Effects of a Flipped Classroom Learning System Integrated With ChatGPT on Students: a Survey From China

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Received 30 January 2024 | Accepted 17 December 2024 | Published 11 February 2025

Abstract

In design education, patterns and symbols representing traditional national cultures are often utilized as teaching materials. However, conventional teaching methods frequently fall short in aiding students' comprehension of these intricate symbolisms and abstract concepts, leading to reduced engagement and ineffective learning outcomes. Therefore, we aim to explore whether ChatGPT, as a powerful tool, can assist in solving this problem. Specifically, we integrate ChatGPT into a flipped classroom learning system to assess its effectiveness in enhancing students' understanding of traditional Chinese culture. This research contributes to the feasibility of integrating ChatGPT in design education, particularly in the context of Chinese culture. Additionally, it serves as an exploratory attempt to apply ChatGPT in teaching practices within the field of design.

Keywords

Chinese Traditional Culture, Cognitive Load, Designed Education, Engagement, Generative AI.

DOI: 10.9781/ijimai.2025.02.007

I. Introduction

Artificial Intelligence (AI) continues to advance and optimize, and it plays a crucial role in digital society. AI's ability to process large amounts of data and automate tasks has revolutionized various fields globally [1]. There are increasing indications that AI can have a positive impact on education [2], [3]. However, using generative AI for educational purposes is a relatively new field, and its potential to enhance human learning remains untested mainly [4]. The past two years have seen significant breakthroughs in various generative AI tools, including ChatGPT, developed by OpenAI, which has garnered significant attention worldwide. These advancements have opened up new possibilities for utilizing AI in creative media and educational content, allowing for tasks previously thought to be beyond AI's capabilities [5], [6].

ChatGPT is an advanced conversational AI interface employing Natural Language Processing (NLP) to interact in realistic interactions. This system uses a large-scale language model (LLM) to generate human-like language [7]. It can answer follow-up questions, acknowledge mistakes, challenge incorrect assumptions, and reject inappropriate requests [8]. OpenAI utilizes deep learning algorithms trained on large numbers of texts. These models learn language patterns and structures by processing extensive data and can deliver related and meaningful content to users based on their inquiries [9]. ChatGPT is a versatile tool for various natural language processing tasks, including free-form conversations, text generation, and language translation [10]. It has experienced unprecedented growth, becoming the fastest-growing application in user adoption in history [11].

While ChatGPT presents numerous transformative applications in the field of education, it also introduces a range of challenges and potential threats, leading to mixed reactions among educators [12]. Some educators view AI, such as ChatGPT, as a powerful tool for driving transformative progress in education, while others approach it with scepticism, perceiving it as a possible risk [13]. Farrokhnia [14] performed a SWOT analysis of ChatGPT to evaluate its benefits, including enhanced access to information, personalized learning and reduced instructional workload, as well as its limitations, such as concerns regarding academic integrity, difficulties in assessing response quality, and the potential for bias and discrimination. Adeshola and Adepoju [15] conducted sentiment analysis on ChatGPT, gathering 3,870 usable messages and categorizing them as "positive," "negative," or "neutral." This analysis demonstrated that the majority of participants rated ChatGPT positively. In a review conducted by Pradana [16], existing research on ChatGPT in education was examined through bibliometric analyses and a systematic literature review, affirming its potential for educational applications and highlighting concerns. These debates and concerns around implementing ChatGPT in education underscore the value of conducting thorough analysis and fostering discussions across various realms of education.

Please cite this article as:
J. Chen, N. A. M. Mokmin, Q. Shen. Effects of a Flipped classroom learning system Integrated with ChatGPT on students: a Survey from China, International Journal of Interactive Multimedia and Artificial Intelligence, vol. 9, no. 2, pp. 113-123, 2025, http://dx.doi.org/10.9781/ijimai.2025.02.007

As generative artificial intelligence (AI) systems, such as ChatGPT, are increasingly deployed globally, it is essential to integrate principles of Open Science to ensure these tools are accessible, transparent, and inclusive. This requires the open sharing of AI methodologies and data and a concerted effort to adapt AI systems to various regions culturally. Ensuring that AI models are sensitive to diverse cultural contexts is vital for reducing bias and fostering global inclusivity. For instance, Cao et al. [17] observed that while ChatGPT exhibits strong alignment with American cultural norms, its effectiveness diminishes when interacting with users from other cultural backgrounds, highlighting the need for culturally responsive AI systems. Incorporating these considerations into AI development aligns with the goals of Open Science, which advocates for the equitable dissemination of scientific knowledge and technology across different cultural and socio-economic contexts.

Users from diverse cultural backgrounds may encounter linguistic and cultural barriers if the generative AI model does not adequately integrate or learn their culture—a research investigation conducted by Virvou et al. [18] explores the impact of ChatGPT on cultural heritage e-learning. The study highlights the potential of ChatGPT in aiding learners in analyzing and interpreting Greek poetic works. However, it also highlights notable limitations concerning the Greek historical context and factual accuracy. In a feasibility study by Żammit [19] on ChatGPT's assistance in Maltese language learning, the findings reveal limitations in providing information related to Maltese grammar and vocabulary, as well as difficulties in understanding and answering Maltese questions and statements, compared to its effectiveness in aiding the learning of English. The study also notes that 98% of the participants surveyed expressed that ChatGPT lacked cultural context. To our knowledge, no research has explored the feasibility of using ChatGPT to facilitate traditional Chinese cultural learning. Furthermore, there is a scarcity of literature focusing on Chinese students' experiences with ChatGPT, particularly in the context of design education. Addressing this research gap is of utmost importance and should be prioritized.

In this study, we developed a flipped classroom learning system that integrated a ChatGPT-driven pedagogical agent to facilitate student learning in a 2D design course. A quasi-experimental research design was used to assess the impact of this developed system on student learning outcomes, cognitive load, and engagement. To address these objectives, we explored the following research questions.

RQ1. Do Chinese students using a flipped classroom learning system that integrated a ChatGPT-driven pedagogical agent perform better than those using a Basic flipped classroom learning system (i.e., without generative AI components)?

RQ2. Does a flipped classroom learning system that integrates a ChatGPT-driven pedagogical agent affect the cognitive load of Chinese students compared to a Basic flipped classroom learning system?

RQ3. Do Chinese students experience improved engagement when using a flipped classroom learning system that integrated a ChatGPT-driven pedagogical agent, in contrast to a Basic flipped classroom learning system?

II. Background

A. ChatGPT in Education

The performance of ChatGPT varies across different subject areas and is applied in various ways within the field of education [20]. For instance, Kieser et al. [21] conducted research to evaluate the ability of ChatGPT to solve concept inventory (FCI) problems in physics education. Lee [22] employed ChatGPT as a virtual teaching assistant in medical education, offering students in-depth information and interactive simulations, enhancing student engagement and learning outcomes. Van den Berg and du Plessis [23] investigated the role of ChatGPT in curriculum planning and educational openness within school teacher training. Li [24] utilized ChatGPT as an assistance tool in a courseware project, observing its positive impact on student performance and perception. Moreover, Tlili et al. [25] suggested that future research should incorporate controlled experiments to evaluate the overall effectiveness of ChatGPT in various professional educational settings.

Additionally, students' experiences using ChatGPT for learning may vary due to their different cultural backgrounds and levels of AI literacy. Fui-Hoon et al. [26] highlighted how generative AI, like ChatGPT, can potentially expand the current digital divide in society, raising concerns about equitable access to AI-driven educational resources. They emphasized that the second level of the digital divide, which pertains to the disparity in Internet skills and usage among diverse groups and cultures, has garnered significant attention with the widespread use of the Internet. This disparity challenges open science principles, which advocate for democratizing knowledge and resources. Individuals residing in areas with limited access may face more obstacles in utilizing ChatGPT for assisted learning, particularly if they possess lower AI literacy and less proficient questioning skills [27],[28].

Moreover, as AI tools like ChatGPT continue to evolve, it is crucial to ensure they are culturally adaptive and inclusive to avoid reinforcing biases and to foster a more culturally aware educational environment. Tlili et al. [25] also showed that the results generated by ChatGPT may differ depending on how the questions are asked, even if the dialogue revolves around the same topic. Consequently, learners must employ critical thinking and develop strong questioning skills to achieve optimal outcomes when utilizing ChatGPT, further underscoring the importance of integrating AI literacy into educational practices to bridge these cultural and technological divides.

As mentioned earlier, relevant generative AI in education literature shows the enormous potential of integrating ChatGPT into education to provide timely feedback and assessment, personalize learning experiences, and expand learning resources. However, researchers have also acknowledged several challenges associated with using ChatGPT in education, including potential flaws in cultural context and factual accuracy [18]. Therefore, it is essential to combine ChatGPT with effective instructional design and teaching strategies to facilitate collaborative student learning with the guidance of teachers [16], [25]. Such an approach encourages students to critically analyze and discuss the accuracy of information critically, thereby enhancing their critical thinking skills [13] [18].

B. Flipped Classroom

The flipped classroom is widely recognized as a relevant pedagogical method in educational technology and has been strongly promoted in higher education [29]. In this instructional model, instructors are responsible for providing relevant learning materials such as instructional videos, course websites, and reading texts for students to study before class [30]. Students participate in discussions, group presentations, and additional positive study activities during class time in response to the pre-class materials [31]. After the class period, students are given enriched assignments or quizzes to reinforce their learning [32]. The flipped classroom, as a student-centred learning model, demands learners to be in charge of their study and decision-making throughout the entire process, with the teacher acting as a facilitator [33], [34], [35].

Although positive outcomes have been observed in various forms of flipped classroom development [36], [37], challenges persist [38]. According to some scholars, numerous educators hesitate to embrace the flipped classroom approach because of the additional time and expense required for course adaptation [39]. These include preparing pre-course learning materials, designing learning activities, and managing the classroom environment. Previous research has indicated that student performance within the flipped classroom is primarily influenced by the quality of the pre-class learning materials [40]. Students with a solid grasp of the materials before class are likelier to engage in class and exhibit greater achievement actively. Conversely, students who struggle to comprehend the materials before class may be less engaged in the flipped classroom format. Furthermore, providing personalized instruction to individual students in a flipped learning approach presents a challenging task to teachers [41].

Prior studies on flipped classrooms have focused on their effects on student learning achievement and engagement [32]. Engagement indicates the degree of students' active participation in the learning activity, seeking guidance from the instructor, or collaborating with group members [42], [43]. Behavioural, emotional, cognitive, and agentic engagement are the four student engagement types that promote active classroom learning Behavioral engagement is defined as observable behaviors required for academic achievement; emotional engagement includes how students feel about the learning experience; agentic engagement refers to self-regulated learning conditions; and cognitive engagement refers to applied learning strategies [46]. Several studies have suggested that engagement strongly correlates to academic performance and is a powerful indicator of students' success [47], [48].

Cognitive load theory offers insights into how people adapt to tasks they perform from psychological, physiological, and cognitive perspectives [49]. Cognitive load is the mental effort required to handle and understand information, comprising three main types: intrinsic cognitive load, extrinsic cognitive load, and germane cognitive load [50]. Intrinsic cognitive load relates to the complexity of the learning material, the learner's knowledge base, and their experience level. Extraneous cognitive load relates to the organization and presentation of teaching designs. Effective instructional designs and procedures are essential to mitigate unnecessary cognitive load [51]. Therefore, when designing instruction for the flipped classroom model, it is imperative to consider cognitive load. Although measuring cognitive load is an open question, self-reported mental effort and perceived difficulty are commonly employed as measures of cognitive load in past studies [52], [53].

C. Design Course and Nanjing Yunjin Brocade

The 2D design course involved in this study aims to teach students basic elements, design theories, and various problem-solving techniques. It covers various topics, including design principles, critical thinking, graphic color, and texture. Through this course, students develop their aesthetic and visual concepts and acquire essential skills for visual communication and creative expression [54].

In China, there is a growing emphasis on education in traditional culture, with schools taking on the responsibility of preserving and passing on the country's intangible cultural heritage. To support this, the Chinese government has implemented educational policies promoting heritage education [55]. The university's College of Humanities and Art was recognized by the City of Nanjing in 2019 as an "Intangible Cultural Heritage Education Transmission Base." The college integrates intangible cultural heritage (ICH) into certain curricula, allowing students to relate ICH to their studies and daily lives. Specifically, in the 2D design course, the patterns of Nanjing Intangible Cultural Heritage "Nanjing Yunjin" are examples. This approach enables students to appreciate Nanjing's cultural heritage and unique characteristics while learning graphic design.

In 2009, the craft of Nanjing Yunjin brocade was recognized as being among the "Masterpieces of the Oral and Intangible Heritage of Humanity" [56]. Originating from Nanjing, Nanjing Yunjin brocade derives its name from its delicate patterns resembling clouds in the sky. Its history can be traced back to the third century A.D. it is considered one of China's top three most famous brocades due to its unique and intricate manufacturing techniques. The brocade's vibrant and ever-changing patterns have significant artistic value, drawing elements from traditional Chinese auspicious motifs encompassing animals, plants, and mythological stories. The patterns are created through a fusion of realistic and abstract evolution. Nanjing Yunjin patterns exhibit a finely composed structure, with clear primary and secondary elements and various forms. Designing these patterns requires a deep understanding of 2D design principles, making it a great case study.

However, despite the importance of the 2D design course for art and design students, its conceptual nature and abstract knowledge can be challenging to comprehend. The traditional "chalk and talk" teaching method limits student participation, resulting in low engagement and interest in learning [57]. This often leads to suboptimal teaching outcomes and hampers cultivating students' design foundations. Therefore, we focus on using Nanjing Yunjin brocade as a case study in a 2D design course at a Chinese university. We adopt a flipped classroom model and integrate a ChatGPT-driven teaching agent to support learning. By cultivating aesthetic concepts and understanding basic design principles, we aim to increase students' awareness of intangible cultural heritage and facilitate cultural preservation and development.

III. Flipped Classroom Learning System With ChatGPT

In this study, we designed learning activities using the flipped classroom model and ChatGPT to strengthen students' comprehension of the intangible cultural heritage of the China-Nanjing Yunjin brocade. The structure of our flipped learning system, as illustrated in Fig. 1, consisted of the flipped learning system integrating ChatGPT, the flipped classroom activity management system, and the server database management system. The frontend was constructed using the Vue framework (based on HTML5, CSS, and JavaScript), while the system functionalities were encapsulated as APIs using the Java programming language for frontend interaction. During the implementation process, access to the OpenAI API was obtained, and the corresponding API key was configured in the environment variables of the Linux server. The frontend pages send requests to the backend server, which, upon receiving the requests, invokes the encapsulated APIs to perform Create, Read, Update, and Delete (CRUD) operations on the MySQL database and interact with the OpenAI server. After processing the requests, the server returns the responses to the front end, presenting the processed information to the learners.

Furthermore, the database management system (DBMS) includes learning material, learning profiles, student profiles, and dialogue databases. The learning material database stored learning materials, study sheets, and guidance notes. The student profile database stores students' information, while the learning profile database stores students' learning records. Finally, the dialogue database was utilized to store student dialogue data with ChatGPT.

The content of this study focuses on a two-dimensional design course centered on Nanjing Yunjin brocade. As shown in Fig. 2, students must access the flipped classroom learning system before attending the class to study the learning materials provided. A learning list is available within the system for students to follow. The learning system

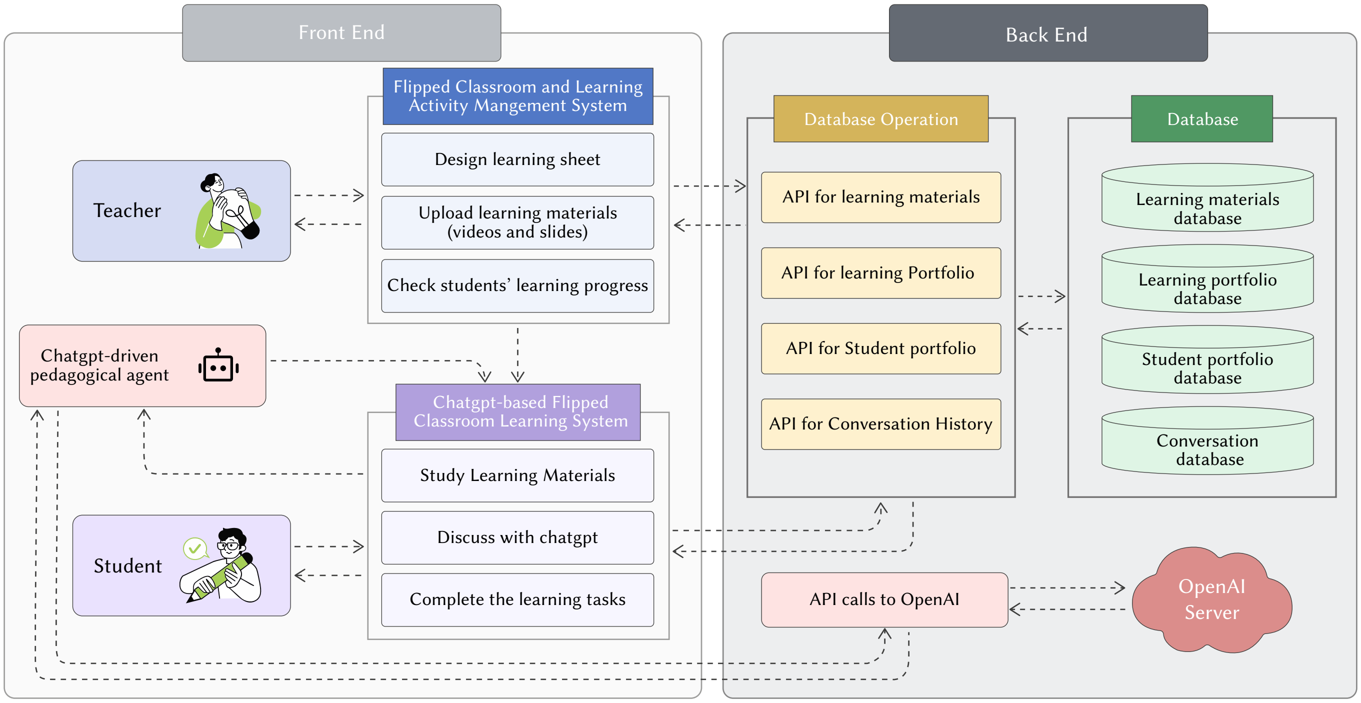

Fig. 1 The structure of Flipped Classroom Learning System with ChatGPT.

Fig. 2 Flipped Classroom Learning System Interface.

offers a range of materials, including slides, learning videos, and text materials. Specifically, slides offer the course's main framework and key points, videos assist in understanding complex concepts through visual presentations, and text materials provide detailed historical background information and relevant academic articles. Students can access and review these materials as often as needed prior to class to gain initial knowledge. Notably, the right side of the interface features a pedagogical agent powered by ChatGPT, designed to assist students in further deepening their understanding and resolving queries. This agent is a standard GPT model whose behavior and generated content are guided by specific prompts. Prompts typically include contextual information or instructions to ensure that the output of the GPT model matches the instructional goals. For example, we have instructed ChatGPT to act as an expert on Nanjing Yunjin brocade in a dialogue, helping students answer questions related to the course content and providing immediate feedback and guidance.

Upon completing the learning content, students must also complete an assignment sheet, which expands on the concepts covered in the learning materials. For instance, they may create a pattern according to Nanjing Yunjin's panel composition principles. Students can discuss with the pedagogical agent powered by ChatGPT at any time and receive personalized references. Furthermore, the flipped classroom learning system emphasizes that ChatGPT is a means of support and that its feedback may not always be correct. Students are encouraged to think critically and can flag any uncertainties to facilitate questions and discussions with classmates and the instructor.

After completing the pre-course learning activities, the teacher organizes group discussions in class, where students can present and discuss their pattern designs. During these discussions, the teacher explains the principles of plate composition and the traditional cultural imagery conveyed. The teacher participates in the discussion and guides the students in response to their doubts, as shown in Fig.3.

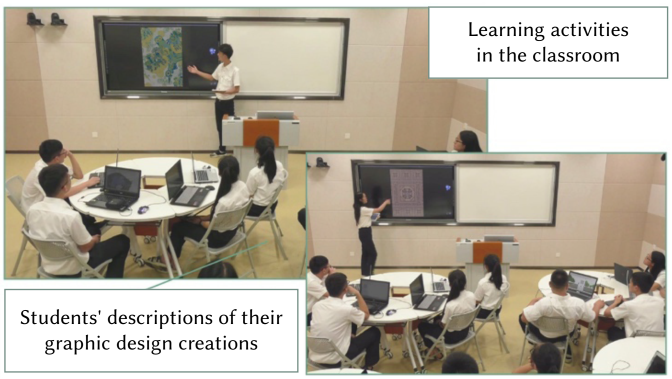

Fig. 3. Learning activities in the classroom.

IV. Methods

A. Participants

This study involved 70 first-year students from a comprehensive university in China (where the language of instruction was Chinese). Participants were selected from design students enrolled in a 2D design course. Each participant was gifted a Nanjing Yunjin brocade artefact.

In this study, we carefully considered the relevant ethical issues. First, participants were required to read and sign an informed consent form prior to participation. The document outlined the study's purpose, procedures, potential risks and benefits, data usage, and the participants' rights, emphasizing their right to discontinue participation at any time without consequence. Secondly, to safeguard participant privacy, all collected data were anonymized and maintained with strict confidentiality for the exclusive use of this study.

After providing informed consent, participants had to provide personal information, including their name, age, gender, and frequency with which they use ChatGPT (on a 5-point Likert scale). Regarding gender identification, participants were allowed to self-report in fill-in-the-blank questions instead of choosing between male or female options. The mean age of participants was 18.43 years (SD=0.73), with 26 (37.1%) males and 44 (62.9%) females. The participants reported infrequent usage of ChatGPT and similar tools in their daily lives (M=1.84, SD=0.58), and indicated that they mainly never used ChatGPT and similar tools for learning purposes (M=1.34, SD=0.54).

The participants were randomized into experimental (n=32) and control (n=38) groups. This research adopted a quasi-experimental design, incorporating several control variables: (1) Due to the potential influence of teachers' teaching styles, both groups engaged in a flipped classroom approach and were supervised by the same university lecturer with significant experience in design education. (2) All participants were familiarized with the flipped learning system used and informed about the purpose of the research. The experimental group was given additional instruction on how to utilize ChatGPT and associated techniques before the start of the experiment.

B. Measures & Instruments

The instruments used in the study included pre-tests, post-tests, cognitive load items and engagement items. The pre-test and post-test learning scales were designed by three university lecturers with over 12 years of experience teaching two-dimensional design courses and were used to assess student performance. The scale tested students' comprehension of graphic layout and Nanjing Yunjin brocade through 20 multiple-choice questions, each worth 5 points. As students choose the correct answer, their cumulative score ranges from 0 to 100. The scale was assessed by two experts, as shown in Table I.

TABLE I. Background and Experience of the Experts Involved in the Evaluation

Experts	Background	Experience
A	Inheritor of Nanjing Yunjin brocade weaving skills	41 years of experience in designing Nanjing Yunjin brocade
B	Professor of Art and Design	20 years of experience in art and design research

A questionnaire by Hwang et al. [58] was used to investigate learners' cognitive load during the flipped learning process. This questionnaire includes two dimensions: 'mental load,' which measures learners' intrinsic cognitive load, and 'mental effort,' which assesses learners' extraneous cognitive load. The questionnaire was rated on a six-point Likert scale, of which five items measure mental load and three measure mental effort. In this study, Cronbach's alpha coefficients for the two dimensions were 0.87 and 0.86, respectively.

To evaluate the influence of flipped classroom environment on student engagement, a questionnaire designed by Reeve [44] was utilized. The questionnaire included 21 items and was scored on a five-point Likert scale. The questionnaire measured four dimensions of engagement: "Behavioral Engagement" (5 items) assessed task attention, course engagement, and effort; "Emotional Engagement" (5 items) captured the feelings experienced during learning; "Cognitive Engagement" (4 items) evaluated the development of learning strategies; and "Agentic Engagement" (7 items) appraised students' self-directed learning. For each dimension, Cronbach's alpha coefficients were 0.78, 0.71, 0.73, and 0.79.

The interview questions utilized in this study were adapted from the methodology described by Hwang et al. [59]. They comprised seven questions uniquely crafted to enquire about Chinese students' perceptions of using ChatGPT to facilitate flipped classroom learning activities. All interviews were recorded in audio format to enable comprehensive analysis. Some examples of the interview questions are: "What are your thoughts on this learning system? Could you provide reasons for your opinion?" and "In comparison to your previous experiences with flipped classroom learning, did you notice any differences when using this learning system?"

C. Experimental Procedure

The experimental procedure is depicted in Fig.4. Before the course began, the instructor explained the procedure to all participants to ensure the experiment ran smoothly. Furthermore, all students completed a consent form and a pre-test to assess their foundational understanding of Nanjing Yunjin brocade. Subsequently, both

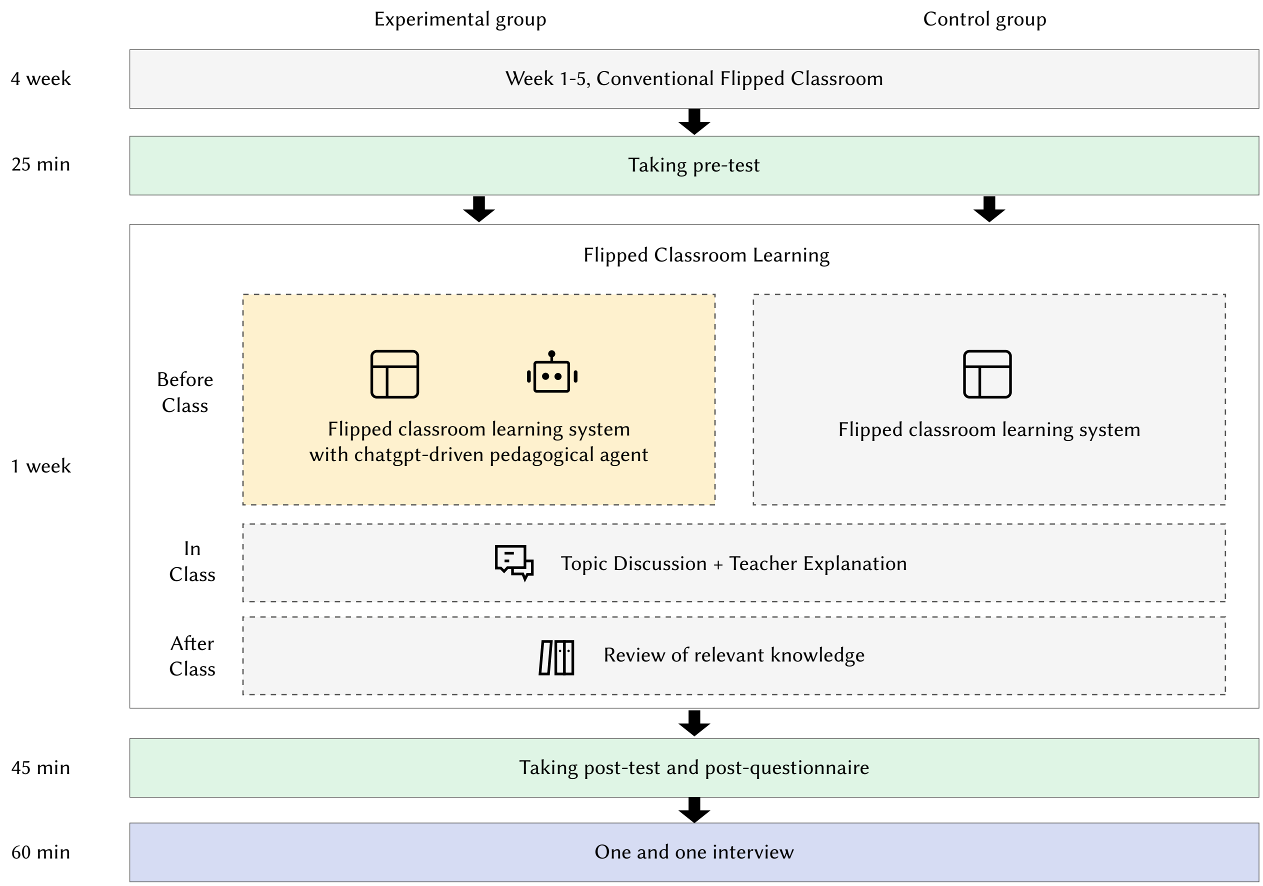

Fig. 4 The procedure of the experiment.

groups utilized the flipped classroom teaching system, with the only difference being the inclusion of ChatGPT. After the learning activity, participants underwent post-tests and completed post-questionnaire regarding engagement and cognitive load. Finally, six randomly selected students from the two groups were interviewed.

V. Results

A. Learning Achievement

A one-way analysis of covariance (ANCOVA) was conducted to examine students' learning achievement. The dependent variable was post-test scores, while the independent variable used two different flipped classroom learning systems for learning activities. Pre-test scores were also included as covariates to account for initial knowledge differences.

A homogeneity test was first performed to validate the ANOVA, which showed that the assumption of regression homogeneity was not violated (F=2.21, p>0.05). Subsequently, an ANOVA was conducted, and the findings displayed in Table II revealed a significant influence of different flipped classroom learning systems on learning achievement (F=15.44, p<0.001, η2=0.19). This indicates that the post-test scores of the two groups varied considerably according to the type of flipped classroom learning system employed. The control group exhibited adjusted mean and standard deviation post-test scores of 70.63 and 10.30, respectively, while the experimental group scored 81.59 and 14.26, respectively. Thus, integrating the ChatGPT-driven pedagogical agent in the flipped classroom learning system improved Chinese students' learning outcomes in 2D design courses, demonstrating a large effect size (η2=0.19, η2 > 0.14).

TABLE II. The Analysis of the ANCOVA on Students' Performance

Group	N	Mean	SD	Adjusted mean	F	η2
Experimental group	32	82.5	14.26	81.59	15.44^{***}	0.19
Control group	38	69.87	10.3	70.63		

$^{***}p < .001$

B. Student Engagement

A t-test was conducted to analyze the scores of four engagement subscales (behavioral, agentic, cognitive, and emotional engagement), as presented in Table III, to examine students' engagement. Overall, the experimental group displayed higher mean scores on all subscales, exceeding the median of 3, although with slight variations in each subscale.

Statistically, no significant differences were found between the two groups in behavioral engagement (t = 1.96, p > 0.05) and agentic engagement (t = 0.18, p > 0.05). This indicates that including ChatGPT-driven instructional agents did not significantly affect Chinese students' behavioral and agentic engagement in the context of flipped classrooms.

However, for cognitive engagement and emotional engagement, there were significant differences in scores between the two groups: t = 3.68 (p < 0.01) and t = 3.07 (p < 0.01), respectively. On the cognitive engagement dimension, the mean values for both groups were 3.68(SD=0.67) and 3.15(SD=0.67), respectively. This suggests that Chinese students using ChatGPT-driven pedagogical agents in the flipped classroom model exhibited higher cognitive engagement than those using the regular flipped classroom learning system. This difference also shows a medium effect size with d = 0.77 (d > 0.50). Similarly, on the dimension of emotional engagement, the mean values for both groups were 3.89(SD=0.77) and 3.36(SD=0.66), respectively. This indicates that students in the experimental group demonstrated higher emotional engagement with their studies than the control group. Moreover, this difference shows a medium effect size with d = 0.73 (d > 0.50).

TABLE III. The T-test Results of Student Engagement

	Group	N	Mean	SD	t	d
Behavioral Engagement	Experimental group	32	3.56	0.65	1.96	0.47
	Control group	38	3.28	0.54		
Agentic Engagement	Experimental group	32	3.43	0.72	0.18	0.04
	Control group	38	3.4	0.77		
Cognitive Engagement	Experimental group	32	3.68	0.67	3.21**	0.77
	Control group	38	3.15	0.7		
Emotional Engagement	Experimental group	32	3.89	0.77	3.07**	0.73
	Control group	38	3.36	0.66		

**p < .01

C. Cognitive Load

To examine the intrinsic and extraneous cognitive loads experienced by the students, t-tests were conducted to analyze the "mental load" and "mental effort" dimensions. T-tests were conducted to examine the intrinsic and extraneous cognitive loads experienced by the students. As indicated in Table IV, regarding mental load, the t-value was -0.75 (p>0.05) between the two groups. These findings suggest that integrating a ChatGPT-driven pedagogical agent in a flipped classroom learning system does not significantly affect students' mental load compared to the regular flipped classroom learning system. Moreover, no significant difference was found in the level of mental load between the experimental and control groups (t=-1.79, p<0.05). The mean values for the two groups were 3.10 (SD = 0.61) and 3.36 (SD = 0.59), respectively. While the difference is not statistically significant, it is observed that students using the learning system with ChatGPT had slightly lower scores in terms of mental effort compared to the regular learning system. These results imply that incorporating a ChatGPT-driven pedagogical agent in a flipped classroom learning system leads to a slightly reduced extraneous cognitive load during the learning process compared to a regular flipped classroom learning system.

TABLE IV. The T-test Result of the Two Groups' Cognitive Load Levels

	Group	N	Mean	SD	t	d
Mental Load	Experimental group	32	3.19	0.74	-0.75	0.18
	Control group	38	3.31	0.81		
Mental Effort	Experimental group	32	3.1	0.61	-1.79	0.42
	Control group	38	3.36	0.59		

VI. Discussion

This study aimed to develop a flipped classroom learning system incorporating ChatGPT to enhance a design course for Chinese university students. A quasi-experiment was performed at a university in Nanjing, Jiangsu Province, China, to investigate the effects of using ChatGPT on Chinese students' academic performance, engagement, and cognitive load. The experiment results demonstrate that combining ChatGPT with a flipped classroom learning system significantly improved students' learning performance and positively influenced their affective and mental engagement. However, the benefits of ChatGPT's integration into educational settings may vary depending on students' cultural backgrounds and levels of AI literacy. Fui-Hoon et al. [26] and others have raised concerns about how AI literacy and digital access disparities may exacerbate educational inequalities. Students from areas with limited access to technology or those with lower AI literacy might struggle to fully leverage the benefits of such advanced tools. This outcome variation underscores the importance of considering these factors in designing and implementing AI-driven educational systems. Notably, it did not significantly affect students' internal or extraneous cognitive loads during the learning activities. The subsequent section will provide a detailed discussion of these findings.

A. Learning Achievement

This study demonstrated that students' academic performance using a flipped classroom learning system incorporating ChatGPT improved, aligning with prior research findings [24], [60]. The system developed in this study aims to provide students with diverse learning materials and immediate personalized guidance. Students can engage in discussions regarding the content with the ChatGPT-driven pedagogical agent and receive tailored feedback. According to Li [24], ChatGPT surpasses other intelligent chatbots in providing learning support, thereby effectively enhancing student performance. Furthermore, students are encouraged to approach the advice supplied by ChatGPT dialectically [20] and discuss them during classroom activities. Through such exchanges, their understanding of the learning content is deepened.

B. Student Engagement

The potency of engagement for learning has been widely researched and is a crucial factor in learning activities, with significant implications for student performance and subject comprehension [61], [62]. In this study, the ChatGPT-driven pedagogical agent positively impacted student engagement. The primary impact was on cognitive, affective, behavioral, and agentic engagement. Cognitive engagement refers to the level of engagement in learning, such as understanding the content [63], [64]. Through interactions with a ChatGPT-driven pedagogical agent, students comprehend and apply what they learn, encouraging critical thinking beyond mere memorization.

Additionally, affective engagement corresponds to emotional responses in education [65], [66]. Flipped classroom learning systems with user-friendly interfaces and ChatGPT-driven pedagogical agents that provide timely feedback and interactions foster a learning environment that promotes student proactivity. Nevertheless, the effectiveness of these interactions can be influenced by the students' cultural contexts and AI literacy. For instance, individuals from different cultural backgrounds might interpret the feedback provided by ChatGPT differently, which could affect their emotional engagement. Moreover, students with varying levels of AI literacy might find it challenging to navigate or fully benefit from these technologies, potentially widening the digital divide within educational settings. However, it needs to be acknowledged that using new technologies in learning may trigger a "novelty effect," which initially enhances engagement and interest [67], [68]. Nonetheless, this effect is transient and diminishes with familiarity with the technology and the associated experience [69], [70], [71].

C. Cognitive Load

Extraneous cognitive load disrupts students' learning and is mainly influenced by how learning materials are presented and how learning activities are organized [72], [73]. Several previous studies suggest that using chatbots to assist with learning tasks can be a powerful way to decrease extraneous cognitive load [74], [75], [76]. However, students in this study who used ChatGPT-driven pedagogical agents for learning did not experience a significant reduction in extraneous cognitive load when compared to the control group of students. Moreover, based on the information obtained from the interviews, the students reported that there were sometimes significant communication barriers when using the ChatGPT-driven pedagogical agent. Students could not always accurately obtain helpful information when asking ChatGPT questions. As a result, the extraneous cognitive load was not effectively reduced. Three explanations are proposed for this. First, students' proficiency in using ChatGPT was low. ChatGPT generates different results depending on how the questions are asked (e.g., wording), even if the dialogue is about the same topic [77], [25]. Second, ChatGPT is mainly trained with English data, and due to the differences in grammatical structure, expression, and vocabulary between Chinese and English, it may encounter challenges, including inaccuracies or unnatural expressions, when processing Chinese text or generating Chinese content [78]. This is attributed to insufficient Chinese data or understanding Chinese language features. Finally, ChatGPT may not be able to cover all aspects of Chinese culture during training [79], resulting in insufficient comprehension of China-specific cultural, historical, and social contexts.

VII. Conclusion

A. Theoretical and Practical Implications

Our findings have both theoretical and practical implications. Theoretically, we explore the feasibility of using ChatGPT in design education within the Chinese cultural context. While previous research mainly centered on the application of ChatGPT in Western cultural contexts of education [80], [81], [82], this study examines its potential for assisting educational purposes in Chinese cultural contexts, shedding light on the distinct needs and varied experiences of learners from different cultural backgrounds and native languages as they engage with ChatGPT.Our study reveals that, despite being primarily trained on English data, ChatGPT can be effectively utilized in Chinese educational settings with suitable adaptation and localization. This research contributes to the literature on generative AI in multilingual and multicultural contexts by highlighting the necessity of optimizing AI tools for different linguistic environments.

From a practical standpoint, our study incorporates ChatGPT into teaching practice, combining ChatGPT with the flipped classroom teaching model and implementing it within an authentic educational setting. Our study demonstrated that we effectively improve student learning achievement and engagement by integrating ChatGPT into the flipped classroom teaching model. One noteworthy benefit of incorporating ChatGPT in flipped classrooms is that it helps students to ask questions and receive immediate feedback on the content they find challenging to grasp during the pre-class period. This suggests that through rational instructional design, ChatGPT can be a powerful tool to promote teaching traditional Chinese culture in design education, particularly in courses that demand high levels of student interaction and creativity. It offers a reference for exploring the combined application of ChatGPT and teaching strategies. Our research also demonstrated that AI tutors (ChatGPT) collaborate with human teachers to support the achievement of teaching goals. During the pre-classroom learning phase, ChatGPT provides personalized guidance and timely question-and-answer sessions for students. In the classroom, the human teacher facilitates in-depth discussions, Q&A sessions, and practical application of knowledge. This collaborative model informs future educational practices. Additionally, while AI has been proven to enhance learning experiences across various fields [83]–[85] there is a scarcity of research exploring its feasibility in design education. This study makes a significant contribution by adding new findings to this study area.

B. Limitations and Future Directions

There are several limitations of this research that need to be noted. The first is that the small sample of participants could have influenced the data analysis, highlighting the need for future research with a larger sample size. Secondly, the experiment was conducted within a two-dimensional design course using the Nanjing Yunjin brocade pattern as the teaching case. Therefore, it is important to recognize that different educational areas may yield varying experimental results. Future research should explore the potential impact of ChatGPT within the Chinese cultural context of education.

Although the ChatGPT-driven pedagogical agent demonstrated adequate learning support in this study, the possibility of hallucinations (i.e., generated content containing inaccurate or erroneous information) cannot be overlooked. However, due to the study design limitations, we did not measure the frequency of encountering misinformation or students' reactions. Future research should address this issue by designing experiments to measure and analyze the provision of error messages by ChatGPT and their effects on students' learning behaviors and outcomes.

Furthermore, variations in participants' familiarity with AI tools in this study may have influenced their learning performance and experimental results. Future research should measure and control participants' familiarity with AI tools, exploring how to achieve equitable learning outcomes among students with varying levels of familiarity.

Lastly, it is imperative to emphasize that using a ChatGPT-driven pedagogical agent in this study inevitably poses the risk of encountering harmful behaviors such as dishonesty, manipulation, and misinformation. Future research should focus on designing and implementing safer and more suitable chatbots as pedagogical agents and, for instance, integrating a real-time user feedback system so that students and instructors can report errors or inappropriate information promptly and optimize the performance of the pedagogical agent through the collected feedback.

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