in the School of Design, University of Technology Sydney and the author was subject coordinator and studio teacher. Project briefs were developed to be semester long and both subjects were delivered as design studios. Setting a design project within a standard teaching semester means that subject objectives address the design process in one of two ways; engage with the entire design process in a superficial manner or focus on specific material. Superficial engagement with the design process is valid as it allows the student to experience each of the gateways of a design process in the context of a whole project. Focusing on specific material is a practice commonly used for the teaching of skills such as computer aided drafting or ergonomics, which allows for deep and detailed learning. Having identified the importance of making and iterating in student IPD projects it was necessary to ensure the projects were structured in a manner which would encourage active engagement by students and deliver on the stated objectives. In re-structuring the project briefs the following constraints were highlighted;

- engage with making as early as possible,
- reduce other components that might negatively impact on a student's ability to make, and
- stipulate that the made object is the main focus of the final deliverable.

Making early

Making, sketch models, material tests, mock-ups, etc. was stipulated as a deliverable and clearly articulated at the beginning of the project. Postgraduate students were required to bring in 3D sketches in the second week of semester and every week thereafter, undergraduate students were given gateways were models where to be presented. In both subjects, each week students presented their work (models, experiments etc.) to the group as this would form the basis for group discussions.

Reduction of deliverables

To facilitate time for making there was a reduction and modification in other traditional deliverables such as mood boards and presentation renderings. A process journal however was retained as a way to record each student's' journey.

The made object as final submission

By the time the middle and final weeks of the semester had arrived students had generated a collection of models and prototypes. The requirement for final submission was an object, precisely constructed with great care given to form, finish and details. In addition all previous models were required as a means to both illustrate and physically articulate the design journey.

Other constraints that impacted on the potential to make and iterate related to the physical characteristics of the object. A small object is quicker and easier to make than a large one; an object made up of few components is easier than one made of many; and, an object made of easy-to-work material is easier than a difficult material. To this end, the furniture subject was assigned a specific typology - low stool, the material - sheet-metal and the production process - digital laser cutting and manual folding. The object in the postgraduate subject was slightly more flexible with constraints limited to; size - no bigger than a shoebox, number of components - maximum three and the processing methods that needed to be easily located.

Observations

As teacher and coordinator of the two subjects I was able to make a number of key observations that revolved around notions of; making inertia, iterative design, design resolution and shared discussions. The first challenge was the need to overcome making inertia. For some students beginning a design project by model-making was different and subsequently a challenge, making was usually left for stages following research and conceptualisation. However, within the first two classes it was made evident that even the most basic of models could instigate positive and productive discussions. It required constant reminding to the students that even unsuccessful experiments were important and needed to be brought to class as they demonstrated that actual work had been carried out and that failing was a necessary part of the journey and that mistakes might be the gateway to new solutions.

On occasion, following a studio presentation and discussion, some students would choose to continue their project by starting again and not engage with the iterative process. In certain situations this was an appropriate strategy, however, other times it highlighted a key characteristic of the iterative process, that focus and discipline is necessary to address the increasingly challenging questions that emerge during a design project.

As it is in professional practice so it is in education, a good design has a better chance of emerging if followed by a comprehensive and reflective process that is the looped cycle of; design, make, evaluate, modify and re-make. Committing to this process ensured students addressed a multitude of questions, and the more they confronted the more complete the final design appeared, right down to the smallest detail such as edge radii, proportion, finish etc.

Having experienced more than a decade of teaching in IPD it was refreshing to observe the ease at which conversations relating to a student's design emerged during the studios. There was a common desire within the group to openly share positive and negative experiences and to assist others by making suggestions on where to source a particular material or processing method, it seemed as though the tangible object each student had constructed was the catalyst to this fluid verbal exchange.

The most significant observation relates to the notion of complexity, which may seem out of place given the typology of objects the students worked on where bowls, plates and stools. Complexity in this context refers to the escalating nature of questions each student needed to address as the project neared a state of completeness. Towards the end of a project each decision needed to consider the decisions already made, with the understanding that each decision would impact the final design unlike any previous one. This presented a scenario common to professional practice were object design is required to be definitive, but one rarely experience by students.

Conclusion

The narrowing of deliverables to physical artefacts does make managing the project more streamlined, and, following an initial moment where students perceive the subject to be an 'easier option' due to the reduced number of deliverables soon realise that the commitment and decision making required to properly engage with object design and making is a considerable challenge. Learning is obtained through experience, and experience is gained through the moment of making an object, not necessarily by the end product (El-Zanfaly 2015). Therefore iterative making as part of a process contained within a project, where making occurs more than once and the project focus continues to narrow, can become a source of deep learning for IPD students. Iterative design is commonplace in professional practice, making the process available to students will deepen their understanding of the discipline and it will allow them an opportunity to realise a design to a higher level of resolution.

The anecdotal evidence presented above suggests that a formal and thorough investigation into object making and the iterative process in IPD student projects is necessary to fully appreciate this topic.

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