FACILITATING STUDENTS' DESIGN SENSITIVITY AND CREATIVITY IN DESIGN DETAILING AND MATERIALISATION THROUGH PHYSICAL MODELS AND PROTOTYPES

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ABSTRACT
With respect to structured design processes, physical models are developed with the intention to give additional insight to the analytical, explorative, creative, detailing and materialisation design activities of the designer. In design education, the final two activities are often underemphasised in a structured design process, as educators tend to teach students to focus on defining problems and developing creative design solution at a strategic and conceptual level. Modes of representation in the form of holistic physical models are then developed to complement the understanding on these early stages of design activities. The neglect of detailing and materialisation activities, because of time constraints, increased accessibility to other modes of presentation such as CAD, or students´ misconceptions that creative exploration should only take place in the idea and conceptualisation stages of the design process, is a phenomenon, which need to be seriously addressed in design education. Furthermore, the student designer is not always aware of 3-D representation tools which are suited to facilitate such a divergent and creative process in this detailing and materialisation stage. The aim of this article is to propose a systematic approach for design students to select the most appropriate models and prototypes to facilitate divergence and creativity in the detailing and materialisation stages of the designing process.

Keywords: Models and prototypes, Detailing and Materialisation, Design Education

1 INTRODUCTION

Modelmaking and prototyping are focal areas in Industrial Design education. Every Industrial Design student should have basic skills in model making to explore form, composition and functionality from idea development to detail design. Being involved in modelmaking at an early stage, may enhance the "young designer's" critical understanding of the design process and experience with experimentation and design decision making [1]. To avoid misconception during the materialisation and detailing stages in the design process, new learning concepts and tools are needed to assist design educators in transferring knowledge and skills to design students. Educators and students in Industrial Design should re-think the functionality of 3D physical models as these tools are not only useful in for generating design ideas, but in conceptualising and materialising the detailing aspects of the final design. Aiming to inculcate a sense of urgency among design students to develop final design concepts with high quality of detailing, this paper will proposes several learning concepts on how to use 3D visualisation, as a tool to communicate among Industrial Designers and to achieve better understanding on how physical models and prototypes can be used during detail designing and materialisation stages. In design education, Charlesworth [2] says physical modelling has always been used by design students to develop and communicate their ideas. However, the introduction of 3D computer modelling software has significantly replaced certain hands-on visualisation approaches, which were characterised by a slow, dirty and difficult process of making, into a quick and clean virtual way of designing and prototyping. On a more careful note, Charlesworth [2] added that the designer may face greater challenges and limitations when using CAD in the materialisation and realisation stages than originally anticipated . This is attributed to the lack of good information from educators to design students about the purpose and the effectiveness of models and prototypes and how these tools may contribute to enhancing students′ creativity and sensitivity.

2 HOW MODELS AND PROTOTYPES FACILITATE DIFFERENT MODES OF LEARNING AND TEACHING

Due to globalisation trends and pressures on “mature and new economies” which requires highly skilled and knowledgeable human resources, educator and learners should be more reflective and critical towards which methods of learning should be promoted in which contexts. They should create a common understanding of “what” should be taught and “what” should be explored and experimented in first instance. Liem [3] emphasized that today’s Industrial Design educator must adopt a radically different and creative teaching strategy to adapt to a paradigm shift in the formation of design education, from a traditional and vocational emphasis on “making” to a broader interdisciplinary focus on “design thinking”. He considering a more practical and operational perspective in higher design education the following approaches in design teaching and learning should be examined: (1) Systematic and Process-oriented Design Teaching, (2) Reflective and Experiential Learning, and (3) Learning through a Master-Apprentice relationship in design [3].

In systematic and process-oriented design teaching, students are taught a strict development process of problems solving [4]. The central concept in such a process, are the systematic and deterministic ways of designing, inspired by a structured design engineering process. Here the main problem is partitioned into smaller sub-problems accompanied by sub-processes, which can be solved using problem-solving methods [5]. Although interaction, divergence and convergence take place in a strict development process, students tend to perceive it as a kind of “recipe” for designing. With respect to models and prototypes, modes of representation are then specifically dedicated to certain stages of the process. For example, a sketch model out of foam is being created to complement the idea generation stages, whereas a non-functional design model is created to supplement the final design. This somehow prescriptive approach on how to use models to support the designing activity may restrict to some extent creative thinking. It may naturally lead to a more straight forward and rather narrow exploration of design details and ways of materialisation.

Moreover, a systematic but linear design approach makes students unable to carry forward and integrate learnings from one stage to the next. They find it difficult to revisit some earlier design decisions, which might qualitatively improve the design [6]. From this perspective, the authors argue for a more constructionist reflection-in-action approach as a reaction to the rational problem-solving philosophy [7]. As design problems are unique and difficult to generalize, designers’ or developers’ actions and efforts, should focus on reflective and conjectural conversations with the situation in order to reinterpret and improve the problem as a whole. Methods applied by the designer are to be based on acquired knowledge, experience, and reasoning. In terms of representation and exploration, such an approach in designing and design learning advocates the use of a broader spectrum of modelmaking and prototyping methods and tools, also for detailing and materialisation.

Learning through Master-Apprentice relationships in design has its roots in the hermeneutic ways of reasoning. Here, the central challenge for the master and apprentice is to gain a sustained and increasing understanding of the designed product, its contexts, values, and functions until the both have decided that saturation has been reached [8]. As the potential solutions and the choices faced are practically infinite, the design apprentice must, with the help of the master, reduce variety by establishing a direct understanding among its objectives, processes and solution [9]. Hereby, the master′ designer’s personal experience and intrinsic knowledge base are invaluable. Complementary, such a Master-Apprentice constellation, demands a research-based learning approach, where the “apprentice” is encouraged to learn from the “master” and have direct access to the latest knowledge and ideas from the “master”. In return, the “master” can assign the students to assist him with creating and experimenting *(Modelmaking and prototyping)* to find new knowledge.

3 CREATIVITY IN THE DESIGN PROCESS

Various literature studies support the fact that designers use their creativity in developing a wide variety of physical models based on their intuition and experience. According to Viswanathan and Linsey [10] there is a limitation as how to teach creativity to designers. However, Hasirci and Demirkan [11], claim that creativity can be stimulated by teaching students creativity methods and techniques. Loewy [12], mentioned that the most important design discoveries took place during modelmaking practices with various materials in the detailing and refinement stages of the design process. He suggested that students should be given a freedom to develop their own design methods and tools by encouraging them to experiment with materials and constructions without being worried of making mistakes or exceeding deadlines.

By appropriately using physical models in the design process, it can help the designers to evaluate and fine-tune their final design as well as confirm certain critical requirements. In this context, Viswanathan and Linsey's [10] experiment also demonstrated that creating appropriate physical prototypes enhances the designer's innovative and creative capabilities at a micro-level of idea generation and conceptualisation, which may contribute to a more elaborate materialisation and detailing design activities. Complementary, Steffany [1] also found in her research that models are one of the greatest assets in inspiring, developing and improving student's awareness concerning aesthetics, construction, durability, proportion, scale, sensory, quality or any other educational dimension.

The use of creativity techniques in design processes can effectively assists designers´ materialisation and detailing activities. Similarly as in industry, Hsiao and Chou [13] proposes a creativity-driven design process to be used in design education. According to them an appropriate product design process comprises of a complete set of integrated creative, analytical and development activities. Additionally, they developed a creativity method based on the natural sensuous ability of human beings, known as "Sensuous Association Method (SAM)", which has the main purpose to produce creative ideas to facilitate designer's individual association and stimulation [13]. Hasirci and Demirkan [11] also proposed a creative design process, adapted from the five stages (5R's) of the Sensational Thinking model of O'Neill and Shallcross. Complementary, Green [14] designed a Major Project Development Model (MPD Model), comprising of a seven stage process, which has been implemented in industrial design teaching at the University of New South Wales. (Table 1)

Table 1. Three creative methods with its proposed operation adapted from Hsiao et al [13], Hasirci and Demirkan [11], and Green [14]

Sensuous Association Method (SAM) Hsao et al. (2008)		**Adapted 5R's Sensational Thinking Model of O'Neill and Shallcross** Hasirci and Demirkan (2010)		**Major Project Development Model (MPD Model)** Green (2007)	
Human Senses	**Operation**	**5 R's stages**	**Operation**	**Phase of MPD**	**Operation**
Looking: Look at the involved things	Gather group of team designer in informative and creative environment	***Readiness:*** activity that being open on possibilities	Imagery, ideas searching and observation.	***Product Planning (PP):*** determine a new product idea ***Task clarification (TC):*** negotiating brief with the client	Literature search , Benchmarking, SWOT analysis, Objectives-tree method, Function analysis
Thinking : Think about origins and evolutionary trends	***Discussions begins :*** thinking logically about the origins and evolutionary trends of target product	***Reception :*** To experience fully and observe with all the sense	imagination, generation, idea selection, refinement evident	***Concept Generation (CG):*** creative design concepts	Brainstorming, Concept selection, Morphological
Comparing: Compare what you look and what you think	***SAM :*** participant has to compare their associations with information/pictures observation and contemplation	***Reflection:*** Remembering activity and allowing time for internal interaction	evaluation, idea development, enriching, expanding discovery	***Evaluation and Refinement (ER) :*** analytical and creative tasks are evaluated ***Detailed Design (DD) :*** developing and validating concept	House of Quality , Design by drawing, CAD, Design review CAD , Value Engineering, Robust design
Describing: Describe your mental image	must be described in a sensuous phrase, and written down by the recorder.	***Revelation :*** Focusing and pattern recognition.	develop and enhance the idea	***Communication of Results (CR) :*** Communicate detail concept to client via 2D / 3D media	Design drawings, Renderings, Prototypes
Stimulation : designer's creative inspiration is increased through interaction	members' interactions will stimulate each other's creative inspirations in a highly conducive environments.	***Recreation :*** To determine full contents and express it by various methods, such as drawing	final representation for missing parts, finishes.	***Preparation for Production (PP) :*** determine the needs of product production.	Revised cost visibility, statistical process control, Fault tree analysis, CAD

In Table 1, three creative design methods were mapped against several stages of the designing process as well as their innate human activities. More specifically, different types of operational activities supporting the SAM and MPD model /methods are then reflected upon how each human activity embraces certain creative methods. A literature survey has shown that these three creative methods have contributed to insights on the role of complex of models and prototypes in facilitating creativity and synthesis through out all stages of the designing processes, especially with respect to detailing and materialisation [11,13,14].

According to Jones [15] the creative design process comprises of three essential stages: analysis, synthesis and evaluation. The process can be described as breaking the problem into pieces, putting the pieces together in a new way and testing it to discover the consequences of putting new arrangement into practice. Figure 1, which shows the creativity based design process adapted from Jones [15], indicates that "Transformation" and "Convergence" happens at the three stages. In the transformation and convergence stages, the detailing and materialisation processes are integrated with Green's model for measuring complexity of projects and Welch's theoretical and empirical codes for problem solving in design process. The contribution of Green [16] to the model is more focused towards Industrial Design practice where ten categories of assessment determine certain learning objectives that are essential for Industrial Design students to develop their sensitivity and creativity with respect to materialisation and detailing. Meanwhile, Welch´s [17] proposed coding scheme for evaluating student's problem solving and designing skills through three dimensional modelling shows ample methods and tools, which are available for students use when modelling, improving and building a solution as well as evaluating it.

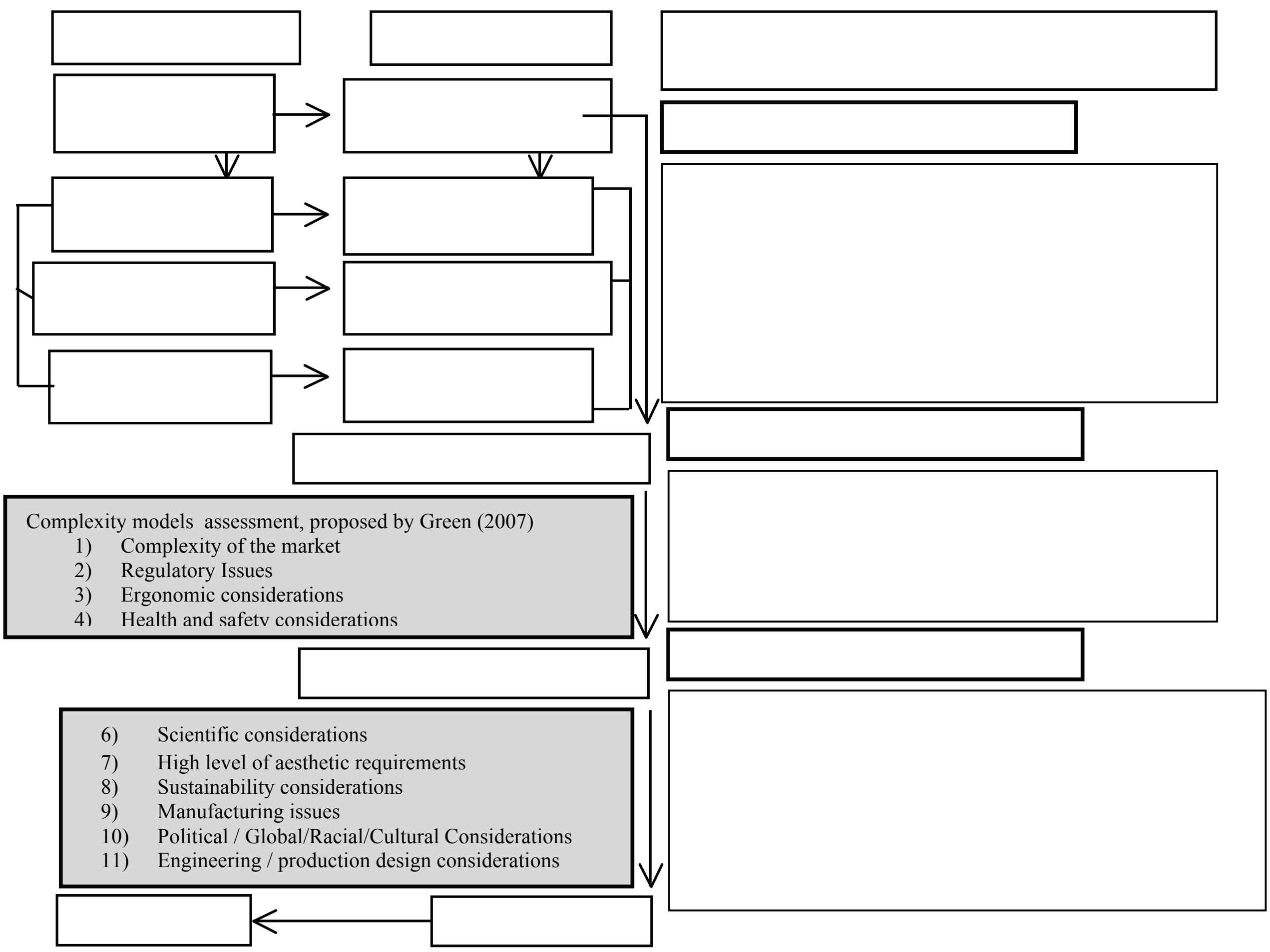

Figure 1. Creative based design processes during convergent and transforming stages. Adapted from Jones [15], Welch [16] and Green [17].

4 DISCUSSION

The use of prototypes and models will help students in broadening their thinking processes and make them conscientious that divergent, convergent and reflective design practices should not be overlooked in these final stages of designing. It is therefore encouraged that students allocate extra time and effort to explore the creative space through physical models and prototypes during the materialisation and detailing stage instead of focussing too much on final presentations. This requires design educators to emphasis more on methods, processes and tools in their teachings with respect to detailing and materialisation. These processes, methods and tools, whether cognitive or visually explicit in nature, should encourage analytical, creative and generative ways of thinking.

Limited research has been conducted concerning selecting the right type of models and prototypes to be applied during the design process, especially with respect to materialisation and detailing stages. As a result, design educators often overlook the importance to train students to select suitable methodologies to develop physical models to facilitate choosing appropriate materials, developing technical constructions and confirming final finishes [1]. However, few approaches were proposed by various researchers to construct physical model to facilitate the design process. As proposed by Michaelraj [18], Hannah et al [19] and Steffanny [1], the taxonomy of physical models is one of the approaches that supports both educators and students in respectively their teaching and learning practices. With respect to creative methods and processes outlined in Table 1 and Figure 1, Michaelraj [18] described various purposes and applications of physical prototypes which support learning, communication and integration. Furthermore, Hannah *et al* [19] indicates the need for this taxonomy to formalise milestones in the design process and guide designers in selecting and identifying the appropriate prototypes in specific design scenarios. In short, the “Taxonomy Physical Model” by Michaelraj [18] and Hannah et al [19] can be used as a roadmap to examine appropriate methods and processes for developing detail design solutions and materialisation design activities.

Numerous research has shown that design students who use physical model as a creativity tool in every stages of their design process will gain a clearer understanding of form, function and construction compared to student who did not do it. However, there is a tendency, that students in Industrial Design prefer to develop their designs mainly through sketches, renderings and 3D computer models as an alternative to being hands-on engaged through for example modelmaking and prototyping at the final design stages. They believe that constructing models can be expensive and time consuming and therefore should only be used when needed. They do not see that exploring the solution space through appropriate models and prototypes will actually enhance their cognitive design capabilities, especially during final stages, where design confirmations are required. Literature reviews have indicated that compared to using CAD tools, increased model making and prototyping practices in the detail designing and materialisation stages enhances students´ sensitivity towards the generation of well- defined and thought through quality products. However, this requires a creativity approach towards integrating modelmaking and prototyping practices in the product design process. The “Sensuous Association Method “, “Adapted 5R’s Sensational Thinking Model of O’Neill and Shallcross”, as well as Welch’s “Theoretical and Empirical Codes to describe Designing and Making” in the “Major Project Development Model”, are methods which can be suggested to educators to facilitate students creativity and synthesis skills in the early idea generation, as well as detailing and materialisation stages of the design process.

Goldshmidt and Rodgers [17] highlighted that educators should teach their students structured and systematic design processes when solving ill-defined problems. However, these processes should not impose rigid ways of thinking, but stimulate exploration and reflection through iterative, divergent and convergent modes of designing throughout all stages of the design process. Given this context, educators are challenged to assist students to plan their design process in such a way as to allow sufficient time for detailing, while in the meantime highlighting the importance of it for creating quality designs. However, the concern is that once an emphasis is placed on detailing and materialisation work, students tend to converge towards concrete solutions quite early in the design process.

5 CONCLUSION

Results have indicated that compared to using CAD tools, increased model making and prototyping practices in the detail designing and materialisation stages enhances students´ sensitivity towards the generation of well- defined and thought through quality products. Hereby, educators are challenged to assist students to plan their design process in such a way as to allow sufficient time for detailing, as well as to highlight the importance of it for creating "award-winning" products. However, the concern is that once the studio teacher has pre-empted the importance of detailing and materialisation work, students tend to converge towards concrete solutions quite early in the design process. Given this educational dilemma, the author proposes an intensive cognitive and descriptive approach for analysing design problems and generating solutions, followed by a strict process of idea generation and conceptualisation. However this, strict development process should be compensated through a more extended divergence and convergence process in the detailing and materialisation stages using models and prototypes, complemented by a "master" and "apprenticeship" interactions between student and faculty to facilitate inquiry.

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