

Exploring the Cultivation of Digital Intelligence Design Talents: A Case Study of Human–AI Co-Creation in Forward-Looking Robotic Application Scenarios

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Abstract This study examined the application of artificial intelligence (AI) technology in design education and its broader impact on the design industry. It analyzed the potential of AI in design and creative processes, emphasizing the importance of cultivating digital intelligence design talent. Through case studies and teaching experiments, the research revealed how AI tools can enhance design efficiency, democratize design processes, and stimulate creativity. The study addressed the limitations and challenges of AI tools in design education and offered future research directions, highlighting the importance of human-centered design, lifelong learning, and the role of higher education in integrating AI technology within design curricula.

Keywords design education, digital intelligence design talents, artificial intelligence (AI), human–AI co-creation

1 Introduction

Large language models (LLMs) and generative artificial intelligence (GenAI) are beginning to play an increasingly significant role in design, particularly in inspiring creative ideas, generating content, and evaluating design concepts. Through human–machine collaboration, these technologies have enhanced designers’ efficiency and innovative capacity (Benkhalfallah et al., 2024), enabling individual

creativity to contribute to collective intelligence and fostering a new design paradigm. To adapt to these advancements, we introduced the course “Design Thinking and Concept Design” at Wuhan University, which integrates LLMs and GenAI to cultivate innovative skills and equip students with the ability to effectively utilize artificial intelligence (AI)-assisted design tools.

2 Objectives, Background, and Research Topics

Recent studies have demonstrated AI’s significant utility in design and creative tasks. For example, Sbai et al. (2019) highlighted the potential of generative networks to inspire human designers. Muller et al. (2022) introduced GenAICHI, a GenAI and human–computer interaction framework designed to facilitate collaboration between humans and AI in design tasks. Additionally, many designers now incorporate image generation into their workflows by using AI to create new designs, patterns, or textures (Oh et al., 2018). AI is increasingly being applied across various stages of the design process, from concept generation to product development, driving the digital transformation of the design industry.

Given this trend, designers need to adapt to digital technologies and learn to effectively manage and utilize AI tools. By examining the application of AI in design education, this study aims to reveal its potential to inspire creativity and enhance design efficiency. Thus, this study addresses the following research questions:

(1) Are the experimental steps and methods

proposed in this study effective?

(2) What positive impacts can human–AI co-creation bring?

(3) What are the limitations of AI tools, and how can human–AI co-creation mitigate them?

3 Methodology

In this study, we employed case studies, self-learning strategies, and reflective analysis to thoroughly examine the effectiveness of AI tools in design education. Similar to existing research, our approach inevitably carries subjectivity, stemming not only from our personal backgrounds and professional inclinations but also manifesting in how we guide students in using AI tools and designing and interpreting research findings. Despite these limitations, we contend that these subjective elements are an advantage within the context of exploratory research and enabled us to conduct in-depth qualitative reflections that would be difficult to achieve through more quantitatively oriented approaches.

4 Specific Methods

This human–AI co-creation teaching experiment was conducted within the “Design Thinking and Concept Design” course at the School of Urban Design at Wuhan University. The program was a 32-hour core professional course offered to third-year undergraduate students majoring in product design. The educational

objectives of this course were to ensure students master the core concepts and methodologies of design thinking, enable them to apply design thinking in innovative design, and completed the design process from concept to prototype. The main teaching components and arrangements included foundational design thinking concepts and methods, concept design practice (divergent and convergent thinking), design implementation (detailed design incorporating design topics), and design presentations and exhibitions. The human–AI co-creation teaching experiments were primarily implemented during the concept design practice and design implementation phases.

The project requirements for this teaching experiment were as follows: Based on collective intelligence innovation methods and human–AI co-creation, explore forward-looking application scenarios, or focus on real-world problems to design corresponding robots or robotic systems.

The experiment was divided into three phases, as shown in Figure 1.

Phase 1: Students generated numerous creative solutions within a set timeframe through group discussions using the classic collective intelligence innovation method, including Gordon method (a brainstorming method that stimulates innovative thinking based on abstract thematic keywords) as a divergent thinking tool, and the 6-3-5 method (a brainstorming method for generating a large number of creative drafts in a short period of time) as an implementation tool (Curedale, 2013), and strictly following the key points of brainstorming implementation.

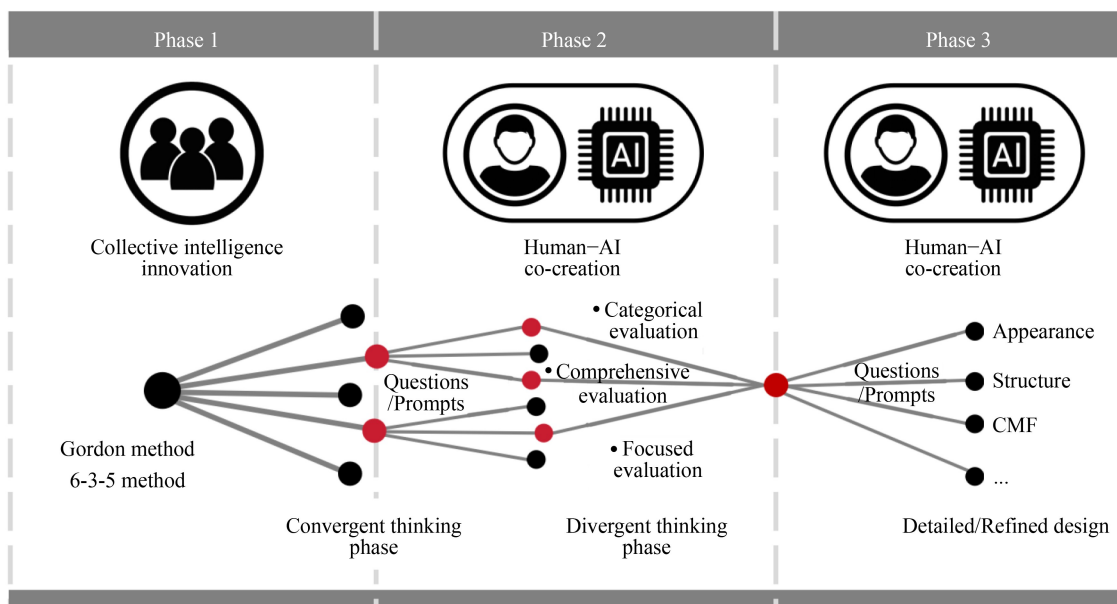


Figure 1 Divergent and convergent thinking based on human–AI co-creation. CMF: color, material, finishing.

Phase 2: Students posed questions to AI tools to obtain indirect or direct answers (divergent thinking phase) and instructed AI to perform categorical, comprehensive, or focused evaluations to select effective creative proposals (convergent thinking phase).

Phase 3: Students used prompts, sketches, and reference images to utilize AI image generation tools to accelerate the development of design solution forms, including but not limited to appearance, structure, CMF (color, material, finishing), and other design elements.

4.1 | Case Study 1: Conceptual Design of an *In Situ* Conservation Robot System for Endangered Orchids

4.1.1 Human–AI Co-Creation in Conceptual Design

During the divergent thinking phase of conceptual design, brainstorming was conducted based on the group leader's abstract proposition of "folding—A highly adaptable form of robotic structure." Students gathered in groups, with each person sketching at least three creative proposals within a five-minute timeframe. When the time was up, the students passed their draft papers to the next student, beginning the next timing cycle. The case facilitator compiled and documented 85 design proposals. Subsequently, centered on the abstract proposition of "folding," the case facilitator prompted the LLMs (ChatGPT-4o, Kimi) from both abstract (obtaining indirect answers) and concrete (obtaining direct answers) perspectives as follows:

Question 1: Help me conceive 30 design solutions related to "folding" and evaluate these 30 proposals by comprehensively considering their social benefits, economic value, and cultural implications. Rank these proposals from the best to the worst.

Question 2: Help me conceive 30 different types of folding robot conceptual design proposals that are highly implementable, creative, unique, and novel which aimed at environmental protection and ecological restoration. Evaluate these 30 proposals by comprehensively considering their social benefits, economic value, and cultural implications. Rank these proposals from highest to lowest.

Phase outcomes. After comprehensively considering the divergent thinking inspired by both classroom groups and the LLM, the case facilitator ultimately determined the design direction to focus on foldable robots on a microscopic scale. Using this as the design subject, the author utilized the LLM to complete the thought organization and research work quickly.

Question 3: What application scenarios can foldable microscopic robots be used for?

ChatGPT response: They can be applied in interdisciplinary fields such as medicine, environmental engineering, manufacturing, biotechnology, precision agriculture, exploration, nanomaterial production, and endoscopic examination.

Question 4: Please provide global data on endangered plants.

ChatGPT response: Currently, more than 45,300 plant species are threatened with extinction, accounting for 28% of all assessed species. These are predominantly distributed in tropical and Mediterranean regions, with *Orchidaceae* plants representing the highest proportion of endangered species at 26%.

Question 5: Describe the habits and characteristics of *Orchidaceae* plants and analyze the survival status and causes of the endangerment of *Orchidaceae* plants in China.

ChatGPT response: In natural conditions, *Orchidaceae* seeds have an extremely low germination rate and require symbiotic association with specific fungi to form endomycorrhizae. These fungi provide nutrients for embryoless seeds, enabling normal germination. Low pollination success and germination rates are among the main reasons for *Orchidaceae* endangerment.

Progress outcomes. Based on ChatGPT's responses, the literature review, and personal reflection, the application scenario was identified as an intervention in *Orchidaceae* pollination/seed sowing. The robot's purpose was determined as *Orchidaceae* seed collection and *in situ* conservation.

4.1.2 Human–AI Co-Creation in Product Form Development

After determining the specific application scenarios and product usage, the process continues to the human–AI co-creation phase for product form development. Thus, the case facilitator posed the following question:

Question 6: What feasible robotic design solutions exist for the pollination and embryo cultivation of endangered *Orchidaceae* plants?

ChatGPT response: Key conceptual elements include:

- (1) Using small drones as pollination mediators, mimicking insect pollination.
- (2) Combining AI with GPS data enables robots to learn and optimize pollination routes.
- (3) Equipping robots with automatic charging systems to ensure prolonged continuous operation.
- (4) Designing modular robots for ease of maintenance and upgrades.
- (5) Developing systems for multi-robot collaboration to enhance pollination efficiency.

Based on these insights, the authors

summarized key terms for product form as follows: biomimetic principles, biomimetic structures, miniature drones, modular structures, robotic systems, and *in situ* conservation.

The authors use Kimi to generate clear and logical textual solutions based on design concepts, and employs ChatGPT to transform these textual solutions into prompts that Midjourney can understand. Finally, Midjourney converts these prompts into visual images. This method leverages the strengths of all three tools, thereby enhancing the efficiency and quality of the design process.

Based on this, the author then posed a query to the generative image model Midjourney 6.1 using these key terms:

Question 7: Hexagonal honeycomb-structured biomimetic robot, nest structure, small-scale, honeycomb, soft silicone material, and framework structure.

As a design reference, the generative image model provided abundant sources of inspiration (see Figure 2). These images offer comprehensive conceptual drafts for form design, enabling the extraction of effective forms and structural elements for further detailed aesthetic and structural refinement.

4.1.3 Design Outcome Presentation

In the design process of the endangered *Orchidaceae in situ* conservation robot, the author adopted a systematic design-thinking approach to improve seedling survival rates and enhance the effectiveness of *in situ* conservation.

The final design is a biomimetic micro-insect robot and nest system (see Figure 3). The biomimetic micro-robot can carry pollen, collect ovaries, and sow seeds. The nest system's functions are to cultivate seedlings and provide a preferential environment for symbiotic fungi.

4.2 | Case Study 2: Design of a Ghost Fishing Gear Cleaning Robot System for Coral Reef Areas

4.2.1 Human-AI Co-Creation in Concept Design

This course team decided to design rotational structures. AI was then firstly employed to expand these ideas and address the knowledge gaps through the following prompts:



Figure 2 Reference images generated by Midjourney and scheme selection.

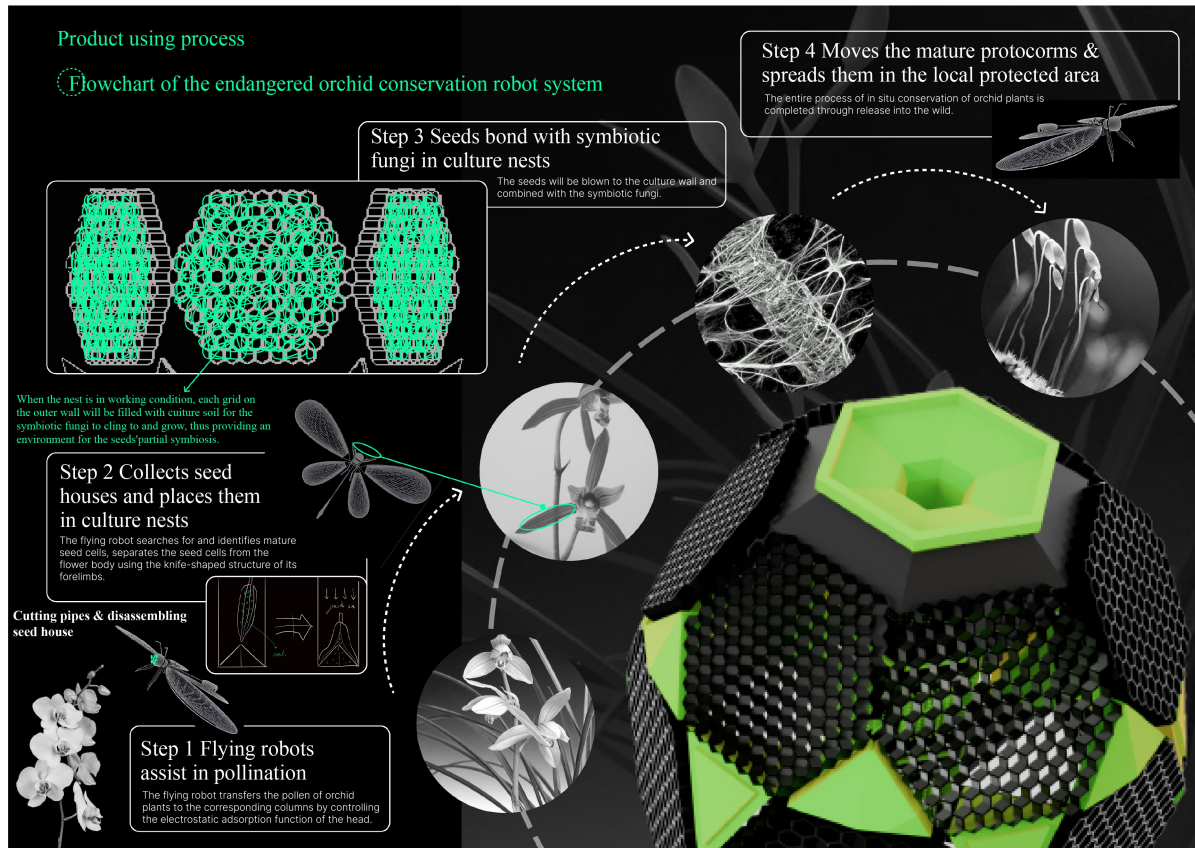


Figure 3 Excerpt from “conceptual design of an *in situ* conservation robot system for endangered *Orchidaceae* plants.”

Question 1: Provide 30 rotational mechanisms inspired by structures, mechanics, and biology.

Question 2: Envision 30 ways rotational mechanisms could integrate with robots, detailing the specific rotation method and functionality for each.

This process provided structural and technical inspiration, narrowing the focus to pressing societal and environmental issues.

Subsequently, we posed questions to ChatGPT regarding the major threats to coral reef ecosystems.

Question 1: What are the main threats to coral reef ecosystems caused by human activities?

ChatGPT response: The primary threats are overfishing, coral bleaching due to climate change, pollution, and ghost gear. Ghost gear is especially dangerous due to its durability and entanglement risks.

Question 2: Why is ghost gear highly detrimental to marine ecosystems?

ChatGPT response: Ghost gear, made from durable and non-biodegradable materials, persists in the ocean, continuously trapping and killing marine life. It also damages coral reefs and disrupts habitats, as supported by scientific research.

Therefore, AI helped identify “ghost fishing gear” as a significant threat to marine ecosystems. Ghost fishing gear, made from durable, non-degradable materials, poses severe challenges to cleanup efforts due

to its complex shapes and locations, thus endangering coral reef habitats and marine life.

After in-depth AI-assisted research on coral reef ecosystems and the hazards of ghost fishing gear, the design direction was established as follows: A robot system capable of adapting to the complex terrain of coral reefs while cleaning ghost fishing gear with minimal disruption.

Preset goals including:

- (1) Adaptability to complex terrain;
- (2) Multifunctional operation;
- (3) Environmental friendliness and sustainability;
- (4) Efficiency and intelligence.

For complex reasoning tasks, we chose ChatGPT due to its strong performance in logical reasoning and language comprehension. For example, Espejel et al. (2023) evaluated the performance of GPT-3.5 (the base model of ChatGPT) on reasoning task datasets, where GPT-3.5 achieved an accuracy of 65.2% on StrategyQA, indirectly reflecting its strong analytical capability.

However, in Question 3, we chose Kimi over ChatGPT because the problem required solutions grounded in existing empirical schemes, not just logical deduction. Kimi’s real-time data access and empirical approach ensure the feasibility of the solutions.

Therefore, the following key questions were posed to two LLMs (ChatGPT-4o and Kimi) to guide the robot design.

Question 1: How can robot design improve ghost fishing gear cleanup efficiency?

ChatGPT response: Use a “task division and collaborative operation” model, where a main unit handles navigation, energy supply, and communication, while sub-robots focus on precise cleaning tasks.

Question 2: What functions should sub-robots have to adapt to the complex terrain of coral reefs?

ChatGPT response: Multi-degree-of-freedom mechanical arms, flexible materials, real-time obstacle avoidance guiding system, underwater grasping and cutting capabilities, and anti-adhesion shell design.

Question 3: How can cleaning operations minimize ecological disruption?

Kimi response: Bionic propulsion mechanisms, such as crab-inspired swimming legs, supported by extensive experimental data, can reduce the environmental impact.

Question 4: How should the mother-child collaborative workflow be designed?

ChatGPT response: A “scan-deploy-clean-recover” framework: A mother ship scans the target area using sonar for location mapping → Sub-robots autonomously navigate to specified positions based on the mother ship’s instructions → Sub-robots execute cleaning tasks and store gear in collection chambers → The mother ship retrieves sub-robots and processes the collected gear.

The design was refined by establishing functional architecture and leveraging AI-assisted

research on relevant technologies and mechanics.

4.2.2 Human-AI Co-Creation in Product Form Design: Inspiration and exploration of form design

During the initial conceptualization phase, the case facilitator leveraged AI tools to generate multiple conceptual sketches of robot forms, as shown in [Figure 4](#). These sketches were focused around keywords such as “rotational structure,” “multi-functional mechanical arms,” and “streamlined underwater design,” providing a rich source of inspiration. However, these AI-generated images were used only as references and were not directly adopted in the final design. Key elements, such as the distribution of modular mechanical arms and streamlined structures, were extracted by the author to aid in optimizing the design.

Final form and structural determination:

(1) Main body design: The main body adopts a streamlined polygonal structure to reduce resistance and enhance stability during underwater operations.

(2) Mechanical arm modules: Two flexible mechanical arms are included, equipped with rotary grasping tools. These arms can accurately cut, grasp, and collect ghost fishing gear while adapting to the complex terrain of coral reefs.

(3) Propulsion system: A bionic crab-inspired swimming leg propulsion system (a multidirectional rear propulsion module) was selected using AI-assisted research. This design maintains stable movement in complex water current environments while minimizing disruption to the seabed ecosystem.

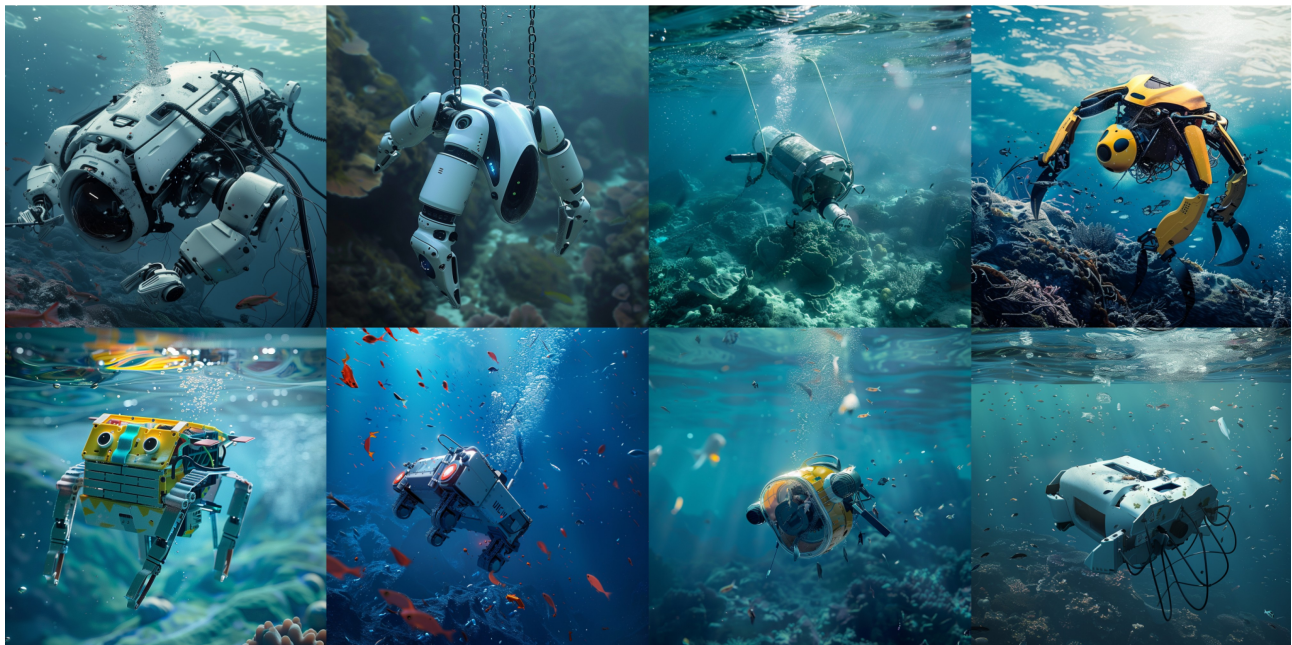


Figure 4 Reference images generated by Midjourney.

Through the human–AI co-creation model, AI contributed diverse sources of inspiration during form exploration. The final design was based on real-world application scenarios, materials science, and engineering principles to ensure functionality and environmental adaptability (see Figure 5).

4.2.3 Design Outcome Presentation

The robotic system features a mother–child collaborative structure to enhance cleaning efficiency and adaptability. It embodies automation, ecological friendliness, and precision in handling ghost fishing gear by combining multimachine collaborative deployment, bionic structures, and system redesign. This design provides a superior solution for cleaning coral reef areas with minimal environmental impact.

4.3 | Experience and Reflection

We summarized the experiences and reflections of this study based on the two representative cases above and the other 24 assignments produced during the course. As the teaching and experimental aspects of the course are optimized, we will continue to accumulate data and

insights regarding the innovative paradigm that combines crowd-intelligence co-creation and human–AI co-creation.

4.3.1 Observations

(1) Effectiveness of the experimental steps and methods

The three experimental steps proposed by the course were reasonable and effective, and the teaching approach proved to be highly practical (see Figure 1). The results showed that all 26 students successfully completed the experimental tasks at each stage, with an overall improvement in the quality of the final course assignments.

(2) Enhancing design efficiency through crowd-intelligence co-creation and human–AI co-creation

The combination of crowd-intelligence and human–AI co-creation significantly improved design efficiency. This included extracting key issues and essential elements, searching for structural patents or relevant literature, and generating suggestions for design directions.

(3) Role of LLMs and GenAI tools in supporting the design process

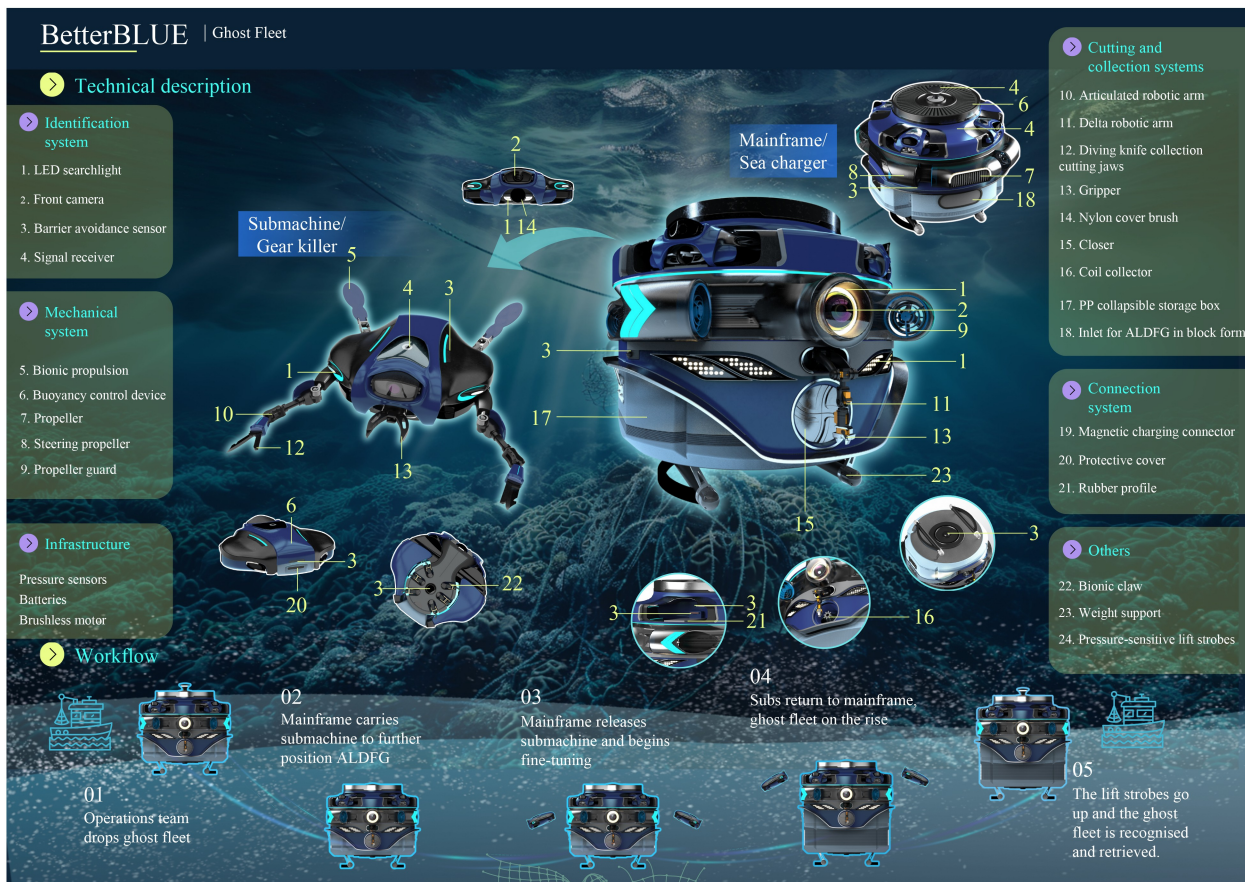


Figure 5 Excerpt from “design scheme of a ghost fishing gear removal robot system for coral reef areas.”

The LLMs and GenAI tools demonstrated substantial utility in the design process. They provided robust data processing and retrieval capabilities and played a critical role in areas such as idea generation, solution optimization, and decision support.

(4) AI tools as references for form optimization and functional improvement

AI-generated outputs served as important references for refining design forms and enhancing functionalities. This process reduced the trial-and-error costs typically associated with traditional design workflows.

(5) Facilitating cross-disciplinary integration through human–AI co-creation

Human–AI co-creation effectively removed disciplinary barriers, promoting knowledge integration across different fields. This approach provided designers with broader perspectives and more diversified solutions, thus expanding their creative and problem-solving boundaries.

4.3.2 Reflection

(1) Limited effectiveness in disruptive innovation

The underlying logic of GenAI inherently reconstructs and reorganizes existing experiences or solutions, which limits its potential to foster truly disruptive innovation. The course results indicate that most innovations achieved were incremental rather than groundbreaking.

(2) Lack of detail and logical consistency in AI-generated designs

AI-generated designs often lack sufficient detail and logical coherence, serving primarily as references for styling. The abundance of AI-generated design drafts requires designers to manually screen, refine, and deepen concepts, which poses a significant challenge for students. Under the framework of human–AI co-creation, designers are not only creators but also curators of aesthetics and guardians of ethical considerations.

(3) Understanding the boundaries of human and AI capabilities

Designers need to comprehend the distinct boundaries of human and AI capabilities. In a co-creation model, designers and AI tools act as collaborative creators (co-creators). While AI can alleviate repetitive tasks and leverage its strengths in efficiency, human designers should address AI's shortcomings in comprehension (e.g., context and object judgements) by amplifying their own unique qualities, such as comprehensive understanding, empathy, critical thinking, and originality, which AI lacks.

5 Discussion

5.1 | Challenges of Crowd-Intelligence Co-Creation in Design Education

In design education, crowd-intelligence co-creation involves collaboration among professional educators (designers), target users, interdisciplinary experts, and students. It emphasizes the integration of diverse perspectives to stimulate innovative solutions for open-ended design problems. However, practical limitations in teaching resources and time often prevent students from fully understanding interdisciplinary and cross-domain knowledge, hindering their ability to broaden perspectives and tackle complex issues effectively.

5.2 | Transformations Brought about by Human–AI Co-Creation in the Design Industry

Human–AI co-creation is reshaping design education and transforming the design industry. As enterprises increasingly employ AI tools for design innovation, there is a growing demand for professionals skilled in digital intelligence design. To meet industry needs, design education must integrate the processes and methods of human–AI co-creation into the classroom to cultivate students' digital intelligence.

5.3 | How Human–AI Co-Creation Changes Design Education

AI has demonstrated significant potential in inspiring creativity, generating content, and evaluating design solutions (Zhang & Han, 2024). Through collaboration between AI and designers (including design students), human–AI co-creation broadens perspectives and reduces the need for extensive interdisciplinary coordination. In the design process, AI can assist in perception, ideation, expression, collaboration, prototyping, and testing (Wu et al., 2021). In practice, incorporating AI into teaching has revealed expanded design possibilities, such as exploring new application scenarios, addressing potential design challenges within these scenarios, and identifying structural innovations to meet functional needs.

6 Future Research

6.1 | Challenges in Cultivating Digital Intelligence Design Talent

Both domestic and international AI software are now

utilized in areas such as media design (e.g., Midjourney and Stable Diffusion), industrial design (Vizcom), branding (UBrand), interaction design (Uizard), and video generation (Runway). This necessitates incorporating human–AI co-creation workflows and methodologies into classrooms to cultivate digital intelligent design talent that aligns with industry demands. The design industry is witnessing rapid advancements in AI tools—ranging from LLMs such as ChatGPT and Kimi to specialized software in various design domains. While these tools lower entry barriers for junior designers, they also disrupt the job market because of possible cost saving. Design students must not only master these tools but also engage in effective design practices during their studies. Gaining practical experience and understanding design implementation processes can enable students to fully grasp digital intelligence design theories and methods. This preparation will equip them for roles that require both crowd-intelligence co-creation and human–AI co-creation skills.

6.2 | Limitations and Risks of Human–AI Co-Creation in Design Education

Developing a talent pipeline for human–AI co-creation must address several issues:

(1) Resource allocation: Access to AI tools and computational resources is uneven, leading to inequalities in education.

(2) Creative limitations: AI-generated designs rely on existing data and algorithms, often lacking disruptive innovation or cultural and emotional understanding.

(3) Overdependence on AI: Automation may lead to students losing initiative and problem-solving skills, neglecting foundational abilities such as sketching and prototyping.

(4) Intellectual property concerns: Overreliance on AI may result in designs overly similar to database entries, raising risks related to patents and ownership.

6.3 | Goals and Research Directions for Digital Intelligent Design Talent Development

Recent frameworks, such as UNESCO's *AI Competency Framework for Students and AI Competency Framework for Teachers* (UNESCO, 2024a & 2024b), emphasize the responsible and effective use of AI in education. This includes defining required competencies, outlining ethical principles, and providing application recommendations. In China, the Ministry of Education

has issued guidelines to enhance teachers' digital literacy and to regulate the integration of AI with educational resources (MoE, 2014, 2019, & 2022). Cultivating multidisciplinary talent proficiency in both industry and digital technologies is essential to meet the demands of high-quality industry development.

Achieving this goal requires emphasis on human-centered design, lifelong learning, and the allocation of sufficient resources for integrating AI tools with existing educational systems. In addition, providing comprehensive training for educators and developing AI tools tailored to the specific needs of educational institutions will enable the seamless fusion of AI technologies and design education, preparing students to adapt to the evolving demands of the future workplace.

7 Conclusions

Crowd-intelligence co-creation in design education emphasizes collaborative innovation from diverse perspectives but is constrained by limited teaching resources and time, often leaving students without adequate interdisciplinary knowledge to address complex problems. Human–AI co-creation, which integrates AI tools with designer creativity, has driven transformative changes in both design education and industry, becoming a cornerstone of enterprise innovation. This shift necessitates incorporating corresponding methods and workflows into educational frameworks to cultivate digital intelligent design talent. However, human–AI co-creation faces challenges, including resource inequities, creative limitations, and overreliance on AI. Addressing these needs requires optimizing training systems and integrating AI responsibly into education. Future design education should uphold human-centered principles, prioritize lifelong learning, and invest in AI-enabled educational innovations to prepare students for the demands of an AI-driven world.

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Data Availability Statements The authors confirm that all data generated or analysed during this study are included in this published article.

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