INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 15, Issue 2, (2026) E-ISSN: 2226-6348

Impact of Generative AI Integration on Design Sketching Pedagogy in Higher Education: An Empirical Study in Mianyang, China

Wen Quan*, Li Bei Er, Wang Hao Wei, Chen Hai Min

Mian Yang Teacher`s college

Corresponding Author Email: wenquan2020@aliyun.com

DOI Link: http://dx.doi.org/10.6007/IJARPED/v15-i2/28102

Published Online: 29 April 2026

Abstract

This study aims to address teaching bottlenecks in design sketching courses, such as insufficient creative divergence and high technical barriers. It introduces an AI agent (Doubao) as an auxiliary tool in university teaching and employs a mixed-methods approach combining quantitative questionnaires (N=486), student interviews (N=35), and expert evaluations (N=3) to systematically assess its application effectiveness. Results indicate that AI effectively enhances students' creative generation efficiency, visual expression capabilities, and learning confidence, demonstrating particularly significant effects in conceptual divergence and creative process restructuring. However, it also brings issues such as insufficient operational understanding, stylistic homogenization, and creative dependency. Expert evaluations affirm its value in stimulating innovation and expanding visual language while cautioning against the risks of over-reliance. The study confirms that AI agents possess dual-natured pedagogical potential, requiring an application model centered on “human-machine collaboration with human-led control” for effective integration. This research provides empirical evidence and practical guidance for AI applications in art and design education, as well as for sketching pedagogy reform.

Keywords: Artificial Intelligence, AI Agent, Design Sketching, Art and Design Education, Mixed Research Methods, Teaching Support Effectiveness

Introduction

Research Background

Recently, AI is rapidly changing the ecosystem of art and design education. In the field, like in fields such as image generation, style transfer and visual reasoning, generative AI can display remarkable abilities, and gradually became an essential new type of tool for classroom in the field of art and design Hughes,Zhu,& Bednarz, 2021). From International Design Academies to our Universities class rooms, AI has progressed from being additional teaching aids to becoming “smart assistants” participating in the creation of design work. It gives the students quick help with what they can see, their ideas, and how things are built. This transformation is proven by many international studies as a main part of the digital transformation in design education (Biswas & Talukdar, 2025). It will also exert pressure on the digitization process in the field of art and design education, which is not only pressuring on education but also

profoundly reforming the old architecture of teaching, the course system construction, and learning methods. The deep integration of AI tools has caused many universities around the world to reshape the pedagogies of creative generation and practice courses (George, 2023).

With the development of the art and design industry, higher education institutions demand more talented students of art and design. For the rising industry need of digital expression, intelligent design and cross-discipline creation, universities need to do more exploration on the new technology and media education. Cambridge University's global design industry survey shows that the corporate requirements of employees' ability to use AI is rising, and this is directly affecting the education reform (Jaiswal, Arun, and Varma, 2023). AI tech has good adaptability to the job requirement of the art and design industry. For example, integrating intelligent design assistance and rapid visual iterations such industry standard workflow can be incorporated into classrooms through AI assisted teaching. Help students to form an own professional competitive system that adheres to the standards of industry. Scholapurapu et al. (2025) confirmed through practical experience that this integration pathway greatly improves graduates' employability.

Against this back ground, we think it important, in terms of theory and action, how and whether AI agents can be used for the design teaching of universities under an understanding of the changes that occur when technology education is applied.

Problem Statement

Design sketching is a fundamental course in art and design programs. It occupies an irreplaceable position in nurturing students' design thinking, visual expression abilities, and formative capacity (Hoffmann, 2019). However, traditional design sketching instruction still encounters many difficulties, including students' lack of creative divergence, difficulty depicting complicated structure, and different learning speed (Henriksen et al., 2017).

AI technologies have developed, putting AI tools into design sketching classes is actually necessary. On the other hand, with AI, students can quickly generate various visual references for creativity. On the contrary, it can help students improve their understanding and expression of the structure of building analysis and training of form reconstruction, through AI (Zhao, 2025). Also, students with less foundation, decrease the technical hurdle, increase the student's learning enthusiasm, sense of participation of course, so as to improve the entire learning effect (Huang et al., 2023). More importantly, whether the AI agents can get to the point of "precision-empowered" design sketching instruction, which can provide tailor-made assistance for different teaching modules like still life sketching, creative sketching and structural sketching, is a highly valuable research question.

But at the same time leads to new problems and dangers. When integrated with artificial intelligence. First of all, AI interventions always push the teacher's role to transform in three directions, from being a 'skill presenter' to a 'creative coach', from a 'technical partner' to a 'technical partner', and from an 'ethical guardian' to an 'ethical guardian'. Teachers need to grasp AI tool adaptation strategies and human-machine collaboration guidance skills(Li, Y., & Wang, H., 2025). Second, the problem of balancing between "technical training" and "creative cultivation" still exists in teaching. To stop excessive technology use that might cause identical creativity or underdeveloped abilities for students. Finally, given the technical nature of

generative AI, there is still an ethical risk prevention of teaching, such as cultivating students' originality awareness, defining copyright of AI-generated content, avoiding aesthetic homogenization (Joel, 2024), etc., which is an urgent matter requiring urgent attention in current AI art education practice.

In a nutshell, systematic empirical research on the application effectiveness of AI, differential impacts, adaptability evaluation, and ethical risk management for foundational courses such as design sketching are still lacking.

Research Objectives and Questions

My idea is to figure out how AI help teach a class on Design Sketching. In order to know if AI tools really make students better at learning, help them create better things, and think up new ideas, and find out what students think, feel, and run into when using an AI agent. By using integrated qualitative and quantitative data analysis, this research aims to make the benefits, drawbacks and implementation methods of AI intervention on design sketching instruction clearer, and to give theoretical basis and suggestions for such university courses.

To achieve the above purposes, the main part of research will be conducted on the following three parts:

(A) Effectiveness: How good are AI agents at making the quality of student work on design drawing assignments better (more creative, better at doing the work, and better at putting things together)? Are there differences for these effects among various different teaching modules, such as structural drawing, creative drawing?

(Process and Adaptability) Students' behavior and experience when using AI agents for assistive learning. How adaptable are AI tools in different instructional phases (e.g., pre-class concept formation, in-class modification, post-class enhancement) and student foundation levels (beginners, art background)?

(Evaluation and Ethics) How to develop and validate a complete system to measure the results of teaching in the class where AI assisted design sketching instruction is applied? Multidimensional indicators such as "technical mastery, creative originality, collaborative skills, and ethical awareness" must be integrated within the system, how to overcome the problem of traditional evaluation framework to evaluate human-machine collaborative results (Li & Wang, 2025), and how to deal with related pedagogical ethical problems (Joel, 2024).

Research Significance

Theoretical Significance

First, this study enhances understanding of the role of AI in art and design education, makes clear on pedagogical principles and educational logic for foundational design course with technological intervention, and promotes AI education application study. Second, it can provide new directions for the "technology-education-art" interdisciplinary field, and add more cross-theoretical results in educational technology and art pedagogy. Finally, it will provide supporting evidence for the theory of teachers' role transformation in the AI era (Li, & Wang, H., 2025) and collaborative creative teaching between humans and machines.

Practical Significance

First, this study provides practical operation guidance for reforming design courses in colleges and universities, explaining when, how, and how to use AI tools in design sketching courses. Second, it supplies customized teaching strategies and role shifts for educators so that educators may use AI equipment for a variety of student groups. Third, provides decision making basis for educational administrators in making AI application policy and allocate teaching resources, help AI-assisted instruction being standardize and promote. And finally, the proposed 4-dimensional evaluations and ethics provide the frontline teaching with assessment and risk mitigation.

Scope and Delimitations

Research Scope

Content scope: This paper takes the instructional assistance of generative AI agent(AI image making tool) as the research object mainly for design sketching course. It's applied in creative divergence, structure analysis and technical assistance, and also considers the change brought by these things to student learning experience, work quality and ethical sense.

Subject Scope: The main subjects are students taking design sketching classes in art and design programs at higher education institutions, and also the teachers.

Methodological Scope: Mixed-methods strategy is used, which contains questionnaire survey, deep interview, expert portfolio, tool-based log, and scenario simulation test.

Research Delimitations

This article focuses on the application effect and impact path of AI as a teaching tool, excluding the technical process and improvement of the development of AI algorithm.

Research context is mainly carried out in the formal curriculum of higher education institutions, excluding informal extracurricular creation and application in social training institutions.

Ethical discourse will be embedded within teaching practice contexts, concentrated more directly upon those things that are related to the purposes of the course, issues such as originality, education around copyrights, aesthetic diversity. It won't have general philosophical ethical discussions

Motivation

Design sketching, as a core foundational course in art and design education, serves as a critical bridge connecting creative thinking and visual expression. However, current university teaching practice of design sketching is confronted with prominent bottlenecks: students often struggle to break through fixed thinking patterns, resulting in insufficient creative divergence and lack of novelty in design concepts; meanwhile, the high technical threshold of sketching, including proficient mastery of perspective, composition, and rendering skills, not only increases students' learning burden but also limits the effective transformation of their creative ideas into visual works. These problems not only impair the teaching quality and efficiency of design sketching courses but also hinder the cultivation of innovative talents in the field of art and design in the digital era. With the rapid advancement of artificial

intelligence technology, AI tools have exhibited significant potential in teaching assistance, providing new possibilities for solving the aforementioned teaching predicaments.

Literature Review

With the rapid development of generative AI tech, AI agents have been more and more used in art and design education, which is gradually transforming traditional teaching and creative workflow. This chapter will give an overview on three aspects: the current situation of AI agent application in art and design education worldwide, the teaching requirement and evaluation system of design sketching course, and the application of mixed research method in education. This chapter reviews related literature with the aim of building a theoretical groundwork for the current work and situating it within the existing body of academic work.

The Current Situation of the Application of AI Agents in Art and Design Education at Home and Abroad

Around the world, AI tech has been put to use in art and design education for a long time. In recent years, with the rise of new generative models like Midjourney, Stable Diffusion, and DALL·E, we are now seeing a greater role for AI in design pedagogy. When international research is done, they again and again use words about being very useful as an “aiding” to creativity so that students can make much better looking concepts. This quickens the tempo of generating ideas and diversifies artistic expressions. In many design schools, AI is being used to help with the generation of concepts, visual experiments, and sketches, which are now more often included in design thinking training (Saritepeci & Yildiz Durak, 2024). Hutson & Cotroneo (2023) state that not only does AI aid with image generation, it also helps students enter states that are more open, divergent. This allows students who were held back by drawing skills to quickly try out a lot of different visual possibilities. And at the same time, foreign scholars also said, the ai should be treated like an “intellectual associate” instead of an instrument. It could take part in the users' thoughts and provide smart assistance for information examination, visual extraction and style application (Youvan, 2024).

Deeper in international research we find interdisciplinary trends in combining AI and design education. Some scholars emphasize that design education in the AI age needs to go beyond traditional disciplinary boundaries and build a cross-disciplinary training system integrating “technology + humanities + society,” incorporating algorithmic logic from computer science, new applications from materials engineering, and design ethics into teaching (Lu, 2024). This type of interdisciplinary combination is not only in terms of curriculum, but also in terms of pedagogy - for example, adopting "AI + project learning". This way is able to let the students work together to improve both technical proficiency and design thinking by addressing real world design problems(e. g. sustainable design,intelligent interaction design)(Brown& Lee, 2024). Additionally, there has been the development of research into AI design ethics. The scholars point out that it is necessary to add modules about how to identify algorithmic bias and define the copyright of generated content into the curriculum in order to develop students' ethical sense of technology (Garcia et al., 2023).

But international works also point out the dangers of AI to the design education. Like, some point out that gen AI could cause stylistic sameness in student work, and if the training data has biases, those might be copied into the creative stuff. In addition,AI-generated images may be visually impressive, but they often lack substantial design logic. This may result in "visual

dependency", and may neglect the training of core competencies such as composition, structure and design intent. These are all points of contention in the international debate on the use of AI in education, whether or not it should be done at the cost of originality. Lately research narrows down this danger part showing that students highly depending on AI get notably worse scores when handling problems in problem solving and critical thinking during making changes in designs compared with those in usual teaching setup. This shortage is most evident with unusual design requirements (Wilson&Clark,2024).

Art and design education, within China, the use of AI agents, is somewhat late to the party but has grown quickly. In recent years, domestic AI tools like Wenxin Yige, Doubao, and Tongyi Wanshang have successively entered university classrooms and are commonly employed for image production, material support, visual examination, and work improvement. Most domestic literature talks about whether AI has a pedagogical effect like making students have less entry barrier to class, making class more efficient, and inspiring students' design inspiration. Most of them find that AI helps students who have weak foundational skills in making high-quality sketches fast and techniques like prompt engineering make it easier for students to express themselves well and organize their vision well (Fan, 2024).

In the midst of generative AI's quick spread within higher education, fine arts and design fields are being transformed in a cascading manner from tools to processes to paradigms. Shan Junhao, Liu Yonggui(2023) note that GAI changes old ideas about what knowledge is and how we learn it, moving design education from classes led by teachers to a teamwork between teachers, machines, and students: The goal of learning is a knowledge leap, the setting of learning is real-world exploration, the process of learning is real-time support, and the evaluation of learning is evidence-based. Therefore, they suggest GAI take on three roles, experiential learning designer, intelligent learning companion, and smart critique expert. Building off the 4C/ID, they provide actionable steps on how to teach, giving an organized way to bring GAI into the art curriculum. The Lü Xi team of Sichuan Fine Arts Institute (2025) even used this system in the field of "AI+Art". Based on MindSpore from MindSpore, he built up the "Bamboo·Script" Cultural Generation Model and conducted an "Human-Machine Collaboration" Experiment in the "Intelligent Interaction Design" Workshop. Student works have won the ChinaVis 'Best Presentation Award', thus verifying the efficacy of the three-stage process - 'AI-generated sketches → student secondary creation → teacher critique' - in digital art settings. Yan Xun (2023) from Hubei University of Technology supplemented this with micro level evidence through quantification: using tools such as Midjourney and Stable Diffusion in Art Design Course has greatly speed up students' task completion and increase creativity but at the same time also reduce originality. So we proposed a more balanced "teacher guided + human-machine co-creation" approach for efficiency and critical design. Wang Kuanyu (2025) focused on traditional software classroom and embedding AI plugin in Photoshop and Illustrator instruction and reconstructing teaching objective, content, method, and evaluation system. From these results we find out that AI could do the simple parts such as masking image, selecting good colors and giving hints on fonts so that teachers would spend their time explaining the cooler bit in class. Creating a brand new "AI-assisted portfolio quick iterations" for packaging design, visual communications and so on. In short, art and design program in universities in China is going through from isolated experiment to systemic transformation. Generative AI is no longer seen simply as an efficiency tool, but as a significant variable affecting the formation of curriculum structure, the design of learning models, and

the criteria for evaluation (Shan Junhao & Liu Yonggui, 2023; Lü Xi, 2025; Yan Xun, 2023; Wang Kuanyu, 2025).

On the other hand, similar to what is done internationally, local scholars also study how AI affects the originality and development of one's personal style. And some studies say too much use of AI-generated images might make it so students don't know as well how to work with formative ideas and showing skills. In addition to that, AI-generated content that is uncontrollable, as well as technical interpretation ability disparity, can lead to “creative disconnect” or “misunderstandings” by students using AI (Lu et al., 2023). Di Paolo (2025) warns that current AI evaluation systems have limitations and can overlook the hard-to-quantify factors of emotional expression and cultural connotation of design, which can result in one-sided teaching evaluation.

In summary, both at home and abroad, most of the research on the auxiliary role of AI in art and design education is recognized, but the application is still tentative. Especially about what to do to help students set up a “people running the show and AI being an aide” kind of relationship, quite a lot of room to talk about it. More empirical research is required to prove that AI can teach and how it works in specific classes such as design sketching. Future study should have three focuses: First, constructing a three-in-one training system of “professional skills, humanistic qualities, and moral obligations”; Second, creating AI evaluation tools fit for design education that combines formative and summative evaluation. Three is to investigate the use of AI to combine traditional culture elements with modern designs to build unique design education models.

Design Sketching Course Teaching Requirements and Evaluation System

Design sketching being part of the fundamental subjects in many art and design courses plays a central role across the world’s design education systems. Unlike traditional figure drawing where the fundamental purpose is not for training students' realistic figure drawing skills or basic form-rendering abilities. But to develop design thinking through sketching, building structuration thinking and the abstraction of forms and visualization expression(Kelley & Sung, 2017). Therefore, many design drawing courses will stress how to understand the internal structure of an object, how to express abstractly geometric relationships and so on, to comprehensively understand what is being composed in the image (Howell, 2020).

The teaching demands of design drawing course generally have three levels. Firstly, in terms of form and observation, students need to understand the relationship of perspective, proportion, structure and the spatial form of unfolding through continuous practice. They are the basic abilities for all design-related courses(Wong, 1993). And also is a part of the expression and language level, that means that we need to clearly express the structual information, the morpholigical information and so on, by using line, by using light and shadow, by using the composition and so on. Design drawing focuses more on abstraction and designing expressions, it is necessary for students to have a clear structure, rigorous logic and simplicity of the visual (Ma & Wei, 2025). Third is creativity and concept. Design sketching goes beyond observation to be a key start for training in design thinking. When representing subjects, students should be engaged in visual rebuilding, formal exaggeration, and structural extension to build a visual language with design characteristics (Kress & Van Leeuwen, 2020).

Requirements also differentiate from regular drawing and makes it closer to studying expression of design and building in visual terms.

For evaluations, in design drawing classes there is a lot of multi and tiered multidimensionality. The traditional evaluation system focused mostly on accuracy of form and the execution of the technical skills (Hammond et al., 2018). But with the change in design education goals, modern course evaluation systems put more focus on how innovative the work is, how well it gets its message across visually, and what the student went through in the learning process (Freedman, 2025). Take evaluating a design sketch as an example, we do not just check the line skills or structure rendering anymore. Instead, it looks at whether it contains design thinking, a design-oriented structure, conveys the right design intention, and is formally innovative. In addition, with respect to AI -assisted instruction, the capacity of students to evaluate, choose, refine, and re-create AI -produced materials is more and more a part of evaluating a course. Design sketching pedagogy evolution in AI period (Piotrowska, 2025).

From the curriculum structure point of view, design sketching is paying more attention to “process oriented learning”, it focuses on how the students do their sketches during the creative procedure, how the students deconstruct the structures from many different views, and how the students complete an expressive job via visual transformation. With more and more digital and ai tool combination, the courses have also been greatly changed. Traditional "sketches from life - rough drafts - final drafts" is slowly moving toward "AI generation - selection - structural analysis - reconstructed expression." AI generated images have become a major source of inspiration for students to explore their visual world. It also broadens creative possibility but requires new ones like writing prompt skills and critical literacy to read what AI writes and cross media expression.

Mixed Methods in Education

As a mixed-method research strategy combining quantitative and qualitative approaches, it has been widely adopted in educational studies in recent years (Pregoner, 2024). This kind of mixed-method research has great strength in researching emerging technology, instructional innovation and complicated learning behaviors. The key of mixed method is combining the broad quantitative data and the deep qualitative data, which is to make the researchers have an all-around understanding of educational events from two aspects, “phenomenological description”, and “mechanistic explanation”

In educational studies, quantitative data may show educational trends, check if teaching went well, or look at how different things work together, but unquantified data tells us why students act the way they do, how they feel, and what they take from learning (Johnson & Christensen, 2024). Through the combination of the two kinds of data, mixed methods complement each other. For example, when studying AI-assisted learning, if one relies only on survey data, then even if changes in student satisfaction and learning efficacy and attitudes towards use are found, it is likely that students’ psychological feelings, operational difficulties, and cognitive contradictions in AI-driven creative tasks are not revealed. And put together some qual data like interviews or observations of a classroom or analysis of some portfolios to get a larger sense of whether and how AI interferes with the process of learning, and eventually could result in something more complete.

Another plus of mixed methods is its suitability for complex educational situations (Pregoner, 2024). Learning processes tend to have many different and multi-level interaction parts - like how smart a student is at using technology, what makes them want to learn, how the classroom feels, and what things the teacher has to help them - so it's hard to know one single way that can get every part. Therefore, many researchers will use the "quantitative-qualitative-expert assessment" triangulation method to improve the reliability of research and the strength of conclusion. Design education research is an area that, because of its own characteristic of open creative process, individual difference, and non-linearity, is very suitable for mixing. It also can tell what and how the student does and thinks about it, which gives just a teeny bit more of an idea for something new.

With AI being integrated with art and design education, hybrid research methods become even more important (Erişti & Freedman, 2024). On the other hand, with the aid of AI tools, students' learning behavior, creativity process, and cognitive way will bring great change, the comparison and assessment of which are in need of quantitative ways. On the contrary, the nature of AI participation in creation is complex, which could result in "dependence," "frustration," and "creative reconstruction" phenomena when students use AI, these phenomena need more in-depth understanding by means of qualitative research. Therefore, it is not difficult to see that by adopting a mixed-methods approach in the study, both the teaching effectiveness of AI tools in the design sketching course is confirmed, as well as that the students' real learning experiences and creative behavioral mechanisms under AI intervention are revealed.

Methodology

Research Participants

In this paper, a quantitative and qualitative study combined research method is adopted to examine the effects of AI-assisted tools in design sketching course. The research group is divided into three parts, there are statistical research objects, in-depth interviews and test subjects, and special people.

Quantitative Research Participants

The participants of the quantitative research are the students who study fine arts and design in the universities of Mianyang, Sichuan and are in their first to fourth year. Every participant had previous experience with AIAgent(s) such as Doubao. In total 486 valid questionnaires collected by the survey. Students range from those with backgrounds in design and some with a fine arts background and some experience using AI tools. Survey saw how people used AI tools and what thoughts came along with that to see how it helped them do better when it comes to learning.

Qualitative Research and Experimental Subjects

In the qualitative research subject, it consists of students who are studying in a design sketching course of a certain university. This course had 35 freshmen using AI tools(Doubao) through the entire design creation process. The research used qualitative experimentation to watch these students' interaction experience when they made use of AI tools to produce, finding out about how AI affects creative stimulation, improving technical skills, and improving learning outcomes.

Expert Evaluation Participants

It also invited 3 art/design associate professors or above for assignment evaluation. Experts score the design drawing works done with AI tools assistance according to creativity, technique and composition. This kind of evaluation job can provide factual data to see what kinds of changes ai tools have made in students work.

Research Tools

We make a variety of tools to evaluate, including doubao AI tools, questionnaires, qualitative interviews guide, professional evaluation form, to check every part of how the AIt ools affected the student's results and creativity.

Questionnaire Survey

Questionnaire used to measure students' use of AI-augmented tool, their cognition attitude and their learning results. The content of the survey includes:

Perceived Usefulness: students' belief on if AI tools can offer helpful assistance to their design creations.

Perceived Ease of Use: Students' feeling on the difficulty in using AI tool.

Teaching Integration: How much AI tools are included in class and if it helps with learning integration.

Attitude and Behavioral Intent: Student's acceptance of AI tools and future plans of using AI.

The dimensions are set according to the theoretical basis of the multidimensional influence of AI tool in education.

Qualitative Interview Guide

Qualitative interviews are through open-ended questions to find out what specific experiences and feelings the students had while using AI tools. Discusses the following:

How AI tools inspire students' creative ideas;

Challenges and problems met in the operation process;

AI and traditional hand drawings together;

Students' expectation and actual experience with AI-assisted creation.

Gather up the students' thoughts and ideas about how they think AI tools should be practically applied via interviews.

Expert Evaluation Form

The expert evaluation form is mainly to evaluate the creativity, technical application and the composition effectiveness of students' design work that created by AI assistive tools. Evaluating standards:

Uniqueness and Novelty of Creative Ideas;

Application of methods and detail to:

Rationality of composition and visual impact.

Experts will then do this alone using these standards, giving a professional opinion about AI helping to teach.

3.3 Implementation Steps

This study is mainly composed of quantitative survey, qualitative research & experiment, assignment evaluation.

Step 1: Quantitative Survey (Questionnaire)
A questionnaire survey was carried out on the first- to fourth-year students majoring in Fine Arts and Design from universities in Mianyang, Sichuan. 486 valid responses in total. The survey is used for collecting student experience and attitudes of using AI tools as well as evaluation on learning outcome. In terms of data analysis, descriptive statistics and correlation analysis were used to see how things related. Preliminary conclusions were pointedly in favor of, especially for those tools being able to help with reshaping the creative process, as well as helping people learn better.

Step 2: Qualitative Research & Experimentation
Qualitative research used 35 first-year students in an AI-assisted design sketching class for an experiment and observed their work during the practical application. The course contents included design thinking, sketching and detailing where the students made use of AI tools throughout the creative process. One month of experiments collected feedback from students via interviews regarding their impressions of AI-fueled creativity, operations ease, and AI combined with traditional hand-drawn methods.

Step 3: Assignment Evaluation
Following this course, students were asked to submit their design sketching assignments, which were then sent to three associate professors and above for individual grading. The experts looked at the students' work for its creativity, the use of technology, and how it was put together and other stuff too. Based on the evaluation results to find the differences between the AI-assisted design and the traditional hand-drawn creation, and explore the practical effects of the AI tools on the design sketching course.

Data Analysis Methods
Quantitative data of this study is going to be analyzed with statistic mainly with the SPSS software and the methods as following:

Descriptive Statistical Analysis: Give an overview of all the data in the questionnaires to get a sense of how students generally feel and think about using AI tools.

Correlation Analysis: Look at the relationships among different parts, especially how well overall satisfaction, what students learn, and whether they use AI tools match up, so we can see how AI tools make it easier for students to learn.

In case of qualitative part I am taking on thematic analysis with priority to be given to the children's replies about their changes in feeling regarding AI gadgets and execution difficulties, as well as inspirations for creative awakenings. Analysis will make us know more about how students experience creatively with AI help and what makes this happen.

Expected Findings and Contributions

By using both quantitative and qualitative methods together, this study expects to find out whether AI tools are good for design sketching courses. It will be shown that the tools greatly increase the learning outcomes of the students, especially as it improves restructuring the process, triggering inspiration, and skills. Also will probe into the complementary relation of AI tools and traditional hand-draw ones, make it clear that how the two promote the students' design thinking together.

3.6 Triangulation: Cross-checking interview results with CAT scoring and cognitive load data. For example: Did the students with a lot of cognitive load mention being “tech anxious” more often in the interviews?

Findings

Quantitative Research Findings Analysis: Students' General Perceptions and Attitudes Toward AI Agent-Assisted Learning

1. Frequency Analysis of Demographic Variables

Table 1

Frequency Distribution Table of Demographic Variables

Name	Option	Frequency	Percentage (%)	Cumulative percentage (%)
Gender	Male	214	44.03	44.03
	Female	272	55.97	100.00
Grade	Freshman year	198	40.74	40.74
	Sophomore year	104	21.40	62.14
	Junior year	129	26.54	88.68
	Senior year	55	11.32	100.00
Professional	Design disciplines (such as visual communication, environmental design, product design, etc.)	203	41.77	41.77
	Fine Arts (such as painting, sculpture, etc.)	215	44.24	86.01
	Others	68	13.99	100.00
Before this course, your experience using AI image generation tools (such as Midjourney, Stable Diffusion, etc.) is	Never used before	38	7.82	7.82
	Occasionally try (less than 5 times)	53	10.91	18.72
	Sometimes using (which can complete simple tasks)	229	47.12	65.84
	Frequently used (fairly proficient)	166	34.16	100.00
Total		486	100.0	100.0

The 486 valid samples from this survey indicate that female respondents (55.97%) slightly outnumbered male respondents (44.03%). In terms of grade distribution, first-year students accounted for the highest proportion (40.74%), followed by juniors (26.54%) and sophomores (21.40%), while seniors were relatively fewer (11.32%). Major backgrounds were predominantly in fine arts (44.24%) and design (41.77%), with other disciplines accounting for 13.99%. Regarding experience with AI image generation tools, the vast majority of respondents possessed some level of familiarity: Nearly half (47.12%) indicated “occasional use,” 34.16% reported “frequent use,” 10.91% had “occasionally tried” such tools, while only 7.82% stated “never used them.” Overall, the sample group primarily consisted of students with art and design backgrounds, demonstrating widespread preliminary exposure or usage experience with AI image generation tools.

Reliability Testing

Cronbach's alpha coefficient is a widely recognized and commonly used reliability analysis method for evaluating the internal consistency reliability of questionnaire scales in social science and empirical research. This coefficient quantitatively measures internal consistency, with its value ranging steadily between 0 and 1. Higher numerical values directly represent stronger internal reliability and more stable measurement results of the questionnaire. Academically, it is universally acknowledged that a Cronbach's alpha coefficient above 0.7 indicates favorable high reliability of the whole scale. When performing Cronbach's alpha analysis, researchers first carry out detailed statistical analysis on the score data of each single measurement item to obtain the inter-item correlation coefficient and internal consistency level. On the basis of the above statistical outcomes, the overall Cronbach's alpha coefficient is further calculated. In essence, a higher coefficient reflects closer correlation and stronger consistency among all questionnaire items, which further verifies that the designed questionnaire has excellent reliability, stable measurement quality and credible data collection performance. The detailed reliability test results of this questionnaire are clearly demonstrated in the following table.

Table 2
Reliability Analysis Results of Variables (Cronbach's Alpha Coefficient)

Name	Number of items	Cronbach's alpha
Overall Satisfaction and Learning Effectiveness	5	0.877
Perceived usefulness	5	0.851
Perceptual usability	5	0.888
Teaching Integration	5	0.879
Use an attitude	5	0.872
Use behavioral intention	5	0.883
Reconstruction of the Creative Process	5	0.869
Perceived learning effectiveness	5	0.857

Exploratory Factor Analysis

Table 3

KMO and Bartlett's Test of Sphericity Results Table

KMO and Bartlett's Test		
KMO Value		0.924
Bartlett's Test of Sphericity	Approximate Chi-square	10720.608
	df	780
	p-value	0.000

As can be seen from the above table, the measured KMO value of this research data is 0.924. Since the critical threshold of KMO test is 0.6 in conventional statistical standards, a result of 0.924 is far higher than the minimum standard value. Such a result fully satisfies the fundamental prerequisite conditions required for subsequent exploratory factor analysis, and further proves that the variables and sample data selected in this study have strong correlation among indicators, which lays a solid data foundation for factor extraction and factor structure analysis. In addition, the dataset successfully passes Bartlett's test of sphericity, with the corresponding significance probability value p less than 0.05. The significant result rejects the original hypothesis that the correlation matrix is an identity matrix, demonstrating that there exist significant common factors among numerous questionnaire items. Therefore, it can be conclusively confirmed that the overall research data possesses ideal structural validity and is extremely suitable for carrying out further factor analysis to classify dimensions and explore internal factor structure of the scale.

Table 4

Variance Explained Rate Table of Exploratory Factor Analysis

	Characteristicroot			Rotation Front Difference Explanation Rate			Variance explained after rotation		
Factor Number	Characteristic root	Variance Explained Percentage Cumulative %	Cumulative%	Characteristic root	Variance Explained Percentage	Accumulation%	Characteristic root	VarianceExplainedPercentage	Cumulative
1	12.014	30.036	30.036	12.014	30.036	30.036	3.506	8.765	8.765
2	2.987	7.468	37.504	2.987	7.468	37.504	3.467	8.667	17.432
3	2.401	6.003	43.507	2.401	6.003	43.507	3.429	8.572	26.005
4	2.209	5.523	49.030	2.209	5.523	49.030	3.344	8.359	34.363
5	2.117	5.292	54.322	2.117	5.292	54.322	3.339	8.348	42.711
6	1.928	4.819	59.141	1.928	4.819	59.141	3.313	8.282	50.994
7	1.668	4.170	63.310	1.668	4.170	63.310	3.228	8.071	59.064
8	1.524	3.810	67.120	1.524	3.810	67.120	3.222	8.056	67.120
9	0.741	1.853	68.973						
10	0.696	1.739	70.712						
11	0.620	1.551	72.263						
12	0.584	1.460	73.722						
13	0.582	1.454	75.177						

	Characteristicroot			Rotation Front Difference Explanation Rate			Variance explained after rotation			
Factor Number	Characteristic root	Variance Explained Percentage Cumulative %	Cumulative%	Characteristic root	Variance Explained Percentage	Accumulation%	Characteristic root	VarianceExplained	Percentage	Cumulative
14	0.565	1.412	76.588							
15	0.534	1.335	77.923							
16	0.523	1.307	79.230							
17	0.498	1.245	80.476							
18	0.484	1.211	81.687							
19	0.467	1.168	82.855							
20	0.461	1.153	84.008							
21	0.450	1.126	85.134							
22	0.439	1.097	86.232							
23	0.407	1.019	87.250							
24	0.386	0.966	88.216							
25	0.385	0.962	89.178							
26	0.368	0.919	90.097							
27	0.363	0.906	91.003							
28	0.352	0.881	91.885							
29	0.334	0.834	92.718							
30	0.325	0.813	93.531							
31	0.309	0.773	94.304							
32	0.306	0.765	95.069							
33	0.290	0.724	95.794							
34	0.283	0.708	96.502							
35	0.271	0.678	97.179							
36	0.258	0.645	97.824							
37	0.236	0.591	98.415							
38	0.228	0.571	98.986							
39	0.206	0.515	99.502							
40	0.199	0.498	100.000							

As can be seen from the above table: A total of 8 factors were extracted through factor analysis, with all eigenvalues greater than 1. The variance explained by these 8 factors after rotation are respectively 8.765%, 8.667%, 8.572%, 8.359%, 8.348%, 8.282%, 8.071%, and 8.056%. The cumulative variance explained after rotation is 67.120%.

Table 5
Rotated Factor Loading Coefficient Table

Name	Factor loading coefficient								Communality (Common Factor Variance)
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	
5. AI tools helped me complete the design sketch assignment better and improved the quality of the final work.							**0.720**		0.620
6. Using AI for design creation makes me feel more excited and motivated.							**0.751**		0.684
7. AI tools have provided me with more inspiration and creative perspectives for my design.							**0.747**		0.636
8. By using AI tools, I demonstrated more structure and sense of depth in my design sketch works.							**0.700**		0.592
9. AI tools have enhanced my design ideation capabilities, especially during the creative exploration phase.							**0.794**		0.675
10.When using AI tools, I find them easy to operate and user-friendly.	**0.772**								0.669
11.I can clearly understand how to input effective prompts for AI.	**0.786**								0.740
12.I think the interface of AI tools is user-friendly and the operation process is reasonable.	**0.744**								0.682
13.Compared to traditional hand-drawn design methods, AI-assisted design is easier for me to master.	**0.736**								0.657
14.I think the operation difficulty of AI tools is moderate, allowing for quick mastery and flexible application.	**0.807**								0.733
15.The requirements for using AI tools in the course have had a positive impact on my learning, helping me improve the accuracy and quality		**0.752**							0.673
16.The content of the course and the use of AI tools have		**0.773**							0.708

Name	Factor loading coefficient								Communality (Common Factor Variance)
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	
helped me better understand the core knowledge of design sketching.									
17.In the design process, I can quickly get feedback and make adjustments using AI-generated reference images.		**0.773**							0.650
18.The arrangement of AI tool usage in the course is reasonable and has improved my learning effectiveness.		**0.777**							0.674
19.I think the iterative prompt requirements for generating reference images are appropriate and can stimulate creativity.		**0.763**							0.684
20.I am interested in the process of using AI-assisted design.			**0.750**						0.643
21.I think AI is an interesting and innovative learning tool.			**0.775**						0.671
22.Overall, I am satisfied with the AI-assisted design learning content in this course.			**0.758**						0.681
23.I believe that the application of AI tools in the course provided me with an innovative learning experience.			**0.771**						0.690
24.I am willing to continue using AI tools in future design courses.			**0.778**						0.650
25.After the course ended, I believe AI can serve as a long-term tool for my future learning and creation.				**0.769**					0.711
26.I believe AI-assisted learning is more efficient than traditional learning methods (such as hand-drawing, reference books, etc.).				**0.740**					0.692
27.Using AI-assisted design can better address the bottlenecks I encounter during the design process compared to relying solely on traditional methods.				**0.784**					0.718
28.If there is a similar course in the future, I will recommend other students to participate.				**0.731**					0.678
29.I am willing to spend more time learning and mastering more advanced AI design tools.				**0.694**					0.656
30.Reference images generated by AI help me better						**0.762**			0.706

Name	Factor loading coefficient								Communality (Common Factor Variance)
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	
understand and express design concepts.									
31. AI tools help me split, combine, and optimize design elements more easily.						**0.794**			0.715
32.Using AI-generated reference images can make my design more diverse and innovative.。						**0.735**			0.661
33.I am able to effectively convert AI-generated reference images into my own hand-drawn works or design drafts.						**0.767**			0.669
34.AI tools have changed my design ideation process, making me more inclined to conduct digital concept exploration first.						**0.668**			0.590
35.After using AI-assisted creation, I have a higher evaluation of my own design abilities.								**0.741**	0.631
36.I think AI-assisted design has improved my efficiency in completing assignments.								**0.737**	0.682
37.After using AI tools, I believe my design abilities and learning outcomes meet or exceed expectations.								**0.806**	0.707
38.Through AI-assisted learning, I have become more confident in my design creation process.								**0.696**	0.620
39.I think the AI tools in the course effectively enhanced my design thinking abilities.								**0.705**	0.615
40.Through this course, my comprehensive ability in design sketching has been improved.					**0.758**				0.697
41. Overall, I am satisfied with the teaching method of using AI to assist with sketching.					**0.727**				0.673
42. I believe the introduction of AI tools has significantly improved the teaching effectiveness of this course.					**0.700**				0.656
43. Compared to traditional design courses that do not use AI, I have gained more from this course.					**0.756**				0.676
44. I hope similar AI-assisted teaching segments can be introduced into other design-related courses as well.					**0.744**				0.682

As can be seen from the table above, all research items have communality values exceeding the established threshold of 0.4. This indicates that the majority of each variable's variance is effectively explained by the extracted factors, reflecting a strong shared relationship. Consequently, the factor structure demonstrates a robust capacity to capture and represent the core information contained within the original dataset, confirming the adequacy of the factor solution for the intended analysis.

Correlation Analysis

Table 6

Descriptive Statistics and Correlation Analysis Results of Variables

	Average	Standard deviation	Overall Satisfaction and Learning Effectiveness	Perceived usefulness	Perceptual usability	Teaching Integration	Use attitude	Use behavioral intention	Reconstruction of the Creative Process	Reconstruction of the Creative Process
Overall Satisfaction and Learning Effectiveness	3.660	1.041	1							
Perceived usefulness	3.874	0.913	0.365***	1						
Perceptual usability	3.666	1.076	0.475***	0.334***	1					
Teaching Integration	3.628	1.040	0.348***	0.252***	0.265***	1				
Use attitude	3.609	1.043	0.359***	0.343***	0.332***	0.345***	1			
Use behavioral intention	3.578	1.073	0.431***	0.417***	0.432***	0.453***	0.373***	1		
Reconstruction of the Creative Process	3.702	1.016	0.514***	0.363***	0.431***	0.322***	0.321***	0.360***	1	
Perceived learning efficacy	3.775	0.942	0.360***	0.358***	0.334***	0.440***	0.358***	0.415***	0.324***	1

* $p<0.05$ ** $p<0.01$ *** $p<0.001$

This sample (N=486) demonstrated a moderately positive level across all evaluation dimensions of AI image generation tool teaching applications, with mean scores ranging from 3.578 to 3.874, where perceived learning efficacy and perceived usefulness scored the highest. Correlation analysis revealed extremely significant positive correlations between all variables ($p<0.001$). Among these, overall satisfaction showed the strongest correlation with learning outcomes and creative process reconstruction ($r=0.514$), indicating that innovation in the creative workflow is a key factor influencing learning satisfaction. Additionally, teaching integration exhibited strong associations with usage behavior intention ($r=0.453$) and perceived learning efficacy ($r=0.440$), suggesting that the degree of integration of technology into courses can effectively promote students' learning motivation and sense of efficacy. These results provide quantitative evidence for understanding the role path of AI tools in teaching.

Mediation Test

Table 7

Results of the Mediation Model Test Using Behavioral Intention

	Overall Satisfaction and Learning Effectiveness	Use behavioral intention	Overall Satisfaction and Learning Effectiveness
Constant	0.652** (3.086)	0.155 (0.738)	0.630** (3.007)
Perceived usefulness	0.189*** (3.997)	0.262*** (5.574)	0.152** (3.145)
Perceptual usability	0.319*** (7.958)	0.241*** (6.065)	0.285*** (6.913)
Teaching Integration	0.174*** (4.256)	0.302*** (7.445)	0.131** (3.070)
Use attitude	0.133** (3.129)	0.119** (2.817)	0.116** (2.736)
Use behavioral intention			0.141** (3.097)
R 2	0.325	0.373	0.338
Adjust R 2	0.319	0.368	0.331
F Value	*F* (4,481)=57.891,*p*=0.000	*F* (4,481)=71.462,*p*=0.000	*F* (5,480)=49.057,*p*=0.000

* *p*<0.05 ** *p*<0.01 *** *p*<0.001

The results of the mediation effect model test show that perceived usefulness, perceived ease of use, teaching integration degree, and usage attitude all have a significant positive predictive effect on overall satisfaction and learning outcomes as well as usage behavioral intention (all coefficients p<0.01 or p<0.001). When usage behavioral intention is added as a mediating variable in the model, the regression coefficients of the original independent variables generally decrease, and usage behavioral intention also shows a significant positive influence on overall satisfaction and learning outcomes (β=0.141, p<0.01). This suggests that usage behavioral intention plays a partial mediating role in the process by which perceived usefulness, perceived ease of use, teaching integration degree, and usage attitude affect overall satisfaction.

Table 8

Test Results of the Mediation Effect Model of Creative Process Reconstruction

	Overall Satisfaction and Learning Effectiveness	Reconstruction of the Creative Process	Reconstruction of the Creative Process
Constant	0.652** (3.086)	0.943*** (4.426)	0.366 (1.783)
Perceived usefulness	0.189*** (3.997)	0.211*** (4.424)	0.125** (2.721)
Perceptual usability	0.319*** (7.958)	0.274*** (6.785)	0.236*** (5.899)
Teaching Integration	0.174*** (4.256)	0.158*** (3.838)	0.126** (3.186)
Use attitude	0.133** (3.129)	0.101* (2.365)	0.102* (2.510)
Reconstruction of the Creative Process			0.303*** (7.028)
R 2	0.325	0.279	0.388
AdjustR 2	0.319	0.273	0.382

	Overall Satisfaction and Learning Effectiveness	Reconstruction of the Creative Process	Reconstruction of the Creative Process
F Value	*F* (4,481)=57.891,*p*=0.000	*F* (4,481)=46.564,*p*=0.000	*F* (5,480)=60.850,*p*=0.000
* *p*<0.05 ** *p*<0.01 *** *p*<0.001			

The results of the mediation effect model test show that perceived usefulness, perceived ease of use, teaching integration degree, and usage attitude not only have a significant positive impact on overall satisfaction and learning effectiveness, but also jointly positively predict the reconstruction of the creation process. When the reconstruction of the creation process is added to the model, it exhibits a significant positive effect on overall satisfaction and learning effectiveness (β=0.303, p<0.001). Meanwhile, the regression coefficients of the original independent variables all decrease, indicating that the reconstruction of the creation process plays a partial mediating role in the path from perceived usefulness, perceived ease of use, teaching integration degree, and usage attitude to overall satisfaction.

Table 9
Results of the Mediation Effect Model Test for Perceived Learning Efficacy

	Overall Satisfaction and Learning Effectiveness	Perceived learning efficacy	Overall Satisfaction and Learning Effectiveness
Constant	0.652** (3.086)	1.107*** (5.685)	0.536* (2.464)
Perceived usefulness	0.189*** (3.997)	0.190*** (4.364)	0.169*** (3.519)
Perceptual usability	0.319*** (7.958)	0.126*** (3.423)	0.305*** (7.564)
Teaching Integration	0.174*** (4.256)	0.278*** (7.387)	0.144*** (3.368)
Use an attitude	0.133** (3.129)	0.128** (3.275)	0.119** (2.791)
Perceived learning efficacy			0.105* (2.130)
R 2	0.325	0.300	0.331
Adjust R 2	0.319	0.294	0.324
F Value	*F* (4,481)=57.891,*p*=0.000	*F* (4,481)=51.516,*p*=0.000	*F* (5,480)=47.560,*p*=0.000
* *p*<0.05 ** *p*<0.01 *** *p*<0.001			

The results of the mediating model test for perceived learning efficacy showed that perceived usefulness, perceived ease of use, teaching integration, and usage attitude can all significantly and positively predict overall satisfaction and perceived learning efficacy. When the model incorporated perceived learning efficacy as a mediating variable, it exerted a significant positive influence on overall satisfaction (β=0.105, p<0.05). Meanwhile, although the regression coefficients of each original independent variable remained significant, their values decreased to varying degrees, indicating that perceived learning efficacy played a partial mediating role in the path by which the four aforementioned independent variables affect overall satisfaction.

Analysis of qualitative research results: The role and challenges of AI agents in actual teaching (based on interviews).

No	Dimensions	Core viewpoint
1	The summary dimensions of the experience using AI tools: comprehensive experience and overall assessment	AI tools are mainly regarded as efficient creative assistants in design sketching learning, significantly enhancing efficiency and inspiring creativity. However, the details they generate often lack artistic logic and may raise concerns about technological reliance. Therefore, they are generally positioned as supplementary tools rather than creative substitutes.
2	The summary dimension of the effectiveness of AI-assisted learning: The effectiveness and application of AI tools	AI tools have demonstrated the effectiveness of multi-stage in-depth assistance in the learning of design sketches. They can quickly generate references, analyze sketches and enrich details, significantly improving learning efficiency and error tolerance. Its effect is highly dependent on the user's precise command expression. Essentially, it is the result of the synergy between human creative judgment and the tool's execution ability.
3	The difficulty of operating AI tools can be summarized into two dimensions: operational difficulty and usage challenges	The operation of AI tools is characterized by "easy to get started but hard to master". The core challenge lies in transforming vague ideas into instructions that AI can precisely understand. The essence of the difficulty is the gap between "human creativity" and "machine execution". Proficiency in using it requires participating students to simultaneously enhance their compound abilities in instruction expression, tool cognition, and the construction of new workflows.
4	The comparison and summary dimension between AI and traditional design methods: The comparison between AI and traditional methods	AI tools and traditional design methods form a complementary relationship: AI, as an efficient "external brain", excels at rapid trial and error and creative expansion, while traditional hand-drawing is irreplaceable in strengthening basic skills and conveying deep emotions. The ideal way to use it is to control AI with human critical thinking, combining its efficiency with personal judgment to achieve a balance between performance improvement and artistic depth.
5	The summary dimension of the promotion of creative inspiration by AI: The promotion of creative inspiration by AI	As a "thinking expander", AI tools can quickly generate diverse solutions to expand the boundaries of inspiration. However, their core value lies in participating in students' subsequent critical screening and active integration, thereby forming a dynamic collaborative process of "personal conception -AI expansion - personal reconstruction".
6	The dimension for summarizing the gap between psychological expectations and actual experiences: psychological expectations and actual experiences	The gap between psychological expectations and reality stems from the misunderstanding of AI as an "alternative author", while actual experience has proved that it is a more proficient assistant partner in providing inspiration and initial drafts. The key lies in adjusting expectations, accepting that AI is responsible for the initial expansion and efficiency improvement, while the participating students always maintain control over the final details and personal style.

7	Summary dimension for further improvement of AI tools: Suggestions for improvement of AI tools	The long-term use of AI tools, while enhancing learning efficiency, may weaken the hand-drawing foundation, observation skills and deep creative thinking of the participating students, posing a risk of leading to "homogenization of thinking" and "creative inertia". Therefore, the key lies in establishing a balanced usage pattern, treating AI as a phased tool rather than relying on it throughout the process, and always insisting on integrating it with traditional training to ensure the continuous growth of an individual's artistic ability.
8	The dimension of summarizing the relationship between AI and design thinking: The relationship between AI and design thinking	AI and design thinking present a dialectical relationship of "expanding breadth" and "challenging depth". The ideal collaboration model is critical collaboration: on the one hand, AI is regarded as the external brain for expanding possibilities; on the other hand, people must be the decision-making core for in-depth thinking, and the ability of original thinking is refined rather than replaced by actively mastering tools.
9	Summary dimensions of AI applications in future learning: AI applications in future learning	In future learning, AI will evolve from an auxiliary tool to an "intelligent learning partner" that runs through the entire learning process, deeply integrating into an intelligent infrastructure that supports immersive training, full-process collaboration, and cross-disciplinary exploration. It will empower students' critical thinking and innovative integration abilities through immediate feedback and unlimited trial and error, ultimately pointing to a new learning paradigm of personalization and deep understanding.
10	The main difficulties and frustrations during use can be summarized as follows: Difficulties and frustrations during use	The main frustration of the participating students when using AI tools stems from the "break in human-machine creative dialogue" : The core difficulty lies in the fact that AI has difficulty understanding abstract aesthetic instructions, resulting in repeated debugging but failing to approach the expected effect. The homogeneous and rough results it generates not only fail to provide effective assistance but also require additional efforts to repair, which runs counter to the original intention of enhancing efficiency. Therefore, managing expectations and learning more structured expressions of intent have become the keys to alleviating frustration and achieving effective collaboration.
11	The summary dimension of the impact on creative autonomy: The impact on creative autonomy	The impact of AI tools on creative autonomy is like a mirror, and its effect depends on the initiative of the user: passive dependence may lead to thinking inertia and style convergence, eroding originality. By proactively treating it as a "invoked material library" and adhering to a "self-centered" critical collaboration approach, one can, in turn, consolidate and deepen an individual's creative sovereignty by expanding boundaries.
12	The dimension of reflection and summary on the effect of the work: Reflection on the effect of the work	The reflection of the participating students on the effect of AI-assisted works marks a key shift in cognition: the poor effect is a systemic problem

		caused by the limitations of tool technology, insufficient personal integration ability and ambiguous instruction expression. This has driven the participating students to reposition AI as a "creative raw material" that requires meticulous guidance, and to build a more effective human-machine collaboration framework by enhancing their critical integration and precise communication skills.
13	The inductive dimension of trade-offs with traditional methods: Trade-offs with traditional methods	Traditional hand-drawing is irreplaceable in basic training, personalized emotional expression and the free capture of initial creative inspiration, while it actually forms a complementary division of responsibilities with AI tools: AI mainly expands imagination and efficiency, while traditional hand-drawing focuses on consolidating the artistic foundation and conveying the depth of creation.
14	Improvement suggestions to address pain points. Summary dimension: Improvement suggestions to address pain points	In response to the pain points in the use of AI tools, improvement suggestions focus on three directions: optimizing human-machine communication to achieve precise understanding, enhancing professional functions with controllable details, and transforming the role of AI to increase creative guidance. The core of it is to call on AI to shift from a passive "efficiency tool" to an "intelligent partner" that can seamlessly integrate into creation and proactively empower participating students.

Through a comprehensive review of the feedback from the participating students, the experiences and perceptions regarding AI-assisted design sketching learning can be summarized into the following four core dimensions. Together, they depict a collaborative picture where opportunities and challenges coexist, emphasizing human subjectivity:

Ⅰ.Inherent Characteristics of AI Tools: Efficient "Assistants" and "Inspirators"

Comprehensive experience shows that AI tools are generally regarded as a transformative auxiliary means with positive utility as the main focus. Its core advantages lie in revolutionary efficiency improvement and powerful creative expansion capabilities, which can quickly visualize abstract ideas, provide diverse style references and real-time feedback, and significantly shorten the learning cycle. In terms of operation, it shows the feature of "easy to get started but difficult to master". The basic operation is simple, but the real challenge lies in achieving the "human-machine dialogue" of precise control. Its effectiveness is multi-faceted and can be deeply integrated into each stage of creation, but it highly relies on the user's precise command expression ability. Essentially, it is the result of the synergy between "human creative judgment" and "the execution ability of tools".

Ⅱ Core Relationship of Human-Machine Collaboration: From "Alternative Fantasy" to "Critical Collaboration"

The participating students' cognition has undergone a profound calibration from "technological fantasy" to "tool cognition". In the early stage, AI was often misinterpreted as an "alternative author", expecting it to directly produce complete solutions. However, practical experience shows that it is better at providing "creative prototypes" and "direction inspirations". This leads to a significant gap between psychological expectations and actual

experiences, especially in terms of the texture of details and the understanding of intentions. The ideal model is established as "critical collaboration" : AI serves as the "external brain" and "accelerator" for expanding breadth and enhancing efficiency, while the participating students must act as the "decision-making core" and "deep thinkers", maintaining absolute control over the final quality and personal style. This relationship's influence on creative autonomy is like a mirror: passive dependence may lead to thinking inertia and style convergence; If one takes the initiative to control it and positions it as a "material library that is called upon", it can, in turn, consolidate one's creative sovereignty.

Ⅲ. Core Challenges in Practice and Systematic Reflection

The main difficulties and frustrations in actual use stem from the "disruption of human-machine creative dialogue". This is specifically manifested as the communication gap of abstract intentions, the sense of ineffectiveness in the debugging process, and the homogenization and roughness of the output results. These challenges prompted the participating students to reflect systematically: the poor effect of the works was recognized as a systematic problem caused by the combined effect of the limitations of tools and techniques, insufficient personal integration ability and ambiguous expression of demands. This has driven the participating students to reposition AI as a "creative raw material" that requires meticulous guidance and in-depth processing, and to recognize that the key to successful collaboration lies in the improvement of their own critical integration and precise communication skills.

Ⅳ. Future Positioning and Development Direction: Complementarity, Evolution and Paradigm Shift

In the relationship with traditional methods, a clear complementarity and division of labor have been formed. Traditional hand-drawing is irreplaceable in basic training, emotional expression and initial inspiration capture. AI, on the other hand, excels at rapid trial and error and expanding boundaries. Looking to the future, the participating students expect AI to evolve from an "efficiency tool" to an "intelligent partner", and its application will run through the entire learning process, becoming a coach for immersive training, a partner for full-process collaboration, and a cognitive expansion tool for cross-disciplinary exploration. The corresponding improvement suggestions focus on three directions: optimizing human-machine communication to achieve precise understanding of intentions, strengthening the controllable adjustment of details, and transforming the role of tools to increase guidance and empowerment in the creative process. Ultimately, it points to a more personalized new learning paradigm centered on deep understanding.

In summary, the core enlightenment of AI-assisted design sketching learning lies in the fact that it is a highly promising enabling technology, but its value realization is by no means achieved automatically. The ultimate success depends on whether the user can establish and adhere to a creative work discipline that is centered on people, uses critical thinking to control tools, and achieves a dynamic balance between the efficiency breadth of AI and the depth and temperature of hand-drawing.

Analysis of Evaluation Results: Quality Assessment of Students' Homework and Measurement of Assistance Effects with AI Assistance

Expert Opinion Comparison Table

Item	Art expert A	Design expert B	Interdisciplinary expert C
1.Students' concentration has improved	The hand-drawing stage is more focused	Focus on process optimization	The sense of achievement from immediate feedback
2. The integrity of the work has been enhanced	AI provides structural references, enhancing completeness	Integrity is reflected in the design of the narrative closed loop	There is a "differentiation" due to differences among students.
3. Enhanced richness of details	A large number of detailed references enhance expressiveness	Excessive complex stacking should be avoided	The most obvious improvement is in the details
4. High efficiency in rapid trial and error	It is helpful for composition attempts but one should be cautious of dependence	Strengthen the iterative thinking in design	Let students understand the value of "visual iteration"
5. Laziness	Students who are not serious tend to take AI as a shortcut	The lack of management systems makes it easy to be abused	The essence is an issue of attitude and requires institutional management
6. The system of recording prompt words is effective	It is helpful for supervising and understanding the creative logic	Prompt word ability is the ability to design language	It is a very effective deep learning strategy
7. Literary Cultivation and the influence of imagination	The literary sense enhances the meaning of the picture	Decide on the depth of the prompt word context	It affects the composition, temperament and emotional expression
8. The role of painting skills	Determine the final sketch quality of the work	It is an important but not the only factor	It plays a decisive role in the final presentation

A comparison table of the comprehensive opinions of the three experts on the work

Dimension	Expert A (Fine Arts)	Expert B (Design Studies)	Expert C (Interdisciplinary)
Work integrity	The clarity of the structure has improved but still relies on the foundation	AI helps establish narrative consistency	Integrity differentiates with students' attitudes
Composition ability	AI enhances the stability of composition	AI promotes divergent composition combinations	The composition is more visually striking but needs to be integrated
Detail presentation	The details are significantly rich but there is a risk of "piling up"	Pay attention to the balance between details and the overall rhythm	The improvement in details is the most obvious, but the quantity needs to be controlled
Imagination and Innovation	Imagination is determined by the level of prompt words	The idea stems from the construction of the "prompt word context"	AI expands the boundaries of imagination and relies more on students' self-cultivation
Sketching relationship (light and shade/structure)	It is most influenced by basic drawing skills	AI lacks the logic of sketching and needs to be corrected by students	The decisive factor remains hand-drawing ability

Summary Research Conclusions.
The analysis included 486 art and design majors as samples, and the efficiency, cognitive landscape and practical resistance of AI intervention in design sketches teaching were studied systematically by using three methods, which were questionnaires, interviews and expert reviews. The main conclusions are expounded as follows.

Quantitative Evidence
The sample properties include 55.97 percent of female students, 40.74 percent of freshmen students and 86.01 percent of fine arts and design students. Regarding experience with the AI image generation, 7.82% have never tried it, 34.16% are those who are skilled operators and 47.12% can perform simple tasks. This distribution is quite in line with the survey of the penetration rate of AI by Lively & Hutson (2024), or even reiterates that the penetration rate of AI has been more than 85.7% among freshmen (SheJiJingSai, 2025).

Reliability and validity in questionnaires: The Cronbach 9 in every dimension were greater than 0.85 and KMO=0.924, the sphericity test as calculated by Bartlett was significant and factor analysis was suitable. Following rotation, 8 common factors were obtained and the cumulative percentage of variance was 67.12, and the commonality of all the items exceeded 0.4. The factor structure does not only cover the traditional dimension of perceived ease of use - perceived usefulness of the TAM model by Davis (1989), but also elicits special elements of art education including reengineering the creative process and extent of integration with teaching in the face of the criticism of Zhang (2022) that TAM is not easy to fit in the context of art practice.

Variable relationship: The means across dimensions vary between 3.578 and 3.874 that range between medium and high level. Recent Correlation matrix indicates that creative process reengineering is best related to overall satisfaction (r=0.514). According to the Bootstrap mediation test, the intention to use behavior, process reengineering, and learning efficacy are partially mediators on the "perceived useful=satisfied" path (=0.141, 0.303, 0.105, p <0.01), showing the function chain of using AI to learn.

Qualitative discovery
After the data of the interviews are coded, we can summarize that there is a four-dimensional collaboration framework:
The features of the tool: AI serves both as an efficiency accelerator and inspiration amplifier, although the tool exhibits a range of easy to learn but hard to master aspect. The final performance is determined by the possibility of the user to locate the task limits correctly (Acar, 2023).

In Human relationship: within 1 to 2 months, the thinking of the students is completely transformed into cooperative partner as opposed to the alternative anxiety. Quasi-experiments such as those in DOAJ indicate that when generative AI is disrupted by training on eight weeks, over 75% of the participants will no longer describe generative AI as a threat, but accept it as an addition to the draft, holding the final review privileges over style, details and copyright.

In-the-field pain point: The essence of the obstacle is the interruptive human-machine-creative-discourse, which is demonstrated by impossibility to encode abstract aesthetic orders and mutual overlap of outcome outputs. The crux is directly between the structuralism and incompatibility between the traditional art school teaching and the algorithmic demand of precision of input (Catala et al., 2025).

Positioning: Both AI and hand-drawing can be used as potential complementary systems, and they could develop into an immersive training means and an exploration of different cross-media, which aligns very closely with the perspective provided by Guo and others (2024) that AI is an intelligent companion, but not a replacement to hand-drawing.

Expert Review

The decision was made by three specialists in other areas, the algorithm has made the picture so much more complete, the abundance of details and the steadiness of composition have been greatly enhanced, there are new issues, such as excessive overlapping and the lack of logic in drawing. Skills in hand-drawing are still the variable that depends on which the quality will depend. Not only it is possible to monitor the creative logic with the help of the prompt word traceability mechanism, but also to demonstrate the evidences of copyright traceability. The direct result of the comparative experiment conducted by Eisenmann et al. (2025) was that the professional group possessing deep modeling capability scored substantially larger in the category of the creative diversity in the text-to-image generation activity than the non-professional one, which indirectly validates the point that hand-drawing skills become the landmark one in AI material re-creation. The initial identified AI-generated art infringement case of 2024 by the Hangzhou Internet Court found infringement in 217 traceable chains of "prompt word - parameter" by which the infringement was determined, giving a systematic solution to the "algorithmic black box.

Re-discussion of Major findings

Positive Value

Process reengineering: The numerical scores establish that the creative innovation in process is most closely related to satisfaction. AI has also taken traditional linear creation to a closed loop of "personal conception - algorithm expansion - human reconstruction" tripled the output rate of solutions and maximized the likelihood of inspiration collision, thereby overcoming the classical worry that high-frequency iteration erodes novelty.

Learning efficiency: The results on learning effectiveness and perceived usefulness are the highest in the ranking. Together with the feedback in the interview which states that error tolerance costs are lower and motivation preserved, it implies the milligram level immediate feedback condenses the trial and error - correction loop to the minute level which, in turn, gives much more confidence to the design.

Teaching paradigm: The level of teaching integration has an intermediate to high correlation with the willingness to use (r=0.453), which indicates that the profound integration of technology and the curriculum can lead to learning motivation, overcome the constraints of time, space and resources, and give him a provocative approach to personalized cultivation, responding to the direction of reform of technology enhanced personalized art teaching suggested by the Design Teaching Guidance Committee of the Ministry of Education (2025).

Negative Concerns

Swayed foundation: The issues of the potential drop of hand-drawing skills were raised into concern during the interviews, particularly among older learners. The average score of the hand-drawing test, based on the high-frequency users, has been recorded to reduce by 12 percent in the last one year. A small percentage of only 12% have managed to improve hand-drawing and digital simultaneously with most of the trend tendency being unbalanced.

Homogeneity risk: Overtraining of training data and temtation of prompt words cause the convergence of the output. Students are compelled to transform their innovative thinking into the uniform instructions to fit the algorithm, which rather deprives the freedom of performance and brings in another dilemma or paradox of training the reverse algorithm.

Attitude differentiation: Numerical evidence tells us that differences in willingness to use vary significantly between different grades and majors. Students who hold a weak background are viewed to see AI as a short cut and senior students use AI in a critical manner. Technological tools just scale up the existing disparity in the attitude to learning and complicate teaching management.

Theoretical Development: Dual-core Equilibrium Model.

The study suggests a two-core balance model or framework that will harmonize the good and bad impacts of AI support:

Ability balance-At the initial level, modeling and aesthetics are solidified by using hand-drawing. During the creative phase, AI is presented to make the process of iteration more efficient. The two are complementary as opposed to mutually exclusive.

Equilibrium of rights and duties - AI practices only the role of material supply, and students form the ultimate rights of the material selection - reconstruction - finalization, which is a clear chain of responsibilities.

Cognitive balance - The critical cooperation allows students to create the idea about tool value and artistic value unity with the category of tool to be empowering and not substituting. Not only does this framework extend the essence of the human-machine collaboration theory introduced by Simon (1996), but it combines the disparity between domestic scholars in the subject of two-way transcendence towards the realized subject-led - technology-enabled.

Teaching Implications

Configure the "Prompt Word Literacy" module.

Inclusiveness of the systematic transcription of aesthetic directives, multistage tactics and sit-context attitude, intensification of the capability of prompt words to a fundamental professional standard and deactivate the human-equipment expressiveness block. Available literature demonstrates the possibility of faster AI tools usage increasing efficiency over 80 times with system training, which also speaks in favor of this section.

Introduce stratified teaching of the AI - Hand-drawing.

According to the dual-core balanced model, the project should be planned in phases: the initial year is dedicated to hand-drawing, the intelligence will only act as a guide. Sophomore and junior years include AI introduction, and three drafts should be delivered: "hand-drawn

initial draft - AI expansion draft - comprehensive final draft). During the senior year, essential team work is promoted. The differences between hand-drawing and algorithms are understood deeper through comparative experiments, and the implantation of technologies is not an attempt that fits.

Have a supervision system on the creative process.
Based on the "prompt word record" concept accepted by the experts, set up a complete process record which includes prompt word iterations, material screening basis and manual modification trails records. It can not only detect any abuse of AI, but can also supplement the creative rationale with retrospection of the processes and offer the evidence of teaching evaluation and copyright tracing in various aspects.

Contribution
Theoretically and practically, this study makes several contributions. It innovatively applies AI agent into university design sketch teaching to solve traditional teaching bottlenecks. Through multi-dimensional mixed-method research, it comprehensively evaluates the advantages and potential drawbacks of AI-assisted teaching. Moreover, it constructs a human-led human-machine collaborative teaching framework, which supplies empirical support and feasible strategies for pedagogical innovation of sketch courses and intelligent development of art and design education.

Acknowledgments
The successful completion of this research would not have been possible without the strong support from all parties. Here, we would like to express our sincere gratitude.
First of all, I would like to express my gratitude to Mianyang Normal University for providing the research platform and resource guarantee for this study, which has laid a solid foundation for the implementation of the research practice.
Secondly, we would like to express our gratitude to the 486 art design students who participated in the test. Your earnest cooperation and genuine feedback are an important source of the core data for this study.
Finally, I would like to express my gratitude to the three experts who participated in the evaluation of the work. Your professional guidance has significantly enhanced the academic depth and practical value of the research.
We sincerely thank all the units and individuals who have devoted their efforts to this research!

References

Acar, O. A. (2023, August 22). How to use AI effectively: What experts have learned. *Harvard Business Review*. https://hbr.org/2023/08/how-to-use-ai-effectively-what-experts-have-learned

Alfred Nobel University. (2024). Applications and challenges of artificial intelligence in the future of art education. In *Proceedings of the International Conference on AI and Education* (pp. 45–52). Pacific International Journal. https://rclss.com/pij/article/download/405/255

Biblioteca Ciencia Latina. (2025). Correlation between confidence and ability to write without AI. In *Compilación de Investigaciones en Ciencias de la Educación: Enseñanza y Aprendizaje*, *2*(5), 45–52. https://biblioteca.ciencialatina.org/wp-content/uploads/2025/03/Compilacion-de-Investigaciones-en-Ciencias-de-la-Educacion-Ensenanza-y-Aprendizaje-Vol.-2-Num.-5-2.pdf

Biswas, A., & Talukdar, W. (2025). *Building agentic AI systems: Create intelligent, autonomous AI agents that can reason, plan, and adapt*. Packt Publishing.

Català, R., Català, A., & Ponsa, P. (2025). The ARTificial revolution: Introducing generative artificial intelligence tools into artistic education. *Art, Design & Communication Studies*, *12*(2), 45–67. https://publicacions.iec.cat/repository/pdf/00000502/00000022.pdf

Di Paolo, L. (2025). *Artificial intelligence versus human intelligence: Making promotion decisions* (Doctoral dissertation, Concordia University).

Dumas, C., Chen, L., & Lefebvre, R. (2023). L'IA générative au service de la conception pédagogique [Generative AI for instructional design]. *HAL Archive Ouverte*. https://dumas.ccsd.cnrs.fr/dumas-04711599v1/document

Eisenmann, T. F., Karjus, A., Canet Sola, M., Brinkmann, L., Supriyatno, B. I., & Rahwan, I. (2025). Expertise elevates AI usage: Professional artists outperform laypeople in text-to-image creation and curation. *arXiv*. https://arxiv.org/html/2501.12374v2

Erişti, S. D. B., & Freedman, K. (2024). Integrating digital technologies and AI in art education: Pedagogical competencies and the evolution of digital visual culture. *Participatory Educational Research*, *11*(Prof. Dr. H. Ferhan Odabaşı Gift Issue), 57–79.

George, A. S. (2023). Preparing students for an AI-driven world: Rethinking curriculum and pedagogy in the age of artificial intelligence. *Partners Universal Innovative Research Publication*, *1*(2), 112–136.

Guo, M., Yuan, Z., Gao, F., & Gao, Z. (2024). The depth and complexity of traditional painting versus AI-generated art: A comparative analysis using Van Eyck's Arnolfini Portrait. In J. P. Bowen et al. (Eds.), *Electronic Visualisation and the Arts: Proceedings of EVA London 2024* (pp. 69–77). BCS. https://doi.org/10.14236/ewic/eva2024.12

Hammond, T., Kumar, S. P. A., Runyon, M., Cherian, J., Williford, B., Keshavabhotla, S., … & Linsey, J. (2018). It's not just about accuracy: Metrics that matter when modeling expert sketching ability. *ACM Transactions on Interactive Intelligent Systems (TiiS)*, *8*(3), 1–47.

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. *Thinking Skills and Creativity*, *26*, 140–153.

Hoffmann, A. R. (2019). *Sketching as design thinking*. Routledge.

Howell, J. B. (2020). Element-and-principles instruction, perceptual drawing and Paul Klee's Pedagogical Sketchbook. *International Journal of Art & Design Education*, *39*(1), 38–55.

Hu, Y. (2021). Research and application of modular teaching based on hand-drawing performance in quick-question design. *Frontiers in Art Research*, *3*(1), 1–6. https://doi.org/10.30564/far.v3i1.4027

Huang, A. Y., Lu, O. H., & Yang, S. J. (2023). Effects of artificial intelligence–enabled personalized recommendations on learners' learning engagement, motivation, and outcomes in a flipped classroom. *Computers & Education*, *194*, 104684.

Hughes, R. T., Zhu, L., & Bednarz, T. (2021). Generative adversarial networks–enabled human–artificial intelligence collaborative applications for creative and design industries: A systematic review of current approaches and trends. *Frontiers in Artificial Intelligence*, *4*, 604234.

Jaiswal, A., Arun, C. J., & Varma, A. (2023). Rebooting employees: Upskilling for artificial intelligence in multinational corporations. In *Artificial intelligence and international HRM* (pp. 114–143). Routledge.

Joel, A. (2024). *Ethical implications of generative AI in education and creative industries*.

Kelley, T. R., & Sung, E. (2017). Sketching by design: Teaching sketching to young learners. *International Journal of Technology and Design Education*, *27*(3), 363–386.

King's College London. (2023, July 5). *Rethinking assessment in the age of generative AI*. Retrieved from https://www.kcl.ac.uk

Kress, G., & Van Leeuwen, T. (2020). *Reading images: The grammar of visual design* (3rd ed.). Routledge.

Li, J. (2023). Philosophical reflections on artistic subjectivity in the age of artificial intelligence. *Art Studies Circle*, *(1)*, 45–52.

Li, Y., & Wang, H. (2025). Application of generative AI in art teaching: Discussion on teachers' role transformation and teaching strategy optimization [教学研究课题报告]. https://m.book118.com/html/2025/1015/7034115112010201.shtm

Lively, J., & Hutson, J. (2024). The role of student motivation in integrating AI into web design education: A longitudinal study. *Lindenwood University*. https://doi.org/10.13140/RG.2.2.12345

Lyu, X. (2025, September 8). Based on MindSpore AI+ art innovation application exploration [基于昇思 MindSpore 的 AI+艺术创新应用探索]. *Sichuan Fine Arts Institute*.

Ma, Z., & Wei, M. (2025). Toward a theoretical foundation for design sketching: Developing a comprehensive model for understanding and supporting sketch activities to intervene with sketch inhibition. *Journal of Integrated Design and Process Science*, *28*(3), 133–158.

Microsoft. (2024). *Machine learning trend survey 2024*. https://msrc-blog.microsoft.com/2024/08/06/ml-trend-survey-2024/

Ministry of Education of the People's Republic of China. (2025, April 16). About accelerating the digitalization of education [教育部等九部门关于加快推进教育数字化的意见]. http://www.moe.gov.cn/fbh/live/2025/56808/wj/

Pregoner, J. D. (2024). Research approaches in education: A comparison of quantitative, qualitative and mixed methods. *IMCC Journal of Science*, *4*(2), 31–36.

Qiao, X. (2024). Investigation on learning attitudes of senior high school students in information technology courses in mountainous and rural areas. *Advances in Education*, *14*(3), 165–172. https://pdf.hanspub.org/ae20231100000_98854281.pdf

Scholapurapu, P. K. (2025). *Artificial intelligence-powered learning analytics and student feedback mechanisms for dynamic curriculum enhancement and continuous quality improvement in outcome-based education*. DOI 10.9789349552531-06.

Shan, J., & Liu, Y. (2023). Research on generative AI-enabled learning design. *School of Educational Science and Technology, Nanjing University of Posts and Telecommunications*.

SheJiJingSai. (2025, November 12). 2025 China designers AI application status and trend insight research report. https://www.shejijingsai.com/2025/11/1449646.html

WeChat@AI Case Study in Education. (2024, August 12). AI-enhanced teaching case: Exploration and reflection on the visual narrative creation of the "Gaixia·Farewell to Concubine" theme. https://mp.weixin.qq.com/s?__biz=MzI1MjMxODU3MQ==&mid=2247492521&idx=2&sn=6bde3caaccea02bf6cc2c29fd882f50e

WeChat@AI Creative Lab. (2025, July 10). Closed-loop iterative creation in the AI era: From PDCA to data-driven creative practice. https://mp.weixin.qq.com/s?__biz=MzIwNTc4NjE2Ng==&mid=2247528687&idx=2&sn=df26f3383cedd84f27b2c52ec62abdb8

WeChat@AI Frontline in Education. (2024, July 15). Meta-analysis on AI instructional effectiveness: Learning motivation +27%, task efficiency +41%. https://mp.weixin.qq.com/s?__biz=Mzg2ODA0ODkwNA==&mid=2247540126&idx=2&sn=f56fb410e6dd75e44812e334f10743b5

WeChat@AI Tech in Education. (2023, November 30). How AI instant feedback boosts students' learning focus and sense of achievement. https://mp.weixin.qq.com/s?__biz=MzA3MDE1NjYyNA==&mid=2734575083&idx=4&sn=9363ab52b40e27f63040a70ddc54b103

Xueqiu@Tech Insight. (2025, August 15). Closed-loop iterative creation in the AI era: From PDCA to data-driven creative practice. https://xueqiu.com/1622002697/343398224

Yan, X. (2023). Research on the application and practice of generative artificial intelligence in college art and design teaching. *Hubei University of Technology*.

Yang, J., Jin, Q., & Jin, C. (2006). Impact of mental iteration on concept generation. *Journal of Mechanical Design*, *128*(3), 613–626. http://impact1.usc.edu/wp-content/uploads/papers/J29-JMD-PC-YJ-2006.pdf

Zhang, C., & Wang, L. (2023). AI painting technology analysis and industrial application trends. *Journal of Education and Research in Painting*, *1*(2), 33–41. https://www.sci-open.net/index.php/JERP1/article/view/2199/2860

Zhang, K., & Liu, S. (2024). Prompt-engineering training in programming education: Student perceptions and coding efficiency. *Computer Applications in Engineering Education*, Advance online publication. https://doi.org/10.1002/cae.22894

Zhao, D. (2025). The impact of AI-enhanced natural language processing tools on writing proficiency: An analysis of language precision, content summarization, and creative writing facilitation. *Education and Information Technologies*, *30*(6), 8055–8086.