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Additive Manufacturing-3D Printing in Product Design Education: Learning experiences using Fused Deposition Modeling (FDM)

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Abstract
This research on the participation of industrial design students' experiences in 3D printing and 3D modelling demonstrates that they are successful in fully utilising additive manufacturing in the design process and as a final fabrication method in the product design area. The project begins with the literature review, prototyping tests, and students' participation in 3D modelling in the specific subject of industrial design. The outcome shared a guideline for how to use Rapid Prototyping (RP) 3D Printers in the model-making and prototyping processes. The result was an example of a design project practice that was made by modelling and then printed with 3D printing.

Keywords: 3d Printing, Product Design, Fused Deposition Modeling

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1.0 Introduction

The advanced technologies that are taking place at the beginning of the 21st century have the potential to change the process, the design, and the manufacturing of final products or prototypes. Usually, product designers have been the ones responsible for developing new products, resolving problems with manufacturing, and meeting the standards that are design-related. However, advanced technologies not only makes it possible for designers, but it can also be used by individual consumers or students to create new and one-of-a-kind products based on enhanced software capabilities and different types of manufacturing technology. Fused deposition modelling, more commonly known as 3D printing, and additive manufacturing, its close equivalent, are both examples of digital fabrication technologies that are gradually creating changes in the industrial sector. This study aims to discuss the use of fused deposition modelling (FDM) and present the initial results of the insertion of the 3D printing technology into the processes of the industrial design students in one of their product design model-making processes. Additionally, this study will present the initial findings of the introduction of the 3D printing technology into the processes of the industrial design students.

Fused Deposition Modeling (FDM) is a technology that will be implemented in the fabrication of one product that will be developed by each student. The research methodology included a literature review of each user's use, functional prototypes tests, and students' participation in 3D modelling from other subjects or courses related to industrial design as a guideline in model-making processes for prototyping processes using Rapid Prototyping (RP) 3D Printers. As a result of this, it is essential to conduct an analysis into the current state of research about the application of 3D printing in learning environments. Students who are engaged in higher education institutions

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are considered to be part of the education system for the purposes of this study. The paper is more focused on the application of 3D printing to educational experiences than on research. However, the research does not take into consideration the implementation of 3DP inside an industrial setting for the purpose of educational purposes.

1.1 Aim and Objectives of The Study

The purpose of this study is to determine the value of 3D printing knowledge in the product design process for Diploma in Industrial Design students at UiTM Kedah. To keep track of the research process, the researcher has also written down two research objectives.

- To assess students' knowledge and understanding of the process of producing product parts using a 3D printing machine (FDM).
- To explore how 3D printing might be included in the development of innovative designs for products.

1.2 Limitations and Scope

This research was done as part of a product/parts design project, with the participation of industrial design students with experience in 3D printing and 3D modelling, in order to fully utilise additive manufacturing in the design process and as a final fabrication method in the product design area.

2.0 Literature Review

2.1 3D Printing overview

3D printing is an additive manufacturing method that transforms a digital model into a physical object. 3D printing has even been designated as the Third Industrial Revolution of manufacturing, changing how we design, fabricate, transport, and store products (Barnatt, 2013). An important part of this research is for students to get hands-on experience with 3D printing and understand how fused deposition modelling (FDM) makes it possible to think of and create new shapes in product design development. It also lets students evaluate and redesign a product based on how well it fits, looks, and works based on a quickly made 3D printed product. The results, on the other hand, show how important it is to know about and have experience with 3D printing and 3D modelling in order to use fused deposition modelling successfully in design modelling and as a final fabrication method in product design. According to James Carroll (founder of the Northern New York Robotics Academy), 3D printing technology is revolutionising education at the academy, providing students with extraordinary levels of motivation and the opportunity to exercise their imaginations while also practising skills that will serve them in the future in an exciting new way (John Dogru, 2015). It used to be mostly used for making prototypes, but now it is one of the ways that final products or prototypes are made and models are made. But the technology is already here, and it's only getting better. So, giving designers and other people a well-researched list of 3D printing's current uses, benefits, drawbacks, and possible future uses will help them make smart choices about how and when to use it in their design process and as a final fabrication method (Kurman & Lipson, 2012). With any tool or technology, education is the key to success, and 3D printing is no exception. The Third Industrial Revolution of manufacturing, which 3D printing represents, is transforming how we create, manufacture, transport, and store goods (Barnatt, 2013). However, a lot of professionals believe that the major issue with this technology is that users don't know when to use it (Miners, 2013). According to Chip Bobbert, who works as a Digital Media Engineer at Duke University, says that hope not only gives students motivation, but also makes them think about problems and solutions in new ways. This kind of technology can change how students see the world, and now is the time to take advantage of it. (John Dogru, 2015).

2.2 3D Printing Education

Students in Malaysia's education are now learning how to use free, simple programmes like Solidwork and Rhinoceros 3D modelling software, which can produce 3D models, and are being taught to think in 3D, much like how to use Microsoft Word at an early stage. Furthermore, CAD software and 3D printers are becoming more geared toward meeting educational needs, particularly in the field of industrial design because these students are the future of designers, artists and educators can explore their students' creative thinking in producing more complex designs (Dogru, 2015).

On top of that, a growing number of organizations are utilising rapid prototyping technology, particularly 3D printing, to realise some of the benefits outlined in Table 1. Educational objects, prosthetics and orthotics, safety-critical aerospace components, hearing aids, dental implants, hip and knee implants, jewellery, wearables, sportswear, toys, and food are among them. The list of applications grows as designers and entrepreneurs discover new ways to use the technology as its performance improves.

Advantages	Challenges
● Direct manufacture from 3D CAD models ensures that no tools and moulds are required, hence there are no switchover costs ● Designs in the form of digital files can be easily sha red, facilitating the modification and customisation of components and products	● Cost and production efficiency ● Modifying how designers approach and think about the usage of additive manufacturing ● eradicating the idea that additive manufacturing (AM) is only suitable for fast prototyping and not for direct component and product manufacture ● New material development and standardisation

● The additive aspect of the process enables material savings, as does the possibility to reuse waste material (i.e. powder, resin) not used during fabrication (estimated at 9598%recyclability for metal powders) ● Novel, complicated structures, such as freeform enclosed structures, channels, and lattices, are possible ● The porosity of the finished pieces is exceptionally low. ● Making to order reduces inventory risk, with no uns old finished goods, while also improving revenue fl ow as goods are paid for prior to being manufactur ed ● Distribution allows direct engagement between local consumers or clients and producers. ● Small batches of customised products are economi cally attractive relative to traditional mass productio n methods	● Validation of the mechanical and thermal properties of e xisting materials and AM technologies ● creation of systems with multiple materials and colours ● Automation of AM systems and process planning to impr ove manufacturing efficiency ● Postprocessing is frequently necessary. This might be as a result of the stair-stepping effect that results from adding layers one at a time, or because finishing layers are required. ● Because support structure materials cannot be recycled, they must be kept to a minimum using sound building principles. ● difficulties with intellectual property, especially copyright

Table 1. Advantages and challenges of additive manufacturing (Ford and Despeisse, 2016)

However, student awareness of this 3D printing technology should be investigated. This is due to the fact that this 3D printing technology is being introduced to Diploma in Industrial Design students for the first time. In this regard, they must understand how to produce production parts using 3D printing machines step by step. As a result, educators must assess their understanding of the principles of the 3D printing process.

Therefore, this 3D printing technology is not only for the engineering elite, but it is widely used and easily accessible in the education system. Students represent the frontier of future designers who have influenced the path of the industry. Hence, when students learn how to create a product that satisfies the restrictions of 3D printing, they also learn that this technology can open the door to unlimited possibilities (Dogru, 2015).

3.0 Methodology

3.1 Description of methodology

This study will use the quantitative method to answer research question (1) because it focuses on fact-finding, evidence, and recording that will be used to test or verify theory with primary data and reliability (Creswell, 2003). As a result, more accurate data on the percentage can be obtained, as well as data to justify the data in relation to participant comprehension. The structured questionnaire surveys will be applied to the required percentage for the finding in this quantitative method phase.

Aside from that, the observation survey method will be used to answer the research question (2). The researcher will observe the construction of producing product using a 3D printing machine in this method, which can be divided into three phases: Phase 1 (Idea in 2D sketches), Phase 2 (3D modelling software) and Phase 3 (Product 3D printing – the implementation of final 3D printing part into final product model). Each phase of the methodology is expected to contribute to the design development process of the evolving technology of 3D printing, as well as to an understanding and experience of the impact of this technology on students in their design and fabrication as part of the model-making process.

3.2 Samplings

During the survey, the observation methods used purposeful sampling to choose the people who would take part. This is because, when talking about Bailey (1987), said that purposive sampling is a type of sampling called "judgmental sampling," in which the researcher uses his own judgement to decide which participants are best for the study. So, a Diploma in Industrial Design student at the Faculty of Art & Design, UiTM Kedah, is chosen for this research. This is because this research will be focused on a project that looks at 3D printing as an interactive design tool in product design by looking at Fused Deposition Modelling (FDM) machines in the design process and as a final fabrication method for product prototypes and final models. Also, a Fused Deposition Modelling (FDM) machine has been added to the Faculty of Art and Design. So, it's a chance to find out what the students think about 3D printing. In this case, the students are just beginning to learn about this technology. In the future, when they design products, they will use 3D printing.

4.0 Findings

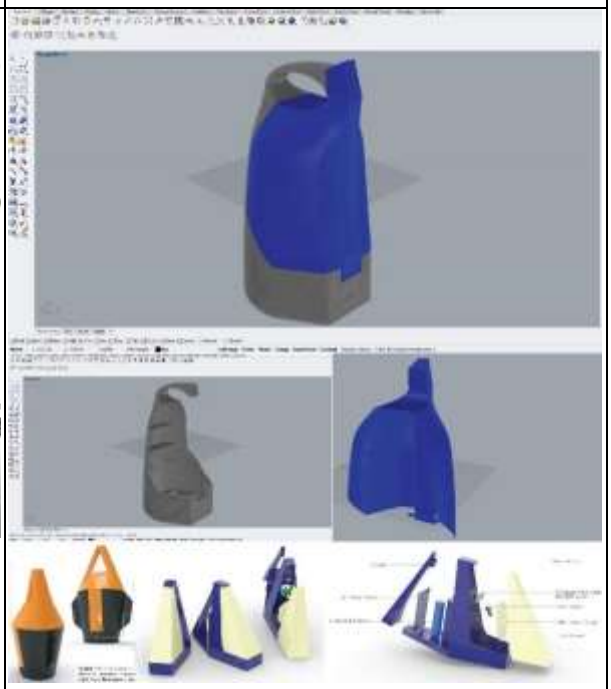
4.1 Ability to Sketch: An Observational Study

During the idea development process, the sketching activity involves an exploration of forms and ideas based on the intent and type of idea manipulation. During the observation, the respondents were students who had completed a task to evaluate their sketching abilities on sketch development ideas. The surveys were carried out by presenting the respondents with a single project brief.

4.2 Assessment of 3D Modelling Skills

Students' performance on the 3D modelling techniques task was evaluated by determining a construction from their sketching activity on idea development based on the method they preferred most. The industrial design students completed the task, which was the portable lighting design project. Students completed the 2-dimensional idea development task while working on an early idea product. It is mostly rough and produced without any additional details. The previous development task was created to explain the design concept's form and structure. A clear sketch on the fundamentals of sketch accuracy on how they do the early concept ideas they develop before moving on to 3D design construction. The question is whether the students use the same technique to generate 3D construction ideas from their sketches.

The results of this project, based on the method described above, are shown in the table below:

Phase 1 (Idea in 2D sketches)	**Phase 2 (3D modelling software)**
 Variations of 2D development sketches generated by selected students during the first phase of the construction idea process.	 The compilation of the 3D project assignment given in the class required students to develop and construct a new and innovative product of their choosing based on their 2D development idea using their selected 3D modelling programmed. (Student used Rhinoceros 3D modeling software)
Phase 3 (Product 3D printing)	

Implementation of final 3D printing into a final product model uses 3D Printers for Rapid Prototyping (RP) in the model-making and prototyping processes

Table 2 Analysis Result - Representative product design process by students

5.0 Discussion

Table 2 shows the analysis results produced by Diploma Industrial Design students. The respondents (students) produced design sketches based on the existing product design process. The results from the observational study indicated that an understanding of the process of producing product details from 2D sketching to 3D modelling construction was gained. Details were added last to understand the details of construction in 3D modelling design later. For the analysis of phase 2, Rhinoceros 3D modelling software was then used to identify new forms. In this phase, students show that they can construct the idea through the early ideation process from 2D development sketches. Once a final design concept was developed, it was decided how the 3D printing process would be integrated into the final design, and full-scale models were printed to test fit, form, and function. During this stage of the third phase design process, 3D printing was used to create concept models, test parts, and generate scaled process and design development models, demonstrating how the final fabrication of a full-scale prototype could be made using 3D printing during the product design phase. Overall, it seemed that students were more comfortable with 3D modelling and understand how to apply 3D printing in their product design process.

6.0 Conclusion & Recommendations

According to the results of this survey, the students who participated had more experience with 3D printing and gained confidence in their use of the technology. Students were able to use 3D printing as more than just a tool for product design fabrication in design education by having an understanding of the experience of using the fused deposition modelling method. 3D printing design experience will aid them in better analysis. Students must understand how the product is constructed from their 2D sketches in detail in order to model with the precision and detail required in the rapid prototyping process using a Fused Deposition Modeling machine when modelling a product for 3D printing (3D Printer).

Another thing they had in common that helped their design process and final results was the use of Rhinoceros 3D software, which has a wide range of commands that help students create complex forms. Their 3D modelling skills, which are essential for using the FDM machine, ranged from skilled student to beginners, but the majority of students considered themselves to be either confident with it or comfortable with at least one 3D modelling software. The plan was for the students to integrate 3D printing technology into the design process, from the initial stages through the final prototype. However, according to student feedback, most were unable to fully utilise the 3D modelling standards because of their lack of modelling skills and knowledge of 3D printing. Although the study's findings are inconclusive, participating students have now been exposed to a new technology that will hopefully influence their future design work, both in design education and as beginning design professionals. This research could assist in creating the significance of 3D printing technology

in the educational system, especially in the creative industry. When compared to other traditional methods, the advantage of using 3D printing as a fabrication method and as a tool within the design process is its ability to manufacture complex objects quickly and efficiently. This resource appeared to be explored by the students during the design process and in the overall design of their newly created products in design education.

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Paper Contribution to Related Field of Study

This paper makes a significant contribution to the fields of study of Industrial Design, Product Design, Design for Manufacturing, Technology, and Additive Manufacturing. This study could serve to establish the significance of 3D printing technology in the educational system, particularly in the design field. Furthermore, students can explore an incredible level of creativity in producing new design ideas that can improve the quality of life.

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