THE VALUE OF PROTOTYPES IN THE EARLY DESIGN AND DEVELOPMENT PROCESS

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Abstract

Prototypes are considered to be efficient tools in engineering design as they help to reveal flaws in ideas and concepts, highlighting problems to be solved. Limited research has been conducted in detail about prototyping activities that have contributed to the increase of designers' ideas in the design process. This study explores the use of prototypes to generate more ideas compared to the designers that were not involve with prototypes in design process. It also investigates how prototypes enhance designers' idea by involving 45 participants in three separate groups in early ideation and concept development process. The aim of this paper is to explore the ability of prototyping to produce creative and innovative ideas in the conceptual phase of design process. Results indicated that the group of participants who were involved with prototypes in their design process produced more amount of ideas compared to the group who did not use it. It also shows prototypes helps designers to generate more creative and innovative ideas .

Keywords: Design practice, Prototypes, Concept Development, Design process

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1 INTRODUCTION

Prototypes have been instrumental over the centuries, in producing innovative representations and forms to connect better with the expectations of different stakeholders (Sanders and Stappers, 2014; Charlesworth, 2007). Hereby, the designer played a key role in shaping representations, which were distributed to non-designers to imagine future objects, future experiences and future ways of living. In the Industrial Design process, physical prototypes have always been used by designers to develop and communicate their ideas (Lafon and Mackay, 2000; Isa and Liem, 2014). However, the introduction of 3D computer modelling software has transitioned 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 (Charlesworth, 2007). On a more careful note, Charlesworth (2007) added that the designer might face greater challenges and limitations when using CAD in early development processes than originally anticipated. Evans (2004) has indicated the possibility that CAD, haptic feedback interfaces and virtual reality may replace physical modelling as tools for design development. However, Charlesworth (2007) claims that virtual reality methods and instruments are merely complementary, whereas physical models and prototypes have proven to be recognized in design industry. In this article, the authors agree with Charlesworth (2007) and Kelly (2001) supporting the existence of physical models and renouncing the dependency on virtual models as a tool for solving design problems. Kelly (2001), strongly recommends that designers should frequently use physical models and prototypes in design process.

Many researchers have extensively discussed the aims, advantages and challenges of using models and prototypes. However, there is a lack of detailed information from existing research about the purpose and the effectiveness of prototypes in design process and how these tools may contribute to enhancing designers´ creativity (Hess, 2012). Some researchers suggested not to use prototypes early in design stages due to building a prototypes that can be expensive, time consuming and only should be used when needed (Dow et. al, 2010; Stowe, 2008; Viswanathan and Linsey, 2009). Others claim prototypes should be used in early design development to develop more communication between stakeholders and designers (Sanders and Stappers, 2014; Kelly, 2001; Charlesworth, 2007; Isa and Liem, 2014). This study will provide evidence on how useful prototypes are in early idea development and concept development processes.

This study focussed on how prototypes are used as supporting tools in design activities. The aim was to argue how prototypes were applied to achieve more innovative and creative ideas. Furthermore, the goal of this research is to investigate how prototyping is being used in idea generation to facilitate the development of early ideas and concepts. This has led to the following hypotheses:

H1: Prototypes increase the amount of ideas in the early ideation and concept development process

H2: More innovative and creative ideas may be generated using physical models in conceptualisation stages of the designing process.

H3: Those, who used prototypes, developed a clearer understanding of form, function and construction compared to those who did not do.

H4: Selecting appropriate prototypes accelerated the idea generation phase and increased the amount of ideas, being developed.

2 EXPERIMENT SET UP

2.1 Participants Selection

45 Participants took part in this study, which comprised of 2 assignments: early idea generation and idea development process. 36 of them were undergraduate students, recruited from the Industrial Design Department, University Technology of MARA, Kedah, Malaysia. 9 Participants were practicing industrial designers having consumed already 2-12 years Industrial experience. The total number of females in this study were 16 (35.6%), and age range of the participants were between 19 – 35 years old. All participants were randomly invited without knowing what their tasks were. In other words, they were recruited on the basis that they are unprepared to elicit spontaneity during the experiment.

2.2 Group Selection

The participants were divided into three groups using different tools in each task of early ideation and idea development tasks. Group 1 and group 2 used prototypes in the early idea generation and idea development tasks given, whereas group 3 was not allowed to use prototypes in any tasks. Group 1 started the early ideation process using sketches followed up with low-fidelity prototypes to deepen out certain pre-selected ideas. Group 2: used prototypes immediately in the early ideation stages and continued with digital software in the further development of idea. Group 3: started early ideation with digital software and continued with idea development using sketches. Each group consists of 15 participants, randomly pick 12 participants from group of student and 3 participants from group of designer. (see figure1)

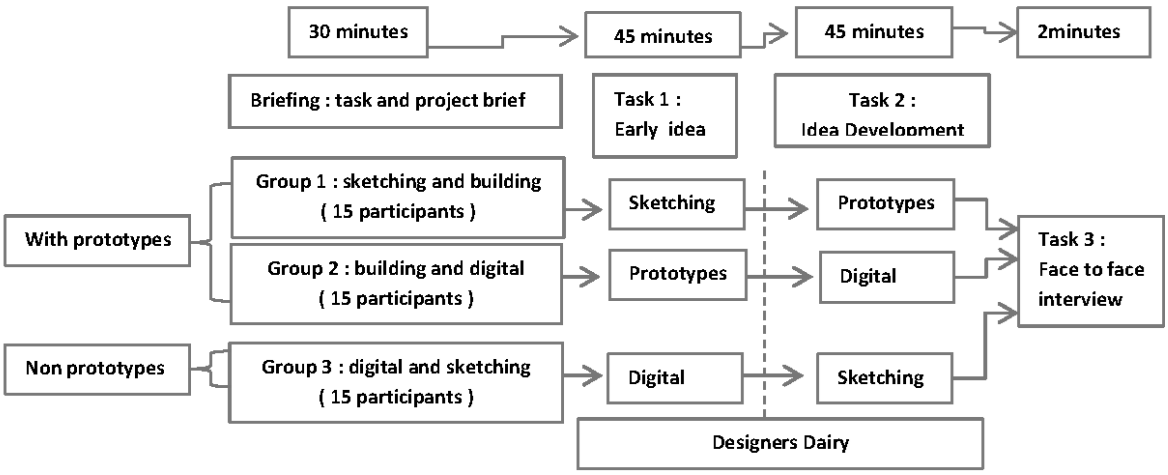

Figure1: The process during the experiment

2.3 The design process

2.3.1 Preparatory steps (30 minutes)

In this introduction and briefing session, background information of the participants were collected. The facilitators verbally explained the project brief and the rules for completing the tasks. All participants were given a set of materials and tools, and were told they could get extra materials and tools if needed. In this phase, the participants were divided into 3 groups randomly (12 students and 3 designers) as shown in figure 1. The next activities involved designing a convertible stool that can be converted to multiple different shape and use.

2.3.2 Early Idea development (45 minutes)

At this stage each participant were performed the task given on to create a range of early ideas using sketching for Group 1, prototypes for Group 2 and digital software for Group 3.

2.3.3. Idea development process (45minutes)

In this phase participants elaborated on the early ideas, which were proposed in the previous stage using a different design tool. In this phase, Group 1 was assigned to use prototypes, Group 2 continued with digital software, and Group 3 used sketches to follow up on their digital design results.

2.3.4. Face-face Interview (maximum 5 minutes)

At the end of the idea development task, individual interview was conducted with the participants to review the task. Facilitators were asking them to comment on the experiences during the design process. Specifically, they were requested to reflect on the processes, which enhanced their critical thinking and creative activities.

2.4 Workspace

The experiment was conducted in Industrial Design Department studio at the respective University Technology of MARA. There were 4 design studios used for this experiment and each of the participants have their own individual separate workspace. The layout arrangement was set up as a classroom style. (figure 2)

Figure 2: Workspace for the experiment

2.5 Provided Materials

Complete list of materials and tools during the process:

Table 1: List of material provided

	Tools	Material
Sketching	Pencil, pen and marker	Paper
Building	Cutter, Scissors, Masking tape, Glue	Boxboard, mounting board, rope, modelling clay, sticks
Digital	Participants were bringing their laptop	

2.6 Data analysis method

The method developed in this study was adapted from the analysis methods proposed by Dermican and Yasemin (2011), Viswanathan and Linsey (2009) and Dow et. al, (2009). The participants were asked to comment on their design process, before, during and after the workshop in a diary, which was given to each of them. Facilitators kept observation notes and took pictures during the design process. The output of the design process was recorded for later analysis. All data were analysed and reported separately in this study. However, the researcher mainly concentrated on a specific segment of the data as well as relevant expert reviews, which reflected in this data.

2.6.1. Analysis on the amount of ideas

The number of ideas was evaluated by 2 expert with Industrial Design background to check the quality of the design produced by the participants. They counted the ideas generated by each of the participants based on the quality and completeness of each representation.(figure 3)

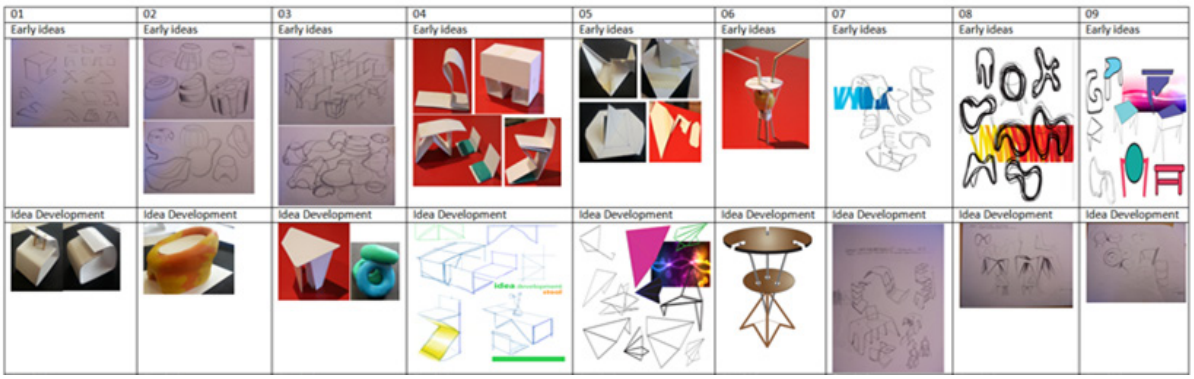

Figure 3: Example of analysis - the ideas produced by participants

2.6.2. Analysis on the on interview

Each interview was videotaped and transcribed, including the scripted question. The analysis was based on the selection of keywords from the transcripts regarding participants' reflection during the whole process.

2.6.3. Analysis on the expert review on the ideas

In order to assess the participant's idea, this study appointed four experts with 2-20 years experiences with an Industrial Design background to measure participants' ideas. Four elements were identified for the expert to review. These are: (1) innovativeness of the ideas (2) functionality, (3) problem-solving quality and (4) creative ideas. The experts were asked to evaluate the total of 90 ideas (45 early ideas; 45 ideas development) on a 5-point Likert scale (1=Very poor; 2= Poor; 3=Average; 4=Good; 5=Excellent).

3 RESULTS

This study supported all four hypotheses mentioned in the earlier part of this paper.

3.1 Result 1: Prototypes increased amount of ideas in design process

Figure 4 shows the quantity of ideas produced by the three groups with respect to the tools they have been using. Group 1 who involved with sketching and prototypes produced 76 (35%) of total ideas. Group 2 who immediately involved with prototypes and digital software produced 82(38%) of total ideas, compared to Group 3 who are not allowed to use prototypes in any tasks only produced 58(27%) of total ideas. This result shows that participants who used prototypes in their design process will produce more amount of ideas compared to the participants who do not use prototypes in their design process. This result supported H1 and aligned with Viswanathan and Linsey (2009) findings that using physical prototypes in idea development produced more useful ideas.

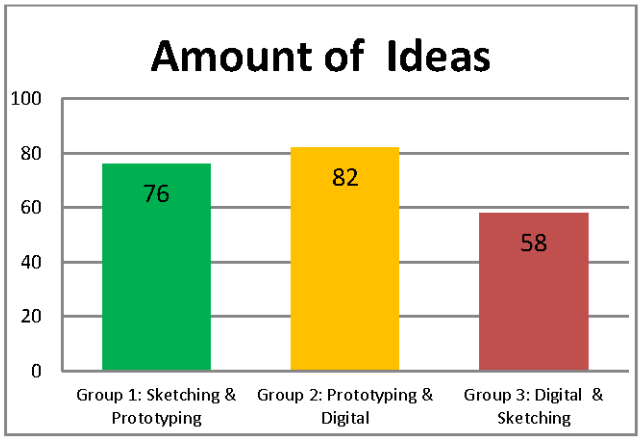

Figure 4: The amount of total ideas from three groups

3.2 Result 2: Prototypes increased number of innovative and creative ideas in early ideation and idea development process

This result compares the quantity of innovative and creative ideas produced by both design process, the early idea and idea development from all groups. The result shows in figure 5, for early idea development Group 2 (Building & Digital) that involved with prototypes were producing higher number of ideas 56(45%) compared to the group that used sketches(Group 1) and digital software (Group2). The same goes with the result of idea development tasks shows the similar outcome, Group 1 that involved with prototypes produced more ideas 36 (39%) compared to the group used sketching (Group 3) and digital software (Group 2). This is consistent with Steffany's (2009) research result which indicated that prototypes are one of the greatest assets in inspiring, developing and improving designers ideas in early phase of conceptual design. In support of H1 and H2, being involved in modelmaking at an early stage, may enhance the designer`s critical understanding of the design process and experience with experimentation and design decision making.

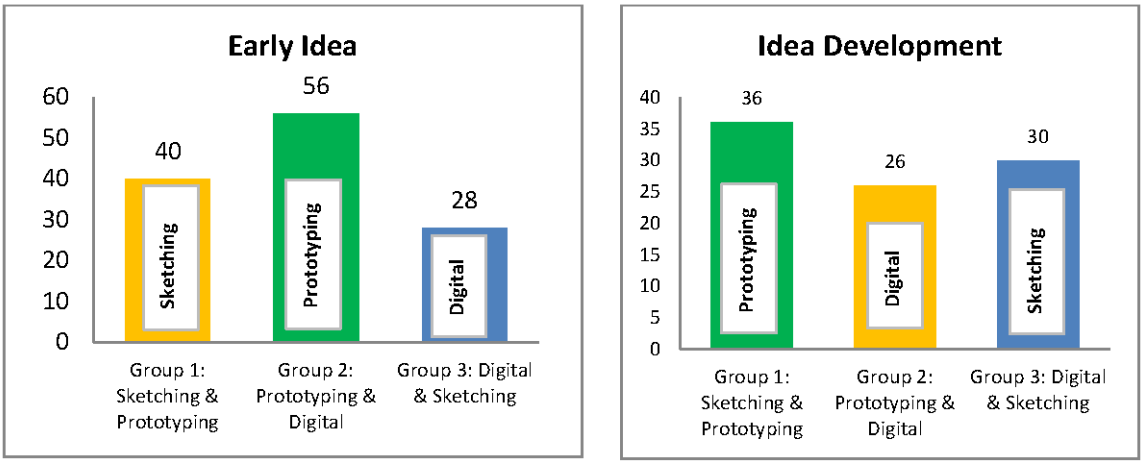

Figure 5: Total of ideas for early idea and idea development tasks

3.3 Result 3 : Expert Rating

Top expert ratings for innovativeness of the ideas, functionality, problem-solving quality and creative ideas were given to the groups that used prototypes during the early idea generation and consecutive idea development activities (see figure 6). For early ideation, Group 2 who used prototypes during early ideation, scored the highest point of 182/225 (overall rating 3,15=Average). In idea development tasks, Group 1 who used prototypes for ideas development scored the highest point of 188/225 (overall rating 3,10= Average). In support of H2 , similarities can be found in Viswanathan and Linsey's (2009) experiment, which also demonstrated that creating appropriate physical prototypes during early ideas and idea development enhances designer´s innovative and creative capabilities at a micro-level of idea generation and conceptualisation. This result also supported H3, which prove that prototypes are a powerful tools for designers to experience with shape, gain clearer understanding of design problem, experiment with form, material and context before moving on to the next stage.

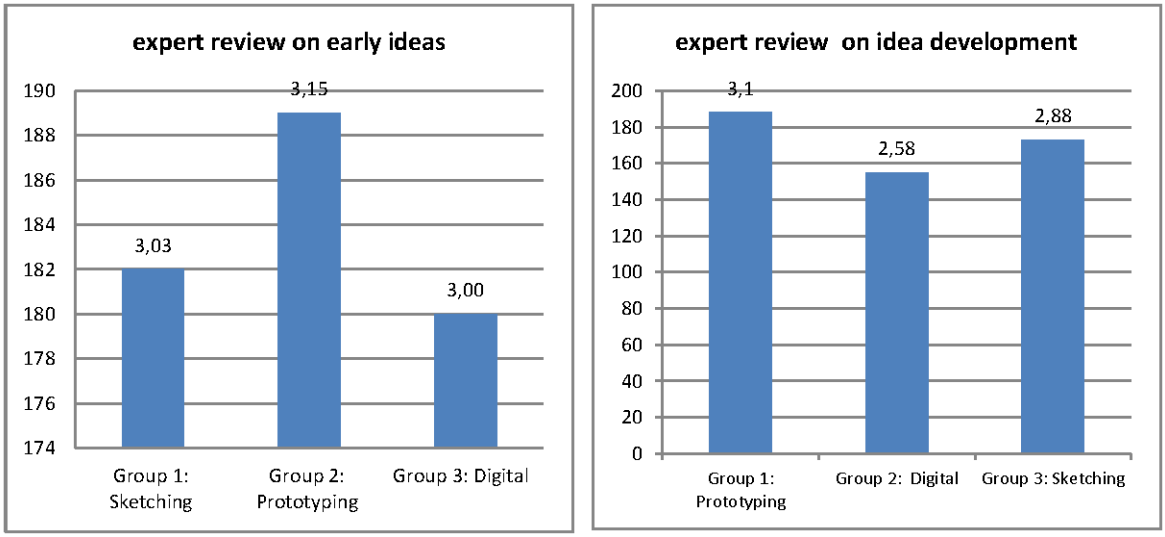

Figure 6: Experts evaluation on the innovativeness of the ideas, functionality, problem-solving quality and creative ideas.

3.4 Result 4: Prototype is one of the fastest medium in generating early ideas and idea development

The result in figure 7 shows the average time spent on prototyping in both design process (early idea and idea development) are most efficient compared to the groups that used digital software and sketching for generating ideas. The average time for participants in Group 2 using prototypes during early ideation to produce one idea were 0,8 minutes (>1) . Whereas, the average duration spent by

participants in Group 1 produced ideas using prototypes during idea development were 1,25 minutes(<1). Furthermore in support of H4, results also refuted the statement of some researchers who suggested not to use prototypes early in design stages, because building prototypes could be too time consuming and only should be used when needed.

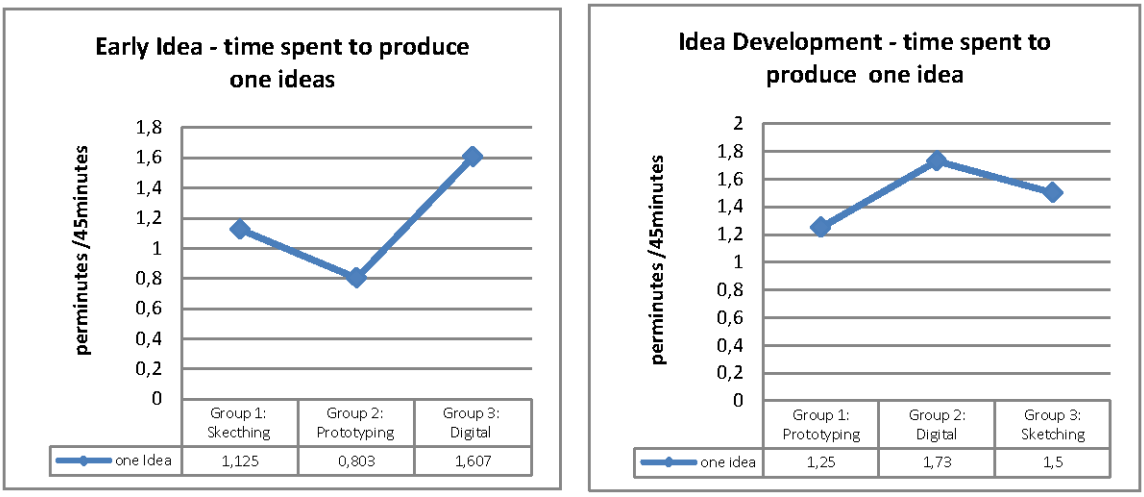

Figure 7: Time spent to produce one idea in early idea and idea development process

4 DISCUSSION

The use of prototypes in early design stages is often not recommended by many researchers because of time constraints, cost and design fixation. However, the results from this study show that prototypes are most valuable to be used in early ideas and idea development process. Therefore, it is recommended that designers should use prototypes extensively and as early as possible in order to plan the design process more accurately in terms of focal areas, expected user involvement and cost estimations for the final design as well as related prototyping and pre-production activities. In particularly, the iterative use of low fidelity (soft) models in the early design stages, highlights key design problems more thoroughly, and enlarges the creative space for generating design solutions in a more cost effective manner. By appropriately using physical models in early idea generation and idea development activities, it can help the designers to evaluate and fine-tune their final design as well as confirm certain critical requirements. The use of prototypes will help designers in broadening their thinking processes and make them conscientious that divergent and convergent design practices should not be overlooked in these early ideas and idea development stages of designing. From the results, it is proven that designers who use physical model as a tool in early idea and design development stages of their design process will gain a clearer understanding of form, function and construction as compared to designers who did not do it. However, there is a tendency that designers prefer to develop their designs mainly through sketches, renderings and 3D computer models rather than being hands-on engaged in prototyping, especially when it concerns the early stages of the design process. They believe that constructing models can be expensive and time- consuming, and do not see that exploring the solution space through appropriate models and prototypes will actually enhance rather than compromise their cognitive design capabilities, especially during the early stages, where design solutions are required. It is therefore encouraged that designers allocate time and effort to study the purpose and value of the different types of model and prototypes with respect to exploring "creative spaces" in the early ideation and design development stages instead of focussing too much on 2-D visualisation tools.

The goal of this study is to investigate the value of prototyping in early ideation and idea development. This was done through experimental research on the influence of the use of low fidelity prototypes to increase the number of ideas in the design process. This paper provides evidence that prototypes have been shown to support idea generation, to evaluate early ideas and to solve design problem. However, the research found that additional studies with more structured research process involving skilled designers should be conducted. Limited number of skilled designers may have implications for

general conclusions for this study. It would be interesting to conduct large-scale analysis and to replicate this study in a variety of setting.

5 CONCLUSION

This paper provided insight on how building extremely quick and inexpensive prototypes accelerated the idea generation phase and increased the amount of ideas, being developed. From the results, it is proven that using physical prototypes produce more valuables ideas in a more efficient manner. Further research is needed to indicate that prototypes are proven to be indispensable tools for designers to create innovative and creative ideas. This study will further expand to investigate whether by making physical model during early idea generation and idea development stages can help designers to visualise and solve complex product and system design problems.

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