Global Journal of Engineering Education

Improving hands-on experimentation through model making and rapid prototyping: the case of the University of Botswana's industrial design students

Keiphe N. Setlhatlhanyo, Sekao Motshubi & Patrick Dichabeng

University of Botswana
Gaborone, Botswana

ABSTRACT: Design model making and prototyping is a valued part of many industries, including product and packaging design, architecture, transportation, etc. It plays an important role in developing students to visualise their 3D work, paying attention to detail on how parts and processes fit together to visualise and communicate their design solutions. A case study was conducted with 15 undergraduate industrial design students. Subsequent to this exercise, in the previous semester, students did sketch work and had not experienced hands-on model making, which presented itself as a challenge. At the beginning of the product design course, a questionnaire was administered and a second questionnaire administered after the hands-on experiments. On a weekly basis, students experimented with new material to visualise their models up to the final model. During the second half of the semester, students modelled components for a chair. In the article, the authors discuss hands-on model making experimentation with industrial design students at the University of Botswana, using materials, such as styrofoam, cardboard and cloth. The results show that students' confidence in model making can be greatly enhanced by exposing them to a multi-stage model making processes, i.e. from sketch modelling to prototype modelling. The skills students have acquired in this course will assist them in their future careers.

Keywords: Modelling, model making, prototyping, product design, design process

INTRODUCTION

Models and modelling in the context, have been in existence for nearly 4,600 years. Egyptians used to make models of houses and furniture. In design education, model making and prototyping has been an indispensable tool for professional designers, because the practice of design is as important as the theory of design. Model making is important not only in making ideas visual, but in making students learn about several details of design.

There are various definitions of model making and prototyping in the literature. Archer describes it as a representation of something created for any purpose [1]. This is a proper definition in the context of design, although it may still seem too general. Hallgrimsson argues that model making and prototyping are different activities, even though they are in principle associated [2]. He defines prototyping as a design method that uses physical prototypes to study and test how a new product will be used, and how it will look in a *manufactured state*. Conversely, he defines model making *…as a step by step method for producing the prototype* [2].

According to Kelley, prototyping is defined as problem-solving. In other words, model making and prototyping is a way for designers to explore form, composition and functionality from an idea to a detailed design [3]. Physical model making and prototyping is one the most recognised and accepted approach that has always been used by the designers to visualise and communicate their design solutions.

Models/prototypes are useful for designers in that they help make designers visualise and develop their designs much better, explore different creative solutions, investigate human interaction more fully and test functionality to minimise the risk of the design process [2].

When designers design, they invest a lot of resources in trying to find solutions to the problems, and if this is not done properly, this might lead to a worthless product. Through modelling, designers test a lot of design requirements as they move to establish, if the proposed solution is worth continuing or not. This helps designers to be able to change things in their designs before they waste time and other resources on something that might not work. By modelling, the designer gets an opportunity to test and evaluate their designs much cheaper considering some of the materials and processes that are involved in model making. In summary, models are experimentations that designers undertake throughout the design of a project to help minimise errors that might be carried over to the final product and the cost to the designer [4].

TYPES OF MODELS

There are different types of models; some can be computer generated and others have to be fabricated in workshops by hand. In this article, the researchers discuss only four physical model types; namely, sketch models, block models, working models and prototype models.

Sketch Models

Sketch models help designers establish the following: sizes, shape and form, proportions, right colours. It must be mentioned that designs that look correct and workable in two dimensional forms can easily deceive the designer into thinking that everything will fit well when making the product. Sketch models help in identifying problems and rectifying them much early in product designing [4][5].

Block Models

Block models are normally done following sketch models and are normally made from a solid block of materials. They are the correct representation of the actual product being designed. These models assume all the modifications that would have been done at the sketch modelling stage. Block models should always show the outward appearance of the actual product. Most, if not all, external details should be captured by the block model, e.g. surface finish, parting lines, fixtures and fixing, etc [6]. This type of model does not require the inclusion of internal parts nor moving parts, as everything is made rigid with external parts. This model is mainly produced to gauge whether the product will appeal aesthetically to the client.

Working Models

After the production of the block model, designers must produce a working model. This type of model requires accurate details of everything in the block model. If the model has a cavity for parts and some moving parts, these are to be provided for as much as possible. These additional parts should be made as accurately as possible.

Prototype Models

The final prototype is the last checkpoint on the journey towards the final product. The final prototype should match the end product as closely as possible. It does not have to be manufactured using the same processes, but it should make use of similar materials and the design should match exactly the final product. It ought to be made from the same plans, which will eventually be used to make the final product.

IMPORTANCE OF MODEL MAKING

Kojima states that the importance of physical models is that they allow designers to experiment with form, material and context, before moving on to the next stage [7]. Dominik argues that the modelling phase saves the designer and the client time and money, whether it is a physical prototype or a virtual one [8].

Good prototypes not only communicate with people, but also possess the leverage to persuade people. According to Hallgrimsson, prototypes play an important role for designers to allow them to see the idea in 3D form, and therefore, they are an essential medium for problem-solving in design [2]. He added that it is important for the designers to prototype and build models, because it assists the designer to identify and solve potential problems. Furthermore, models not only have the role of assisting the student designer to develop ideas, but also to enable effective communication with others. They have a third role in education, because they help the educator to assess the progress and learning needs of their students.

In the context of design, model making is highlighted as *the language of the design area* [1] and Baynes in his study with children uses the words: *It is through the use of tools and materials that people are able to realize their design ideas* [9]. These may vary in sophistication from relatively simple study models to full prototypes [7][10]. The type of model most associated with industrial design practice is the appearance model, which embodies the form of the production item, but not functionality of the product [11]. Hallgrimsson asserts that the comprehensive range of model making and prototyping methods must be used to stimulate creativity and develop the functionality and appearance of a product before it goes into production [2]. Other designers view model making as a logical next step in the thinking process for every design idea [7][12][13]. This means that when someone starts using materials and fabrication techniques, they can refine their ideas better. This implies that each person is served by a model making approach, when they need to translate an idea into a physical reality.

RESEARCH METHOD

A case study was conducted with 15 undergraduate industrial design students in level 300 at the University of Botswana. Given the number of participants involved, the specific context of investigation and the in-depth inquiry in the area of

research to be undertaken, a case study was deemed to be the most appropriate research method [14]. A case study is an empirical inquiry that investigates a phenomenon within its real-life context [15].

The approach allows the researcher to explore individuals or organisations, through interventions, relationships, communities or programmes and supports the deconstruction and the subsequent reconstruction of various phenomena [14-16].

This research was conducted in two phases as part of a semester course called Product Design. Students were challenged to create simple everyday objects using a series of modelling materials, such as cardboard, clay, wood, metal and styrofoam. The students experimented on a weekly basis with each material. At the beginning of the semester, students were given a questionnaire on model making to complete before they started their design work. This was to gauge their prior knowledge and understanding of model making and prototyping as a design tool. After completing their projects, another questionnaire was given to students to complete, to further gauge after being exposed to different modelling techniques. It also sought to establish how students used modelling techniques to help themselves through their design work. The two sets of questionnaires were analysed.

Out of 15 students doing the course, only eleven completed the survey for the first part, representing a response rate of 73%. All 15 students completed the questionnaire for the second part of the course. The data were analysed through SPSS by using frequencies, means and percentages. Qualitative data were coded and analysed using Atlas.ti software and reported using the emergent themes. The overall data were presented in terms of tables, graphs and text.

RESULTS

The results show that 89% of students had little skill of model making at the start of the course, which changed to 42% at the end of the course; with 58% saying they had a lot of skill (Figure 1).

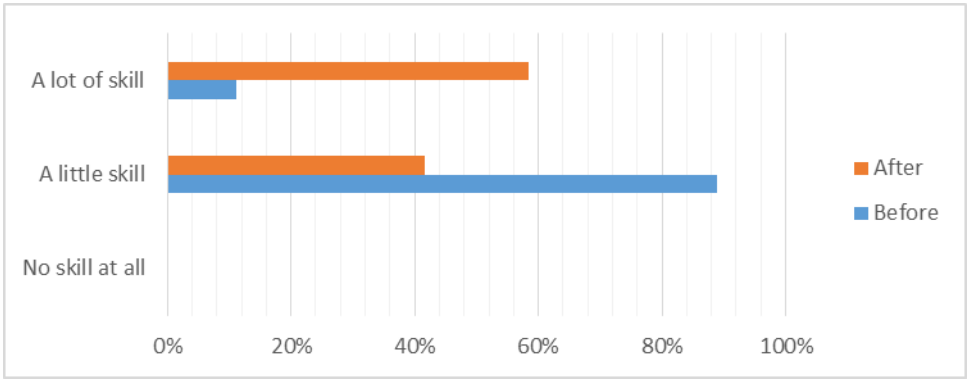

Figure 1: Student perception of model making knowledge at the start and end of the course.

Respondents rated their level of awareness on the importance of model making in design at 82%, and awareness on the impact of model products, services, processes and systems at 78%. The majority of students (64%) believed the course could help develop a response to hands-on activities, and 55% believed the course could improve job prospects (Table 1).

Students reported their main sources of information on modelling and prototyping to be based previous courses (88%) and from carrying out the design process (86%). Design magazines (56%) and television programmes (60%) were rated lowest as sources of information. Through the course, students mostly expected to perform tasks that were interesting and relevant to future jobs (94%) and learn methods and tools for 3D model design (89%).

Table 1: Motivation for choosing the course.

		N	Percent	Cases
Motivation[a]	Could be interesting	1	4.0%	9.1%
	Develop a response to hands-on activities	7	28.0%	63.6%
	Improve job prospects	6	24.0%	54.5%
	Interest in model making	7	28.0%	63.6%
	Expected to take the course	4	16.0%	36.4%
Total		25	100.0%	227.3%

a) Dichotomy group tabulated at value 1.

Students further reported that they were most confident on: 1) design processes; 2) problem-solving; and 3) the use of on-line tools and methods. See Figure 2 below.

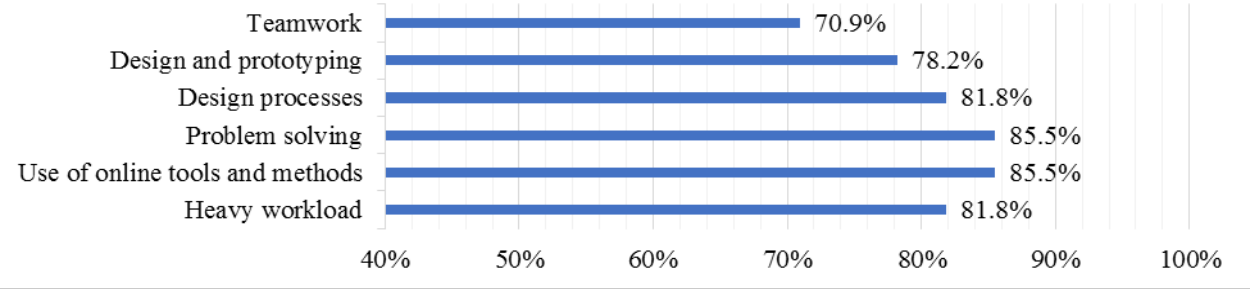

Figure 2: Confidence levels on own capability.

At the end of the course, a second questionnaire was administered to assess students' awareness, and perceived difficulty and usage of modelling techniques, and as reported earlier (Figure 1), their confidence level on their skills. Students rated as excellent their awareness levels on the role of modelling in design (87%), the benefits of modelling in design (85%) and the level of application (80%) (Figure 3).

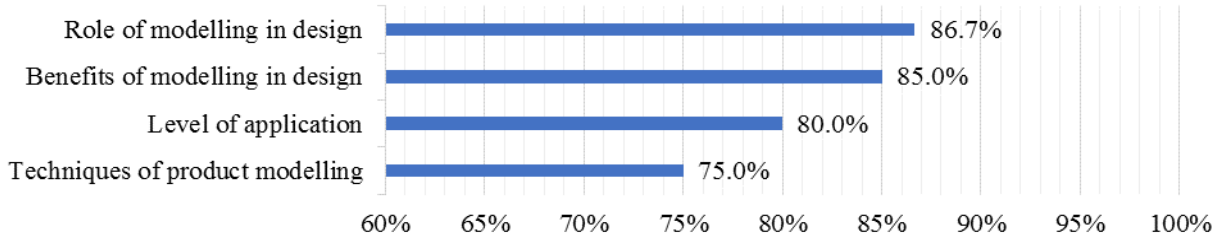

Figure 3: Levels of awareness.

Students perceived prototype modelling (75%) and work modelling (75%) to be the more difficult techniques, and consequently they were the least used.

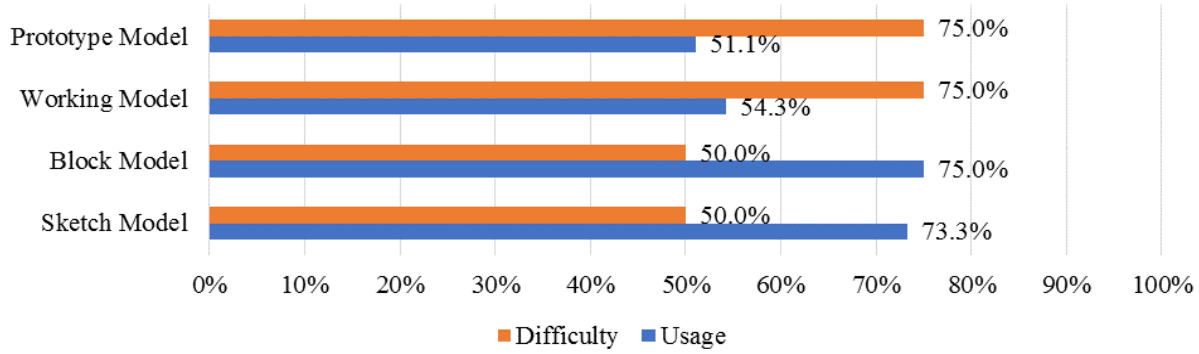

Figure 4: Perceived difficulty and usage of modelling techniques.

DISCUSSION

In theory, students understood the concept of modelling in relation to design. The knowledge about model making (Figure 1) was high, whereas the skills of modelling were low. This does not speak well to design students since a lack of skills in modelling results in students lacking one of the key design thinking process [7]. Their level of confidence on design and prototyping was second lowest among the six areas that were rated in Figure 2. Students' low confidence in prototyping further shows they were neither able to develop their ideas adequately, nor to communicate those ideas effectively. Evans emphasises that prototypes usually demonstrate a high level of functionality, which is representable to the final design solution that automatically implies that a prototype needs to be constructed from CAD based on today's technology and production challenges [4].

Towards the end of the semester, students engaged in building models and prototypes, during which they could identify problems within their models and further modelled in their endeavour to solve identified problems. Hallgrimsson views this part of design as an important step that designers must undertake for them to see their ideas in 3D [2]. The level of students' awareness in model making was raised, though the techniques of product modelling were lower than other areas (Figure 3). In rating all the four modelling stages against the level of difficulty and usage, students found it more difficult to work with working models and prototypes as opposed to sketch models and block models. The usage of sketch models and block models were highly used by students as oppose to working models and prototype models. More emphasis was on the first two stages of modelling (sketch and block model) as these were the areas that were traditionally not done by the students.

The study shows that there is a knowledge gap in teaching different types of model making. If this area can be improved, it can help students to design better products. Therefore, lack of skills in model making can leave the students feeling lost or confused, and making advances on the next steps of the design process will prove to be problematic. This study has demonstrated the multiple stages of model making has helped students advance their skill set, and to develop confidence on hands experimentation and appreciating how components of the design interact with each other. It was further noted that hands-on experience by students was a powerful tool to enhance manipulative and making skills.

CONCLUSIONS

This study has demonstrated the gap areas where teaching and learning pedagogies need to be focused to help students improve and master the model making and prototyping skills. Further, models and prototypes are indispensable representation tools for practicing designers. Physical prototypes enhance designers' creativity and insight to solve design problems, develop creative ideas and concepts, and thoroughly refine the final design. From a presentation and communication perspective, it is essential that designers use models and prototypes to communicate their designs with different stakeholders to gain a better understanding of their needs and interests. In addition, such skills would benefit the students in their future professional careers, especially in the model making industry. The information gathered about the product through modelling can prevent costly initial outlays of time, money and resources.

REFERENCES

1. Archer, B., *As Complex as ABC*. In: Modelling: the Language of Designing. Loughborough: Loughborough University of Technology (1992).
2. Hallgrimsson, B., *Prototyping and Model Making for Product Design*. United Kingdom: Laurence King Publishing (2012).
3. Kelley, T., Prototyping is the shorthand of innovation. *Design Manage. J. Summer*, 35-42 (2001).
4. Evans, M., Model or prototype which, when and why? *Proc. IDATER Conf.*, Loughborough University (1992).
5. Cottis, J., *Product Modelling*. United Kingdom: Oxford University Press (1991).
6. Field-Smith, D., GCSE Resistant Materials Technology for OCR (2002).
7. Kojima, T., *Models and Prototypes. Clay, Plaster, Styrofoam, Paper*. Graphic Publishing Co. Ltd., 2, 37 (1991).
8. Dominick, P.G., *Tools and Tactics of Design*. John Wiley; the University of Michigan (2001).
9. Baynes, K., *The Ethics of Representation*. In: Modelling: the Language of Designing. Loughborough: Loughborough University of Technology (1992).
10. Knoblaugh, R.R., *Model Making for Industrial Design*. New York: McGraw-Hill (1958).
11. Powell, D., *Presentation Techniques*. London: Macdonald (1990).
12. Hasdogan, G., The role of user models in product design for assessment of user needs. *Design Studies*, 17, 19-33 (1996).
13. Terstiege, G., *The Making of Design. From the First Model to the Final Product*. Birkhauser Berlag (2009).
14. Zainal, Z., Case study as a research method. *J. of Kemanusiaan*, 9, January, 1-6 (2007).
15. Yin, R.K., *Case Study Research, Design and Methods*. Newbury Park: Sage Publications (2003).
16. Baxter, P. and Jack, S., Qualitative case study methodology: study design and implementation for novice researchers. *The Qualitative Report*, 13, **4**, 544-559 (2008).

BIOGRAPHIES

Keiphe Nani Setlhatlhanyo is a lecturer in product design at the University of Botswana, Gaborone, Botswana. She received her BDes (design and technology) from the University of Botswana and her MA (product design innovation management) in 2011 at Nottingham Trent University in the United Kingdom. Her research interests include traditional knowledge (TK) and design, design related aspects of innovation process, integrating TK into the design process.

Sekao Junior Motshubi is a lecturer in product design at the University of Botswana, Gaborone, Botswana. He has a BDes in secondary education, and design and technology from the University of Exeter (UK), as well as a Masters in educational studies from the University of Newcastle (Australia). He specialises in areas of material technology and process, and model making.

Patrick Dichabeng is a lecturer in product design at the University of Botswana, Gaborone, Botswana. He has a BDes in design and technology education, and received his MSc (integrated product design) in 2011 at Delft University of Technology in the Netherlands. He specialises in areas of computer-aided product design, rapid prototyping and design automation.