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Exploring the Impact of Generative Artificial Intelligence on the Design Process: Opportunities, Challenges, and Insights

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ABSTRACT

Generative artificial intelligence (GAI) created a whirlwind in late 2022 and emerged as a transformative technology with the potential to revolutionize various industries, including design. Many design practitioners have also begun utilizing GAI as a design tool, stimulating creativity, integrating data more rapidly, and facilitating iterative design processes. However, while enjoying the convenience of generative artificial intelligence, many underlying negative impacts can also exist. This study comprehensively explore the potential applications and limitations of generative AI in the design process, this study employs the Double Diamond model as a framework to examine the impact of GAI on the design process. The findings of this study demonstrate that generative AI holds significant potential for optimizing the design process, significantly increasing the divergent part's breadth and the convergent part's efficiency. However, existing generative AI has a significant limitation in the define phase. Furthermore, interpreting the authenticity and bias issues in the content generated by generative AI tools depends on the ethical awareness and judgment of the designers using these tools.

Keywords: Generative artificial intelligence, Design process, Double diamond, ChatGPT, Midjourney

INTRODUCTION

According to a survey conducted by McKinsey in 2022, the adoption of Artificial Intelligence (AI) has doubled in the past five years, and generative artificial intelligence (Generative AI, GAI) tools like ChatGPT and DALL-E are gradually transforming people's lifestyles (Chui, 2022). ChatGPT not only engages in realistic conversations with people but also can create new content such as poetry, stories, and novels(Tlili et al., 2023). Simultaneously, since 2021, the discussion surrounding text-to-image generation systems has become a popular means for creating digital images and artworks (Crowson et al., 2022; Rombach et al., 2022).

Many design practitioners have also begun utilizing Generative AI as a design tool, stimulating creativity(Koch et al., 2019), overcoming obsticles more rapidly (Liao et al., 2020), and facilitating iterative design processes (Zeng et al., 2019). However, excessive reliance on Generative AI in design

may lead to losing the uniqueness emphasized in the field and raise concerns regarding ethical implications(Robinson et al., biased information (King, 2022), user acceptance, and the preservation of human-centered approaches.

However, with the increasing power of generative artificial intelligence tools, there hasn't been comprehensive research to fully understand generative the impact, applications, and existing limitations of generative AI tools on the design process. Therefore, this study employs the double-diamond design process model as a framework to examine the impact of Generative AI on the design process.

LITERATURE REVIEWS

Generative Artificial Intelligence (Generative AI)

Due to advancements in Generative Models and Deep Learning (DL), Generative Artificial Intelligence can now generate diverse content on a large scale using existing media such as text, images, music, and videos(Gui et al., 2020). Existing literature has defined two main types of Generative Artificial Intelligence (GAI): Generative Pre-trained Transformer (GPT) and Generative Adversarial Networks (GANs)(Jovanović and Campbell, 2022).

The Generative Pre-trained Transformer (GPT) generates text in various languages. It can create human-like words, sentences, and paragraphs for any topic and writing style (Jovanović and Campbell, 2022). In November 2022, OpenAI's AI research laboratory introduced a chatbot called ChatGPT. ChatGPT is a conversational AI powered by Natural Language Processing (NLP) that interacts convincingly.

Since the inception of Generative Adversarial Networks (GAN) in 2014, deep learning for text and image generation has significantly progressed (Goodfellow et al., 2014). In January 2021, OpenAI released the Contrastive Language-Image Pre-training (CLIP), which marked a significant breakthrough in Text-to-Image Generation (Radford et al., 2021). CLIP is a contrastive language-visual model designed for image classification tasks by providing names of visual categories to recognize (Zhou et al., 2022). After CLIP's release, AI enthusiasts created systems that combine GAN with CLIP for digital art generation, leading to the development of systems like "Big Sleep" (Colton et al., 2021) and Style-GAN (Gal et al., 2021) with CLIP integration. These combinations have taken text-to-image art to a new level and become standard techniques in the field (Oppenlaender, 2022). Nowadays, users have a range of text-to-image generation systems to choose from, with diffusion models being the most advanced, including Stable Diffusion(Rombach et al., 2022), DALL-E (Ramesh et al., 2022), Midjourney, and Imagen (Saharia et al., 2022).

Design Process

The design process represents the path from problem exploration (starting point) to solution implementation (end point), encompassing actions, methods, thinking, and their combinations. Design processes can take various

forms, with the most common being Design Thinking developed by IDEO and Stanford University and the Double Diamond or 4D process proposed by the Design Council in the UK in 2005(Howard et al., 2008). All design processes involve the concepts of divergence, convergence, and iteration, which are essential in the design process.

Integrating AI Into Design

Early machine learning applications included image search assistance and AI-assisted drawing tools, which showed promising results in enhancing the design process (Cutting et al., 1992; Fogarty, Forlizzi and Hudson, 2001; Oh et al., 2018). AI has been found to facilitate inspiration and provide "unexpected design references" (Chen et al., 2019). AI has also been applied to the ideation phase, predicting design barriers and offering guidance to overcome them (Liao et al., 2020).

Looking at the design process as a whole, AI has enhanced the process by introducing diversity to user inputs, allowing designers to rapidly expand their solution space while maintaining the iterative cycle of creation and reflection (Zeng et al., 2019). Integrating AI into design processes poses two main challenges: AI capabilities' uncertainty and AI outputs' complexity (Yang et al., 2020).

METHODS

In order to comprehensively explore the potential applications and limitations of generative AI, the researchers participated in interdisciplinary conferences and seminars. Insights and perspectives were collected regarding the potential applications and threats of generative AI from different domains. Then, interviews were conducted with design professionals with extensive experience utilizing generative AI in their workflow.

Conferences and Seminars

The researchers attended conferences and lectures organized by a comprehensive university to explore generative artificial intelligence. These events invited experts and scholars from fields such as law and psychology, as well as information engineering researchers and experts with more than ten years of experience in artificial intelligence.

Interviews

This study employed a semi-structured interview approach to delve into the depth and breadth of relevant topics (Tashakkori and Teddlie, 2010). Interviews were conducted in person or online via Google Meet, and all interviews were recorded. The interviews covered the potential applications and challenges of generative AI tools in the design process and the competencies required for utilizing AI tools.

Interviewees

Four experts were selected for interviews in this study. Considering the relative novelty of generative AI tools (such as ChatGPT and Midjourney version 4, released on November, 2022), professionals with more than

six months of experience using generative AI tools and practical experience throughout the complete product development process (including all four stages of the Double Diamond model) were chosen as experts (see Table 1).

Table 1. General description of interviewees.

Interviewee	Background	Tool used	Experience level
E1	Design Department Faculty	ChatGPT, Midjourney	6 months
E2	Design Department Faculty	ChatGPT, Midjourney, Stable Diffusion	6 + months
E3	Ph.D. Candidate in Industrial Design	ChatGPT, Midjourney, TensorFlow	6 +months
E4	Ph.D. Candidate in Industrial Design	ChatGPT, Midjourney, TensorFlow	6 +months

Analysis

This study transcribed the recorded interviews verbatim using the vocal.ai speech collaboration platform. The transcriptions were reviewed and edited by the researchers to eliminate any errors in the text. The edited transcriptions were then imported into the free qualitative analysis software, Taguette for analysis. The data was coded by the researchers conducting the interviews to ensure familiarity with the data and understanding of the textual themes (Thomas, 2006). Additionally, triangulation was conducted by cross-checking with the other researchers to validate the interpretation of generative AI applications.

Since utilizing generative AI for design assistance is a relatively new paradigm, predetermined coding schemes could limit the researchers' inventory of generative AI functionalities. Therefore, the researchers adopted a "bottom-up" approach to thematic coding during the coding process (Silverman, 1998), rather than having predetermined coding schemes before the coding process.

RESULTS

In this study, the statements of the interviewees in applying generative AI were categorized and summarized into advantages, limitations, and applications within the four stages of the Double Diamond model (see Table 2). We also organize the functions of GAI in the Double Diamond model (see Figure 1). In this section, we have edited the interview quotes by removing pauses, fragmented sentences, and repetitions to facilitate the integration and presentation of the interview findings to make them more cohesive and coherent.

Table 2. Themes organization.

Theme	Class & Categories	Description
Advantages	Creating Breadth	Providing Designers with More Diverse and Extensive Information
	Improving Efficiency	Reducing the Time and Effort Designers Spend on Data Analysis, Rendering Outputs, Sketching, and Other Design Activities
	Enhancing Communication	Facilitating Designers in Communicating Concepts and Ideas
Limitations	Decision-Making Impairment	Serves as a Reference Only. Final Decision Rests with Humans
Discover Phase	Augmenting Data Sources	Augmenting Data Sources
	Assisting with Data Analysis	Organizing and Analyzing Information or Issues. Additionally, Generating Content to Fill Gaps When Data is Insufficient
	Assisting with User Research	Assisting in Questionnaire Design. Simulating User Behavior, Needs, and Feedback
Define Phase	Assisting with Problem Definition	Assisting in Transforming Problems into Clear Definitions
Develop Phase	Assisting in Ideation	Generating Reference Images to Inspire Designers. Assisting in Sketching and Brainstorming
	Assisting in Evaluating Solutions	Assisting in Evaluating the Feasibility and Value of Various Solutions
Deliver Phase	Assisting in Design Brief	Assisting in Design Concepts and Copywriting
	Generating Design Deliverables	Transforming Design Concepts into Final Product Renderings or Interactive Designs, etc

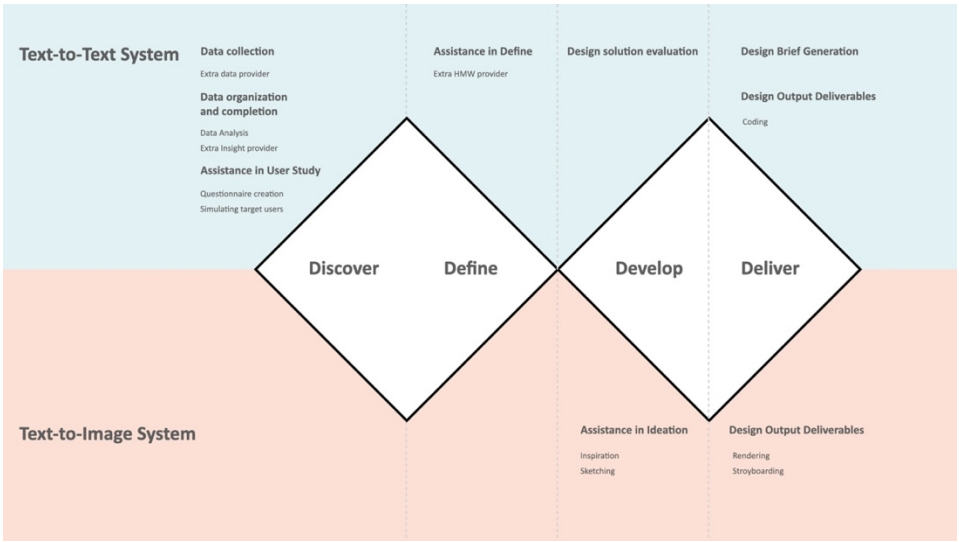

Figure 1: The functionality of GAI in the double diamond model.

Applications in the Discover Phase

"Text-to-text generation systems can help us (designers) collect data from different countries and regions..." (E3), assisting designers in quickly and extensively gathering relevant information during the discover phase. Additionally, generative AI tools can raise designers' awareness of marginalized issues. For example, *"Using Midjourney to present less attention-grabbing topics can make designers realize that there are different perspectives..."* (E4), helping designers gain a more comprehensive insight.

Secondly, Generative AI can organize and analyze vast amounts of information and help make sense of messy data. *"In qualitative research, we usually have transcripts with much information. Previously, it required human effort to interpret and extract key points. That is why we needed grounded theory to explore its insights. However, ChatGPT can efficiently extract key points from an article or something someone said that was not clear"*(E2). Furthermore, when designers encounter data scarcity or gaps, generative AI can leverage existing data and background knowledge. *"...AI-generated content can supplement the insufficiencies of professionally-generated content and user-generated content "*(E1), providing designers with more comprehensive information to support decision-making.

Lastly, Text-to-text generation systems can assist in user research, such as *"using ChatGPT in the questionnaire design process to help designers write questions, select appropriate question types, and validate the logic and flow of the questionnaire"* (E2). Additionally, *"(Chat)GPT may have the potential to partially replace some user research work in design because it can also simulate user behavior, needs, and feedback as additional sources of user research data"* (E1), helping designers gain a deeper understanding of user expectations and needs or providing unexpected ideas.

Applications in the Define Phase

The define stage aims to converge the information gathered in the discovery phase and define the problem, pain points, or opportunity points. In this stage, generative AI can provide designers with problem definitions from different perspectives, helping to broaden their thinking and explore more potential design directions. *"The quality of decisions sometimes depends on whether you have sufficient options. In the past, due to limited options, we could only choose one from six 'How might we' statements. However, now with generative design tools, we can have twenty 'How might we' statements to choose from, which increases the chances of selecting better questions"* (E1).

Applications in the Develop Phase

In the develop phase, Text-to-image generation systems *"can materialize the wild ideas in designers' minds; generate reference images quickly, inspiring designers"* (E4). *"It can also compensate for the lack of visual experience in designers and achieve what we call 'designing with your mouth.' By inputting a few prompts, designers can quickly and abundantly generate sketches"* (E2).

Text-to-text generation systems can help designers evaluate the feasibility and value of various solutions, prompting the team to choose the most promising one. *"Throughout the (design) process, We usually use ChatGPT in the middle stages. We do not rely on it to generate ideas or creativity. However, we might not be certain which is best or most feasible. That is when we ask ChatGPT to help us assess the pros and cons of these solutions, and then we make the final implementation decision"* (E1).

Applications in the Deliver Phase

In the deliver phase, designers are responsible for completing the final design and development work, such as producing the final product or service. During this stage, generative AI tools can assist designers in generating design brief and final design deliverables.

"ChatGPT can assist in the final stages of design, especially during presentations. If we want better storytelling and elaboration, we can let ChatGPT help us refine and improve the content" (E4). This effectively helps designers communicate design intent, value propositions, and product features. Furthermore, text-to-text generation systems can assist designers in coding or modifying code when it comes to game or interaction design. *"…We tested the programming capabilities of ChatGPT 4.0 version, which has an accuracy rate of up to 90%. This makes it very effective in assisting us with programming tasks, especially in creating Unity games or Arduino interactions, as it greatly enhances efficiency"* (E3).

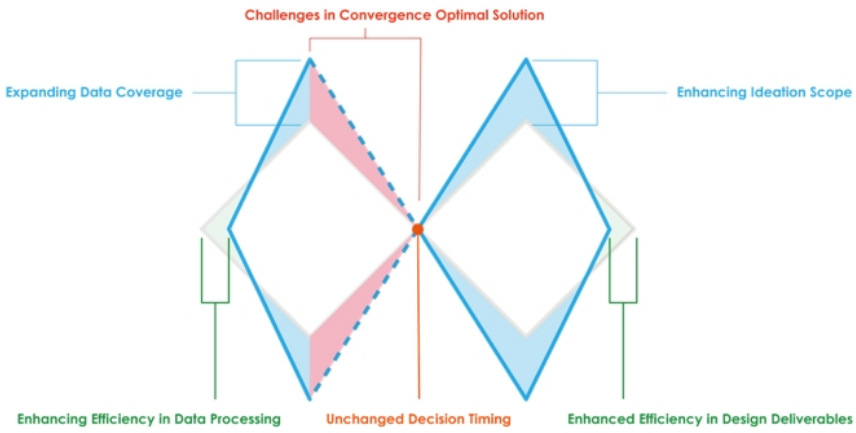

Figure 2: GAI-integrated double diamond design model.

Text-to-image generation systems' high-quality rendering techniques can transform design concepts into finalized visuals. *"In the past design process, it often involved sketching, followed by 2D or 3D rendering, creating contextual images or scenarios, and then using software like Photoshop or Illustrator for compositing. However, with current generative AI tools, designers can directly generate contextual images based on prompts, eliminating the tedious steps..."* (E2).

DISCUSSION

The generative AI tool will change the existing Double Diamond design process model, significantly increasing the divergent part's breadth and the convergent part's efficiency (see Figure 2).

Zeng et al., (2019) argued that AI allows designers to expand the solution space rapidly. The results of this study is similar. The feature of generative AI to generate text and graphic content in large quantities and quickly can provide a large number of reference sources to expand the required knowledge, information, and experience needed for the dispersal of temporal moments in Double Diamond, which promotes the designers to come up with unexpected inspirations (Chen et al., 2019), e.g., *"the text-to-speech system can provide more insights in the Discover stage"* (E1), and *"the text-to-image system can enhance the designer's visual experience in the Develop stage"* (E2), which can also fulfil similar functions as the past AI models-providing the designer with a large number of reference sources (Koch et al., 2019), aids to drawing (Oh et al., 2018)-and even more powerful.

Generative AI tools can also significantly improve the efficiency with which designers conduct their designs. In the first Diamond (problem space), a text-to-text system can be *"utilized to speed up the review of data in order to extract the key points of the data quickly."* (E2); in the second Diamond (solution space), AI can help designers to quickly execute the design results (Zeng, Sun, & Liao, 2019), and in the Develop stage, "by giving many instructions quickly, the text-to-image system can help designers to do thumb sketches" (E2), which assists designers to think creatively, and "help designers to do thumb sketches" (E2) when they are in a chaotic state of mind. When confused, it can also "help designers visualize their wild ideas" (E4). In Deliver stage (solution space), "Rendering the finished drawing through Midjourney reduces the time and effort needed to utilize computer-assisted design rendering software and saves the money needed to conduct commercial photography." (E2).

However, in this new model, the midpoint of the model (i.e., the critical point between the problem space and solution space) and the point of the divergent part and convergent part remain unchanged from the original two-diamond design model because "the generative AI tool only acts as an (information provider), the decision-making task is still on the human." (E3).

Existing generative AI models can only assist designers in decision-making and *"help evaluate solutions"* (E3), which can *"help to improve the quality of decision-making"* (E1). However, while text-to-text systems are suspected of generating misinformation, text-to-image systems are suspected of generating bias problems (King, 2022). Therefore, *"the interpretation of the AI generated content becomes very important. The designer should need to have a considerable degree of knowledge about the generated content so as not to be misled by it"* (E4), and it is also possible to *"utilize multi-party double-checking to determine the authenticity of the generated content."* (E2), and it is also important for designers to *"use generative AI from a benign starting point."* (E2).

"There is no single or standardized answer to the convergent part of design, so we cannot be sure which is the best solution, and today's generative AI tools cannot tell designers the best solution" (E1). This is also a major shortcoming of today's generative AI tools. In addition, since generative AI can provide more sources and perspectives, will it make decision-making more difficult due to more choices? This may be an opportunity for future research to explore in more depth.

LIMITATION

In previous studies, AI collaborative design tools have been shown to actively engage in the design process by inspiring designers (Fu and Zhou, 2020) and proactively predicting and assisting designers when encountering difficulties (Liao et al., 2020). However, current generative AI tools rely on user-controlled instructions through prompts, creating a passive collaboration mode. This may result in suboptimal utilization and effectiveness if designers fail to identify appropriate usage timing or make appropriate judgments. Furthermore, this study only focuses on mainstream text-to-text and text-to-image generation systems, excluding other generative AI tools such as generative AI for modelling assistance(Liu *et al.*, 2022). Future research could explore how these generative AI tools can provide more diverse assistance in the design process.

CONCLUSION

This study indicated that generative AI tools significantly aid the existing Double Diamond model. Generative AI can expand the breadth of possibilities, providing designers with more versatile and diverse references while accelerating the design process's efficiency. It expedites data collection and organization and speeds up the production of design outcomes. However, because design decisions ultimately rest with humans, this study also identified challenges in the convergence phase of generative AI. Furthermore, the researchers found that interpreting the authenticity and bias issues in the content generated by generative AI tools depends on the ethical awareness and judgment of the designers using these tools.

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