Transforming AI-Generated Text-to-Image Concepts into Functional Final Designs: A Case Study on Lighting Product Design in Industrial Design Education

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Received: 02 November 2024
Accepted: 09 January 2025
Date Published Online: 31 January 2025
Published: 31 January 2025

Abstract: *This study explores the integration of generative AI, particularly text-to-image generators, into industrial design education and its role in enhancing creativity during the idea-generation process. Focusing on a lighting product design project, the research examines how students use AI-generated concepts as a starting point and refine them through sketches and 3D models into fully functional designs. Generative AI has significant potential to facilitate creativity by breaking down traditional barriers to ideation and speeding up the concept-generation process. However, turning creative output into practical, manufacturable products can be challenging. The research involved 20 Bachelor of Industrial Design students tasked with transforming AI-generated imagery into functional lighting products. The methodology followed a three-phase process: AI-based concept generation, design refinement through sketches, and final 3D modeling. The findings reveal that while AI tools provide creative inspiration, students need to make substantial refinements to ensure the designs are both practical and user-centered. Main adjustments included form simplification, functional enhancements, and material considerations. This highlights the critical role of human intervention in bridging the gap between AI-generated concepts and fully realized, functional products. This research contributes to the growing understanding of how to incorporate generative AI into industrial design education effectively.*

Keywords: *Functional Design, Generative AI, Industrial Design Education, Text-to-Image Generation.*

1.0 INTRODUCTION

The rapid integration of generative AI into creative industries has opened new avenues for design exploration. Text-to-image generators, in particular, have gained attention in industrial design as tools for quickly visualizing ideas based on textual descriptions. These AI technologies provide designers with immediate visual outputs, offering new perspectives that may not have been considered through traditional sketching methods (Oppenlaender, 2022). The creative potential of these tools allows designers to explore novel forms, styles, and concepts that push the boundaries of conventional design thinking (Liu & Chilton, 2022).

Generative AI can significantly enhance creativity in design education by offering a wide variety of innovative design alternatives in short timeframes, thereby fostering rapid exploration of design possibilities. This enables designers to transcend traditional ideation barriers, spurring inspiration through AI-generated imagery. However, the challenge of aligning these AI-generated concepts with practical design considerations, such as ergonomics and material constraints, tempers this potential (Faruqi et al., 2024; Hashem & Hakeem, 2024). Moreover, while these models excel at generating aesthetically pleasing images, they may struggle to produce visuals that accurately reflect novel functional concepts or support the interpretation of design functionalities (Brisco et al., 2023).

In the field of product design, where both aesthetics and functionality are critical, the ability to quickly generate and explore diverse design concepts through AI can be especially valuable (Crowson et al., 2022). However, while these AI-generated designs can ignite creativity, they often lack the technical precision or practical considerations required for a final product, particularly when designing functional items like lighting products. The question arises: "How do these AI-generated designs influence the final design process?" and "Can students refine and develop these initial ideas into more coherent, functional products that meet specific design criteria?". The transition from a raw, AI-generated idea to a well-developed, functional design requires students to bridge the gap between creativity and practical application.

This paper explores how industrial design students utilize text-to-image generators during the ideation phase and how these AI-generated designs evolve through the sketching and development process. We examine the methods students employ to enhance and modify AI-generated ideas into practical lighting products.

2.0 PROBLEM STATEMENT

Despite the increasing use of text-to-image generators in design ideation, there remains a significant challenge in translating these AI-generated visuals into functional, user-centered product designs. Text-to-image generators often produce creative but impractical concepts that lack consideration for technical and functional requirements, especially in fields like product design, where factors such as product features related to material choice and user interaction are critical (Qiao et al., 2022; Faruqi et al., 2024). Students, while inspired by the initial AI-generated images, struggle to refine and adapt these outputs into designs that meet product-specific criteria (Dortheimer et al., 2023). This gap between initial ideation and final product design calls for an examination of how AI-generated ideas evolve through the design development process. It is crucial to understand whether the final designs maintain the essence of the original concept while improving upon their functionality and aesthetic logic.

This research aims to analyse the transformation of text-to-image generated designs into refined and functional final design sketches within the context of lighting products. Specifically, the study will examine how students develop and refine AI-generated concepts, ensuring that the final designs meet the intended product features and improve upon the initial ideas in terms of functionality and aesthetic logic.

3.0 OBJECTIVE

Objective 1: To compare the differences between the initial text-to-image generated designs and the final designs created by students.

Objective 2: To evaluate whether the final designs meet the intended functional and aesthetic features required for lighting products.

Objective 3: To explore how the design development process, from AI-generated imagery to final sketches, improves the overall design quality, with a focus on logical refinements and technical considerations.

4.0 LITERATURE REVIEW

4.1 THE ROLE OF GENERATIVE AI IN DESIGN EDUCATION

The integration of generative AI tools in design education has introduced new possibilities for how students approach the ideation and conceptual stages of design. Traditionally, industrial design education emphasized manual sketching, prototyping, and problem-solving as core skills for students to develop. However, the advent of generative AI, specifically tools like text-to-image generators, has expanded the creative boundaries within which students can operate. AI tools allow for the rapid generation of design concepts based on text prompts, providing students with a platform to explore numerous possibilities without the constraints of traditional design methods (Bartlett & Camba, 2024).

Research shows that AI's ability to produce visually diverse concepts aids students in breaking through design fixation (Karimi et al., 2020), allowing them to explore a broader array of aesthetics in a shorter time frame (Hutson & Cotroneo, 2023). Hashem & Hakeem (2024) argue that AI tools like Generative AI not only accelerate the ideation process but also help students overcome creative barriers by presenting unexpected design alternatives, thus expanding their creative horizons. This aligns with the broader view that AI-driven platforms provide opportunities for students to iterate rapidly, test various design concepts, and pivot more effectively when ideas fail to meet functional or aesthetic requirements (Liu & Chilton, 2021).

However, despite these advantages, there are challenges in translating AI-generated ideas into functional products. Many of the concepts produced by AI tend to lack the technical and functional considerations necessary for product design, particularly in fields like industrial design where ergonomics, material constraints, and manufacturability are critical (Hong et al., 2023). Hashem & Hakeem (2024) emphasize that while AI-generated designs can serve as a rich source of inspiration, students must learn to critically evaluate these outputs and refine them to ensure they align with practical design needs, particularly through tailored prompt engineering and focused feedback mechanisms.

4.2 THE CHALLENGES OF TRANSLATING AI-GENERATED DESIGNS INTO FUNCTIONAL PRODUCTS

One of the main limitations of generative AI in industrial design education is the disconnect between creative ideation and the technical feasibility of AI-generated outputs. While AI tools can quickly produce imaginative and diverse concepts, they often neglect essential functional considerations such as usability, material strength, and manufacturability (Qiao et al., 2022). Students frequently struggle to balance their aesthetic ambitions with the practical requirements of design, particularly when working with AI-generated outputs that prioritize form over function (Elnokaly, Elseragy & Alsaadani, 2008). Hashem and Hakeem (2024) further emphasize the importance of teaching students to utilize prompt engineering to gain greater control over AI-generated design outcomes, thereby narrowing the gap between creative exploration and practical implementation.

The need to balance AI-generated outputs with human-centered design principles, including the incorporation of user feedback and ergonomic considerations throughout the refinement process remains critical (Leão, Silva & Costa, 2024). Moreover, AI-generated designs often fail to provide adequate information regarding material selection and production techniques, resulting in a gap between conceptual creativity and real-world feasibility (Faruqi et al., 2024). While AI can serve as a powerful tool for design inspiration, human designers must intervene to make the necessary refinements that align the designs with practical constraints (Weisz et al., 2024).

In industrial design education, this challenge is particularly pronounced, as students are still developing their understanding of how to integrate functional considerations into their work. As students' progress from ideation to final design, they must learn to evaluate and adapt AI-generated concepts to meet the demands of usability, manufacturability, and material durability. This ability to refine and adjust AI-generated designs is critical to bridging the gap between imaginative concepts and fully functional products.

5.0 METHODOLOGY

5.1 RESPONDENT SELECTION

This study involved 20 students in Semester 3 who were registered under the subject Advanced Industrial Design for Manufacturing (IDE510) and enrolled in the Bachelor of Industrial Design (CAAD244) program at the College of Creative Arts, UiTM Kedah Branch. The students were selected based on their participation in a lighting product design project in subject IDE510, which required the use of generative AI tools (recraft.ai, ideogram.ai & stablecog.com) to support the ideation process. The participants were tasked with transforming AI-generated design concepts into fully refined sketches and 3D models for lighting products. All students voluntarily participated in the study, and consent was obtained before data collection.

While the study involved 20 respondents, 5 were selected for detailed presentations to highlight diverse design outcomes. These respondents were chosen based on a set of criteria, including variations in design styles, the level of functionality achieved, and the degree of innovation demonstrated in their final outputs. This selection ensured that the showcased examples represented a wide range of design complexity from straightforward functional adjustments to highly innovative solutions. This approach aimed at aligning the presented data with the study's objective of analysing the transformation of AI-generated concepts into practical final designs.

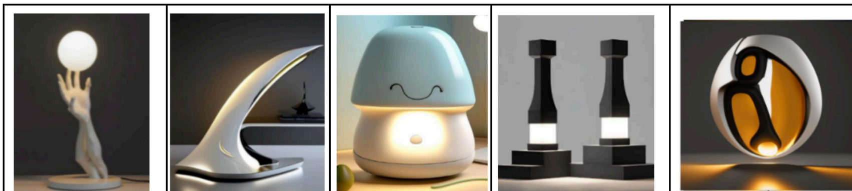
The data collection and procedure were divided into three key phases: (1) AI-generated concept creation, (2) design refinement through sketches, and (3) the development of 3D models. These phases were aligned with the research objectives, focusing on the transformation of AI-generated imagery into final design solutions.

5.2 PHASE 1: TEXT-TO-IMAGE AI GENERATION

During the first phase, participants were introduced to text-to-image AI tools such as Stablecog.com, ideogram.ai, and Recraft.ai. They were instructed to generate initial lighting design concepts using specific text prompts. These prompts were designed to ensure creativity while maintaining relevance to lighting design. Each student used the following basic prompt structure: *"[Type of lighting], inspired by [subject], [design concept], [aesthetic style]".*

For example, a student might generate an image using the prompt: "Standing desk lamp, inspired by nature, organic forms, minimalist design style."

The resulting AI-generated images served as the starting point for the design process, providing a creative yet technically incomplete concept for further development. (See Figure 1.0).



Participant A	Participant B	Participant C	Participant D	Participant E

Figure 1.0: Example of AI-Generated Design Images from Selected Participants in Phase 1

5.3 PHASE 2: DESIGN DEVELOPMENT (SKETCHES)

In the second phase, participants were tasked with developing their selected AI-generated images into more detailed and functional design sketches. Students were encouraged to refine the aesthetic and technical aspects of the designs, ensuring that the sketches addressed practical features required for lighting products, such as light source placement, material choices, and user interaction elements (e.g., switches, cords, bulb handles). Students were required to create a series of development sketches that gradually improved upon the AI-generated image, making logical refinements in functionality and aesthetics. These sketches demonstrated the progression from concept to a more feasible product. (See Figure 2.0)

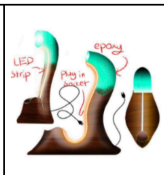
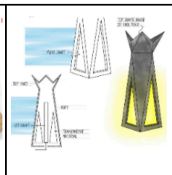
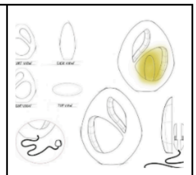
				
Participant A	**Participant B**	**Participant C**	**Participant D**	**Participant E**

Figure 2.0: Example of Final Design Sketches from Selected Participants in Phase 2

5.4 PHASE 3: 3D MODEL RENDERING

In the final phase, students transformed their final design sketches into 3D models using 3D Rhinoceros modeling software. The 3D models represented the most refined version of the lighting products, incorporating both the aesthetic and functional improvements made during the sketch development phase. These models allowed for a final evaluation of the design's practicality, usability, and manufacturability. (See Figure 3.0)

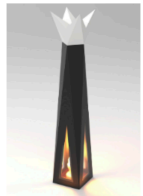
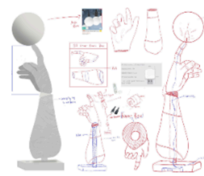
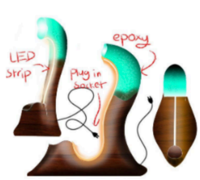
				
Participant A	**Participant B**	**Participant C**	**Participant D**	**Participant E**

Figure 3.0: Example of Final 3D Model Renderings from Selected Participants in Phase 3

The following table summarizes the main transformations across the three phases for each participant, highlighting changes in form, functionality, and aesthetic alignment between the AI-generated designs, final sketches, and 3D models. (See Table 1.0)

Participant	**AI-Generated Design**	**Key Changes in Final Sketch**	**Key Features in Final 3D Model**	**Summary of Improvements**
A				The design transitioned from an artistic concept to a more functional product with enhancements in balance, usability, and ergonomic considerations. The base and switch improved practicality.
	An organic hand-like structure holds a light source at the top.	Added a base, explored proportions, refined the posture of the hand to ensure balance, and incorporated a switch.	Retains the hand form with added structural stability in the base and resizes the light globe for light bright.	
B				Enhanced usability by integrating a light source and ergonomic elements while maintaining a unique geometric aesthetic. Improved the balance between form and function.

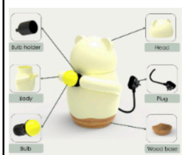
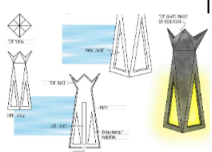
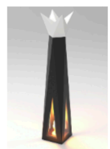
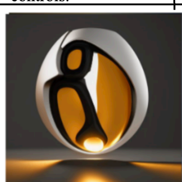
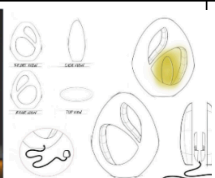
	Sharp, blade-like form with no visible light source or user interaction points.	Added a light source (LED strip), ergonomic modifications for easier interaction, and adjustments to the form for improved user-friendliness.	The 3D model retains the sharp geometric form but adds a visible light source and refines material use, such as wood and acrylic.	
C				The playful aesthetic is preserved, with major improvements in functionality, such as defined lighting and user interaction points, enhancing practicality while maintaining the fun design.
	Cute, character-like lamp with soft edges but undefined lighting elements.	Defined the light source, added functional switches, and refined proportions for better user-friendliness and visual appeal.	Retains the playful, abstract form but incorporates practical switches and a defined light source.	
D				Successfully balances a minimalist aesthetic with usability improvements, such as functional lighting and better accessibility through height and control adjustments
	Minimalist design inspired by a chess piece, vertical lines, and no clear light source or user controls.	Adjusted the height for usability, refined the form, and added interaction points like switches and a light compartment.	Maintains the minimalist form with the addition of a functional light source and interaction points.	
E				The design evolved from an artistic light sculpture to a more practical, ergonomic lamp. The refined proportions increase usability, while the secure placement of the light source ensures functional stability.
	Oval-shaped, abstract design with a central glowing light source, covered in a sculptural, organic form.	Refined to a more logical round form that meets the internal lighting compartment. Adjusted proportions for stability and usability.	Retains the abstract oval form, now featuring a smoother surface, with the light source visibly secured and an opening for user interaction.	

Table 1.0: Comparative Analysis of AI-Generated Designs, Final Sketches, and 3D Models in Lighting Product Development

6.0 DESIGN TRANSFORMATION ANALYSIS

This section presents the findings based on the comparison and evaluation of the design process, focusing on the content and qualitative aspects of the transformation from AI-generated designs to final sketches and 3D models. The comparative analysis was conducted by the researcher, who has considerable expertise in industrial design, thereby providing a comprehensive and reliable evaluation. The analysis followed a predefined rubric that emphasized functionality, aesthetic quality, and usability. This rubric, based on the principles of functional design, included parameters such as ergonomic considerations, material feasibility, and alignment with aesthetic goals. The researcher's academic background and professional expertise in industrial design established a solid foundation for the effective evaluation of the transformation process.

6.1 COMPARISON OF AI-GENERATED DESIGNS AND FINAL SKETCHES

The analysis begins by comparing the preliminary AI-generated designs with the final sketches drawn by the students. Several significant distinctions were observed, particularly concerning form, functionality, and user interaction:

a) Form Refinement: Students made notable refinements to the original forms provided by the AI-generated outputs. While the AI-produced designs tended to focus more on abstract shapes or aesthetic forms without functional constraints, the final sketches reflected a clear attempt to simplify and rationalize the forms to better suit the needs of a lighting product. For instance, designs that were too creative or complicated were modified to make sure the product was stable and balanced.

b) Functional Adjustments: The AI-generated designs often exclude essential functional components, like light sources, switches, and support structures. In the final sketches, students corrected these flaws by incorporating essential elements, ensuring that the designs were both aesthetically pleasing and functional for practical use. The shift from abstract to functional emphasised the students' capacity to critically evaluate and modify the AI-generated results.

c) Aesthetic Consistency: The relationship between the AI-generated designs and the final sketches varied. Some students successfully retained the core aesthetic elements, such as minimalist or geometric forms, while integrating functional elements like buttons and bulb sockets. However, other students had to deviate from the original form due to practical constraints. For example, incorporating functional elements like switches, adjusting the height for ergonomic reasons, and placing light sources logically required modifications that altered the aesthetic.

6.2 EVALUATION OF FINAL DESIGNS' FUNCTIONAL AND AESTHETIC FEATURES

The evaluation of the final designs focused on whether they met the intended functional and aesthetic requirements for lighting products.

a) Functional Elements: The final designs successfully incorporated essential lighting features, such as light source placement, switches, and user interaction components. Students demonstrated the ability to adapt their designs to include these features without significantly compromising the design's aesthetic appeal, although some adjustments were necessary to meet functional needs.

b) Aesthetic Quality: Many of the final designs maintained a strong aesthetic connection to the original AI-generated images, particularly in terms of overall style and form. However, in cases where functionality took priority, some aesthetic elements were modified to improve usability or ensure the design's feasibility in production. The balance between aesthetics and functionality was a recurring theme, with students needing to adjust their designs to achieve both.

6.3 IMPROVEMENT IN DESIGN QUALITY THROUGH THE DEVELOPMENT PROCESS

The development process, from AI-generated imagery to final sketches and 3D models, demonstrated clear improvements in design quality, particularly in terms of logical refinements and technical considerations.

a) Logical Refinements: Throughout the design process, students made critical adjustments to enhance the practicality and usability of their designs. This included adding stability elements, adjusting proportions, and ensuring that light sources were placed appropriately for the intended function. The iterative sketching process allowed students to reflect on and refine their initial ideas, resulting in more logically structured and clear final designs.

b) Technical Considerations: The transition from sketches to 3D models highlighted the increasing attention to technical details. Students demonstrated a growing awareness of material selection, manufacturability, and ergonomics, ensuring that their final designs were not only aesthetically pleasing but also feasible for real-world production. These technical considerations marked a significant improvement over the AI-generated designs, which lacked such practical elements.

7.0 CONCLUSION

This study demonstrates that while text-to-image AI generators can provide valuable creative inspiration, they are limited in producing fully functional and feasible product designs. The students were able to refine and adapt these initial AI-generated concepts through an iterative design process, resulting in improved functionality, technical feasibility, and user interaction.

The findings highlight the need for human intervention in transforming AI-generated designs into practical products. AI serves as a valuable ideation tool, but the final design process requires critical thinking, technical knowledge, and iterative refinement. The balance between aesthetic consistency and functional requirements remains a key challenge, and design education must continue to emphasize the integration of both to ensure well-rounded design outcomes. Moreover, the study underscores the importance of iterative design development in bridging the gap between conceptual creativity and practical usability. Students demonstrated a growing awareness of how to adapt AI-generated outputs into feasible and user-friendly products, reinforcing the value of hands-on design experience combined with AI ideation tools.

Building on the findings of this study, several paths for future research emerge. First, expanding the application of AI-generated design beyond lighting products to other categories, such as furniture, consumer electronics, or wearable technology, could offer valuable insights. These fields bring different functional and technical challenges, which may impact how AI-generated designs are adapted for usability, manufacturability, and aesthetics. Investigating these diverse product categories could help determine whether the patterns observed in this study are consistent across other design disciplines.

8.0 ACKNOWLEDGEMENT

The author would like to extend heartfelt appreciation to the Industrial Design Department at the College of Creative Arts, UiTM Kedah Branch, for their constant encouragement and the resources provided throughout the development of this paper. I am particularly grateful to my colleagues and peers for their collaborative efforts and constructive feedback, which have substantially improved the quality of this research. The author is also grateful to the participants and contributors whose valuable insights and expertise were instrumental in the success of this study. The contributions have been crucial in the successful completion of this project.

9.0 FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

10.0 AUTHORS' CONTRIBUTION

Mohd Hamidi Adha Mohd Amin led the writing of the manuscript, organized the data collection, and conducted the data analysis. The author also contributed to refining the research, analysis, and manuscript.

CONFLICT OF INTEREST DECLARATION

I certify that this article is the original work of the authors. The article has not been published previously and is not under consideration for publication elsewhere. I testify to the fact that the Author has contributed significantly to the work, the validity and legitimacy of the data, and its interpretation for submission to IJELHE.

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