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Exploring Idea Generation of Parametric Concept on Industrial Product Design

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Abstract
This research explores the use of parametric design tools, specifically Rhinoceros and Grasshopper, during the early stages of idea generation in industrial design education. By analyzing students' cognitive behaviors through experimental protocol analyses, the study aims to identify effective methods and measures for enhancing the conceptual design process. The focus is on improving the influence of sketching and digital tools in generating creative solutions. Results are expected to provide insights into the efficient use of parametric tools, streamlining the design process and enhancing the quality of design outcomes in education.

Keywords: 3D Modeling, parametric, ideation, product design

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1.0 Introduction

The ideation stage is a central aspect of the industrial design process that creates a foundation for the formation of creative and innovative designs. In industrial design, ideation is vital in creating unique and effective solutions to complex design challenges. At this stage, industrial design students and professionals use various methods, sources of inspiration, and creative approaches to produce deep design concepts. The ideation process involves deeply understanding technical aspects, ergonomics, aesthetics, and user needs. This involves exploring sources of inspiration such as existing product designs, nature, and the latest technology. In addition, industrial design students and professionals also need to overcome challenges in expanding their vision, finding a balance between function and aesthetics, and applying lateral thinking to achieve uniqueness in design concepts. As such, this study digs deeper into the ideation stage in industrial design by focusing on the various aspects involved in this process. This study will provide insight into the strategies used by students and professionals to face challenges during ideation, as well as produce designs that positively impact industry and daily use. Nevertheless, it is hoped that the results of this study will provide valuable guidance to the industrial design community in encouraging innovation and creativity in the ideation process (Hossam Eldin et al., 2021). (Darmawan, 2021).

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1.1 Process, Protocol and Tools for Idea Generation

The industrial design sketching method visually demonstrates the functionality, various part designs, and aesthetic representations of a product from multiple perspectives. Sketches play a crucial part in the product design process by facilitating conceptualization and aiding in identifying and preventing design flaws. Moreover, they serve as a first step prior to transitioning to more advanced (three-dimensional) 3D modeling software for the finalization of the design. Sketching is an innovative form of visual communication employed by designers to propose, explore, revise, and effectively express their ideas. Note that the early phases of product development are essential to a product's success, and time consuming adjustments should be avoided in later phases. Accordingly, this paper explores an innovative parametric approach for generating concept solutions in the form of drawings during the earliest stages of product development.

This research explores the use of parametric design tools, specifically Rhinoceros and Grasshopper, during the early stages of idea generation in industrial design education. The objectives of this study are to explore the potential of parametric design tools in guiding the idea generation process in industrial design education.This approach will help us understand how students interact with these tools, how they influence their creative thinking, and what measures can be taken to improve the process. By analyzing students' cognitive behaviors through experimental protocol analyses, the study aims to identify effective methods and measures for enhancing the conceptual design process. The focus is on improving the influence of sketching and digital tools in generating creative solutions.

The initial phase of design, often referred to as the idea generation or conceptual phase, is crucial as it sets the foundation for the entire design process. During this stage, students brainstorm, sketch, and explore various possibilities prior to narrowing down their ideas to the most promising ones. Despite the abundance of resources available online and the vast array of existing product designs that students can study, there is a noticeable lack of structured approaches or frameworks to help them systematically generate and refine their ideas.

One of the main challenges in this context is that while digital tools and online resources provide a wealth of inspiration, they can also be overwhelming. Without a clear strategy, students may struggle to sift through the vast amount of information and effectively integrate it into their design process. This can lead to a scattered approach where potential ideas are not fully explored or developed.

Furthermore, traditional idea generation methods, such as sketching and physical prototyping, still play a vital role in the design process. However, integrating these traditional methods with digital tools and resources is not always seamless. Therefore, students need guidance on how to balance and blend these approaches to maximize their creative potential.

Despite their potential, the effective use of parametric design tools in the early stages of the design process is not well documented or widely understood in the context of industrial design education. There is a need for research that explores how these tools can be integrated into the idea generation phase to enhance creativity and efficiency.

This research will provide valuable insights into the effective use of parametric tools, offering practical guidelines for educators and students. Notably, by understanding the interplay between traditional sketching methods and modern digital tools, we aim to enhance the overall design process, making it more efficient and effective. The results are expected to inform best practices in industrial design education, ultimately helping students generate more innovative and well developed design solutions and to provide insights into the efficient use of parametric tools, streamlining the design process and enhancing the quality of design outcomes in education.

In conclusion, while industrial design students have access to a wealth of inspirational sources, there is a pressing need for structured approaches to guide their idea generation process. This research seeks to bridge this gap by exploring the role of parametric design tools in early stage design, aiming to enhance creativity, efficiency, and the quality of design outcomes in educational settings.

2.0 Literature Review

In industrial design, parametric design and digital technologies have become increasingly vital. The rise of digital tools has sparked interest in exploring an all digital curriculum for undergraduate and graduate programs. Caetano et al. (2020), emphasized the theoretical and practical potential of parametric tools in enhancing creativity, particularly in design environments that benefit from flexibility, customization, and real time feedback. According to Caetano et al. (2020), also emphasizes that parametric design enhances abstraction, promotes systems thinking, and enables designers to externalize logic and relationships visually. This focus on educational integration and design pedagogy makes the work a valuable contribution to bridging theory with instructional application. According to Sawatmongkhonkul, (2024), the study successfully demonstrated how parametric tools, particularly in design software like Grasshopper and Rhinoceros, can facilitate innovative outcomes by allowing designers to make real time modifications and adapt products to diverse user needs. J.D. Camba et al. (2018) highlighted the significance of digital sketching technology in supporting industrial design ideation. In concequences, this study show how designers adapt to and utilize digital tools and how early exposure to these technologies influences industrial design education. Li, Pan, Bousseau, and Mitra (2020), particularly relevant in educational and early design contexts, as it offers a model for integrating analog and digital workflows. By maintaining the natural fluidity of sketching and enhancing it with computational interpretation, the system supports iterative idea generation and rapid prototyping, key components in industrial design education. From that, during the early stages of ideation, students should attempt to generate their own ideas and develop them in relation to the parametric design method.

2.1 Parametric Grasshopper 3D Modeling

Grasshopper is an advanced parametric modeling tool that integrates with Rhino to provide a new, powerful, and effective design process. Grasshopper is a plug-in that comes with Rhino and contains several plug-ins. The software industry never sleeps. However,

recent years have accelerated the development of this trend, spreading the use of digital technology. This affects how we want to experience their presence in design studies, emerging phenomena and future product design trends.

Along with the latest trends and the results of this study, industrial design students can employ this parametric design study as one of the methods of ideation formation prior to proceeding to the design concept process. This is a new method that industrial design students will practice. The research map focused on the fundamentals of parametric design through Idea Generation Exploration (IGE) in product design to translate the ideation for the early stage into parameter relationship ranges using digital software tools (Grasshopper/Rhinoceros/3D software). Industrial Design students generate ideas in a single session and then use parametric design to transform these ideas into alternative designs.

2.2 Research Gaps and Conclusion

Parametric design, a popular concept in architecture and furniture design, has not been extensively studied in industrial product design. The existing literature mainly focuses on technical aspects like algorithmic processes and software capabilities. Nevertheless, there is a need for further research to understand how parametric strategies can be optimized for industrial designers' ideation processes and support mass customization in consumer products. Additionally, understanding the decision-making processes of designers working with parametric tools can provide insights into the cognitive aspects of idea generation. This understanding can guide designers in effectively incorporating parametric methods into their creative workflows. Moreover, by addressing these gaps, future research can enhance parametric design practices and align them more closely with industrial product design demands. Furthermore, by exploring various parameters and rules, designers can generate diverse forms, promoting creativity and fostering mass customization. Therefore, further research is necessary to deepen our understanding of how parametric design influences idea generation, particularly in the industrial design context.

Table 1

Author	Year	Title	Method	Key Findings
Ju Hyun Lee et al.	2013*	Exploring Design Strategy in Parametric Design to Support Creativity	Case studies and analysis of parametric design strategies	Identified strategies for enhancing creativity in parametric design, emphasizing the role of rules and constraints in fostering innovation.
I. Caetano et al.	2020	Defining parametric, generative, and algorithmic design	Literature review and taxonomy development	Provided a comprehensive taxonomy of computational design terms, highlighting the potential of parametric design in idea generation and innovation.
Y. Sun et al.	2018	A Look at the Research on Design Idea Generation in Industrial Design: Literature Review from 2003 to 2017	Literature review	Analyzed the state of research in idea generation for industrial design, identifying trends and future research directions.
A. García-Dominguez et al.	2020	Integration of Additive Manufacturing, Parametric Design	Development of design methodology	Explored the synergy between additive manufacturing and parametric design, highlighting its role in optimizing product parts.
K. Sawatmongkhonkul	2024	Exploring Parametric Concepts and Principles for Furniture Design	Experimental design and case studies	Demonstrated how parametric design facilitates innovative furniture design, emphasizing real-time modifications to adapt to user needs.

Table 1 summarizes studies on the idea generation of parametric concepts in industrial product design. Ju Hyun Lee et al. (2013) explored how rules and constraints within parametric design can drive innovation. Meanwhile, Caetano et al. (2020) comprehensively analyzed computational design terms, such as parametric and generative design, and their applications in idea generation and product innovation. At the same time, Sun et al. (2018) reviewed the literature on idea generation in industrial design, highlighting areas requiring further exploration. In addition, K. Sawatmongkhonkul (2024) applied parametric principles to furniture design, highlighting the adaptability of parametric concepts in real-time design modifications. Accordingly, these studies highlight the evolution of parametric design thinking in industrial product design and the need for continuous exploration.

3.0 Methodology

3.1 Research Design, Population, Sample Size, and Sampling

This study adopts a qualitative research design to explore the idea generation processes of Industrial Design students at Universiti Teknologi MARA, Kedah Branch (UiTM), using parametric design tools. The qualitative approach is preferred as it fully explains how participants engage with design tasks, focusing on their experiences, thought processes, and interactions. As research design determines how data is collected and analyzed, the qualitative nature of this research emphasizes subjective understanding, making it ideal for exploring creative processes like idea generation.

3.2 Sampling

This study employed a purposive sampling technique to recruit a sample of Industrial Design students from UiTM. Purposive sampling is effective in qualitative research as it ensures the recruitment of participants directly relevant to the study's objectives. In this case, the students were selected based on their involvement in parametric design coursework, ensuring they had the necessary experience with

design software and ideation processes to provide meaningful insights. The sample size was small to allow for detailed observation and analysis, reflecting the qualitative approach.

3.3 Observation and Analysis

This study adopts Verbal Protocol Analysis (VPA) as the primary research method due to its effectiveness in capturing the real time cognitive processes involved during idea generation in industrial product design. VPA enables participants to verbalize their thoughts while engaging in a design task, offering direct insight into their reasoning, decision making, and interaction with parametric design tools such as Rhinoceros and Grasshopper. This method is particularly suitable for examining design cognition, as it provides a detailed understanding of how students navigate between traditional sketching and digital modeling during the early stages of concept development. Other common methods such as interviews and surveys were considered but ultimately not selected as primary approaches. While interviews are useful for exploring participant reflections after the design activity, they rely on retrospective recall, which can introduce memory bias and omit spontaneous thought processes. Here, participants were provided project briefs that required them to engage in the conceptual design phase, focusing on parametric tools to generate ideas.

Following the distribution of project briefs, focused group sessions (focus group 1+1) were conducted to collect qualitative data on the students' thought processes. This group based approach encouraged interaction and discussion among participants, helping to reveal collective and individual ideation patterns.

4.0 Findings

The findings revealed valuable insights into how students navigate the idea generation process while utilizing parametric design tools. First, the VPA technique demonstrated that students typically begin with traditional sketches to conceptualize initial ideas prior to transitioning to more advanced parametric tools. Note that this transition was often iterative, with students revisiting their sketches to refine their designs based on the parametric software's capabilities.

Furthermore, the analysis of the video recordings suggested that parametric tools not only facilitated idea generation but also challenged the students to think critically about their design constraints and possibilities. The tools offered a structured yet flexible environment where students could experiment with various forms and configurations without the limitations of traditional sketching methods. As such, this interaction with parametric tools was essential in helping students push the boundaries of their creativity.

The focused group sessions provided additional insights into the students' experiences with parametric design. Many participants reported that while the tools allowed for rapid ideation, they required a deep understanding of the software's functions to be used effectively. Furthermore, this finding suggests a learning curve associated with parametric design, and students must invest time in mastering the tools to fully leverage their creative potential. Overall, the study's findings highlight the significance of parametric tools in the modern design curriculum, emphasizing their role in enhancing students' creative abilities. In particular, the VPA technique proved invaluable in highlighting how students transition from initial sketches to digital ideation, offering a clear view of their creative processes and interactions with parametric tools. Additionally, this method highlighted the effectiveness of parametric tools in enhancing the conceptual design phase. It also provided a detailed understanding of how students integrate these tools with traditional sketching techniques to develop their ideas phase.

4.1 Parametric Design Process

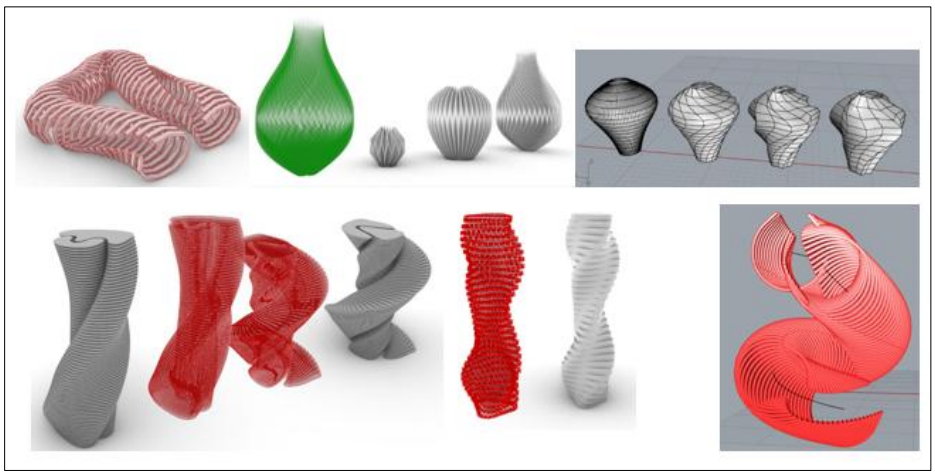

Fig. 1: Preliminary stages, Idea Generation using parametric as an approach of ideation. The ideation phase is a judgment-free zone where the group is encouraged to venture away from the norm, explore new angles, and think outside the box.
(Image by authors)

In contemporary product design, the traditional top down approach has evolved. Modern designers increasingly rely on parametric tools to streamline the entire design process. These tools offer efficiency and open up vast creative possibilities through the use of digital modeling technologies. Moreover, parametric design involves selecting key factors that influence the form of a product as parameters and then establishing logical connections (or algorithms) using computer software. This generates a digital model that serves as a random form generation for the product. This method significantly enhances the process of idea generation in product design by allowing for dynamic adjustments and variations, which lead to more innovative outcomes.

4.1 Creating an algorithm

To develop an algorithm, the relationships between various parameters are analyzed to understand both their logical and transfer connections. Based on this analysis, a structured algorithm controls these parameter relationships. This allows for the generation of models by compiling a set of logical rules. In the context of product design idea generation, this process optimizes the creation of models by defining how parameters influence each other, leading to efficient design outputs through automation and control.

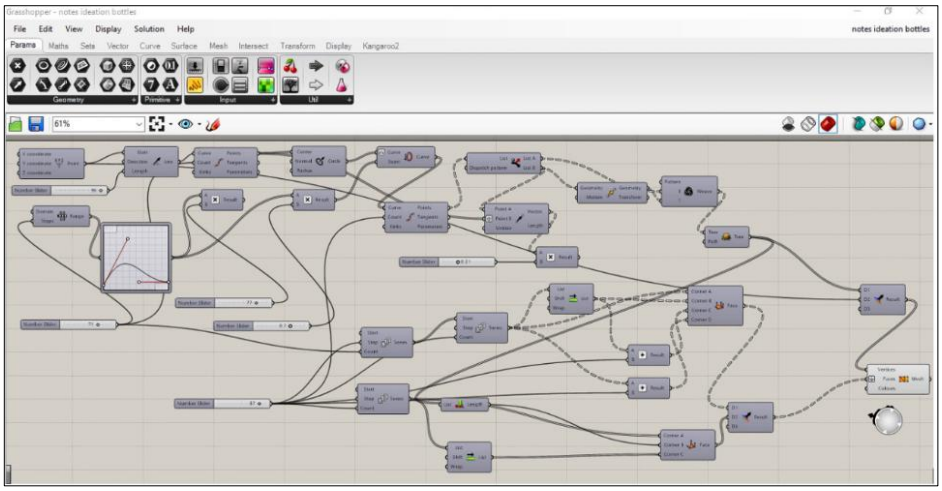

Fig. 2: Writing of logic program of Idea Generation (product design)
(Image by authors)

5.0 Discussion

The study clearly demonstrates that students generated a diverse array of form designs using a parametric approach. Through this method, Industrial Design students successfully developed sketching techniques that facilitated their exploration and creativity during the design development phase. Futhermore, sketching emerged as a fundamental process supporting creative ideation, enabling individuals to visualize and refine their ideas freely.

Sketching, as observed in this study, is a vital and straightforward technique that significantly aids in the creative process of generating and conceptualizing ideas. It allows designers to quickly iterate on concepts without the constraints of rules or conditions, making it an essential tool for professional designers in industrial practice and students in an academic setting. In addition, the unique nature of each sketch reflects the personal touch and creativity of the individual designer, distinguishing it as a work that is inherently personal and not necessarily meant for reproduction.

The study highlights the significance of combining parametric tools with traditional sketching techniques in industrial design education. Parametric tools like Rhinoceros and Grasshopper allow for the creation of adaptable models based on mathematical algorithms, which are crucial in the early stages of design development. Sketches, on the other hand, reflect each student's unique style and perspective, valuing originality and personal expression. This approach enhances students' ability to generate diverse form designs and encourages their overall creative and problem solving skills, making it an invaluable part of their design education. Therefore, the study concludes that combining sketching techniques and parametric design tools is a powerful combination that supports the creative process and fosters the development of innovative and unique design solutions.

6.0 Conclusion and Recommendation

In conclusion, this study highlights the vital role parametric design plays in enhancing creativity and innovation in industrial product design education. The findings demonstrate that students were able to explore a wide range of form designs using parametric design tools, which provided them with a flexible, iterative, and dynamic environment for idea generation. This aligns with current literature that emphasizes the benefits of parametric design in handling complex relationships between design elements and facilitating rapid

prototyping. Additionally, integrating sketching techniques during design development allowed students to freely express their creativity without being constrained by rigid design rules, encouraging more organic and individualized design solutions.

To improve the research's transparency and rigour, it is important to recognise a few limitations, even though this study offers insightful information about the application of parametric tools for idea development in industrial design education.

First off, the study was only carried out in one university, which could have limited the findings' generalisability and introduced contextual bias. The way that students interact with parametric design software may differ depending on their educational background, experience to digital tools, and design culture. Second, the study's sample size was somewhat limited, which limits how broadly the results may be applied in other educational environments. Furthermore, the study focused on two software programs: Grasshopper and Rhinoceros. Despite their popularity, various parametric or generative tools could have distinct features, interfaces, or learning curves, which could have an impact on the experiences and results of students.

On the other hand, institutions should invest in providing students with access to state of the art parametric design software, such as Grasshopper or Rhinoceros. Furthermore, hands on experience with these tools will better prepare students for professional practice. Future studies should explore the integration of artificial intelligence (AI) and machine learning (ML) in the idea generation phase, particularly in combination with parametric tools. Nevertheless, by implementing these recommendations, educators can better prepare students for the demands of modern product design, ensuring they are equipped with both creative and technical skills necessary for the evolving industry.

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Paper Contribution to Related Field of Study

This study highlights the benefits of combining parametric design tools with traditional sketching techniques in industrial design education. By integrating tools like Rhinoceros and Grasshopper, students gain flexibility and adaptability in the design process, allowing rapid exploration of complex forms. This approach supports dynamic, iterative design, especially in early ideation stages, which enhances creativity and innovation in form creation. The findings provide a framework for educators to blend digital and traditional methods, improving student preparedness for industry demands. Overall, the research offers a basis for further exploration and practical guidance to refine educational strategies in design.

References

Binbin Sun, Shangyou Huang (2019). Realizing product serialization by Grasshopper parametric design. IOP Conf. Ser.: Mater. Sci. Eng. 573 012078

C. M. Herr, N. Gu, S. Roudavski, M. A. Schnabel, Circuit Bending, Breaking and Mending: Proceedings of the 16th International Conference on Computer-Aided Architectural Design Research in Asia,429-438. ©2011, Association for Computer-Aided Architectural

Caetano, I., Santos, L., & Leitão, A. (2020). Cognitive processes in parametric design: A systematic literature review. *Automation in Construction, 112*, 103084. https://doi.org/10.1016/j.autcon.2020.103084

Cham, J. G., and Yang, M. C., 2005, "Does Sketching Skill Relate to Good Design?" Proc. of IDETC/CIE 2005 ASME 2005 International Design Engineering Technical Conferences & Computers and Information in EngineeringConference, Long Beach, CA, ASME, New York

Darmawan, A. (2021). A methodological examination of multidisciplinary research of mak yong theatre: Text, heritage, and performance pemeriksaan metodologis atas pendekatan multidisipliner dalam kajian tentang teater Mak Yong: Teks, warisan budaya, Dan Pertunjukan. SPAFA Journal

Goel, V., Sketches of thought. 1995, Cambridge, Mass.: MIT Press. xv, 279. J. Design Research, Vol. 16, No. 2, 2018, Conceptual product design in digital and traditional sketching environments: a comparative exploratory study, Copyright © 2018 Inderscience Enterprises Ltd.

Hossam Eldin, H., Bakir, R., & El-Fiki, S. (2021). An interdisciplinary approach for tacit knowledge communication between the designer and the computer. Open House International, 46(3), 416–431. https://doi.org/10.1108/OHI-02-2021-0037

Lee J. H., Gu N. and Williams A. P., Exploring design strategy in Parametric Design to Support Creativity, in: Stouffs R., Janssen P.H.T., Roudavski S., Tunçer B., eds., *Open Systems: CAADRIA 2013*, Singapore, 2013, 489–498.

Li, C., Pan, H., Bousseau, A., & Mitra, N. J. (2020). Sketch2CAD: Sequential CAD modeling by sketching in context. ACM Transactions on Graphics (TOG), 39(6), 1–15. https://doi.org/10.1145/3414685.3417764

Nagai, Y. and H. Noguchi, An experimental study on the design thinking process started from difficult keywords: modeling the thinking process of creative design. Journal of Engineering Design, 2003. 14(4): p.429 - 437.

Paul Rodgers and Alex Milton, Product Design, Laurence King Publishing Ltd. 2011

Schütze, M., P. Sachse, and A. Römer, Support value of sketching in the design process. Research in Engineering Design, 2003. 14(2): p. 89-97

Suwa, M. and B. Tversky, What Do Architects and Students Perceive in their Design Sketches? A Protocol Analysis. Design Studies, 1997. 18(4): p. 385-403

Ullman, D.G., S. Wood, and D. Craig, The Importance of Drawing in the Mechanical Design Process. Computers & Graphics, 1990. 14(2): p. 263-274.

Verstijnen, I.M., et al., Sketching and creative discovery. Design Studies, 1998. 19(4): p. 519- 546.

Vogiatzaki, Maria; Douroudi, Effie; Lantavou, Maria; Symeonidou, Ioanna (2019). The parametric design process. Anglia Ruskin Research Online (ARRO). Media. https://doi.org/10.25411/aru.9976613.v2

Yang, M.C. An Examination of Prototyping and Design Outcome. in 2004 ASME Design Engineering Technical Conferences. 2004. Salt Lake City, Utah USA.