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The impact of an interdisciplinary co-creation teaching model on the design and creative abilities of college students in a smart classroom environment

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Abstract

The aim of this study was to investigate the impact of the interdisciplinary co-creation teaching model on students' design creativity and learning perception within a smart classroom environment. Eighty participants were randomly selected from a Chinese university and assigned to either the experimental or control group in this quasi-experimental study. Students in the control group were instructed with an interdisciplinary teaching model in the traditional classroom while respondents in the experimental group were taught with an interdisciplinary co-creation teaching model in a smart classroom environment. The two groups' differences in perceptions of learning and design creativity were measured using pre- and post-tests. Independent t-test samples were used to analyze data for design creativity and paired sample t-tests were used for learning perception. The results showed that there are significant differences between the impact of the interdisciplinary teaching model used in a traditional classroom environment and the interdisciplinary co-creation teaching model used in a smart classroom environment on students' design creativity and learning perception. The latter approach was found to be more effective in improving students' design creativity and learning perception. It can be seen that the interdisciplinary co-creation teaching model in the smart classroom environment is not only a teaching tool but also a new teaching model. It allows students to obtain comprehensive learning and perception improvements during the learning process thereby improving students' design creativity.

Keywords: Co-creation learning, Design creativity, Design education, Interdisciplinary learning, Learning perception, Smart classroom environment.

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Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
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1. Introduction

Design innovation has become a crucial measure of knowledge and economic success against the backdrop of today's information-driven and globalized economy. It is important for sustainable innovation and has a substantial impact on both individual well-being and business performance [1]. Consequently, an increasing number of countries, societies and educational institutions have started emphasizing the cultivation and development of students' design creativity as a means to enhance their competitiveness [2, 3]. In the context of development design and creativity, education holds a paramount role. It not only aids in shaping individuals' innovation awareness and refining innovative thinking but also effectively brings about change and drives the sustainable development of human activities across various domains including industry, commerce and education. Therefore, the cultivation and development of individuals' creativity are not only central objectives of modern design education but also indicative of the direction for the future development of design education [4].

Creativity is regarded as a comprehensive skill. It is considered a core competency for students in the field of design [5]. Creativity involves students' ability to access and apply knowledge and skills from various disciplines to accomplish tasks while continually developing new methods to address diverse problems. This reflects students' possession of strong comprehensive thinking abilities [6]. Existing research has highlighted that creativity can be developed and enhanced through teaching, learning methods and practice [7]. Similarly, external factors such as communication, environment, motivation and emotions play a significant role in shaping students' creativity in the process of learning [8]. Therefore, the improvement of creativity is influenced not only by factors like teaching methods but also by external elements.

New tools have emerged that offer students novel ways and environments for learning and communication with the rapid development and widespread adoption of Information and Communication Technology (ICT) and Artificial Intelligence (AI) technologies such as Chat Generative Pre-trained Transformer (ChatGPT) and Mind Journey (MJ) [9, 10]. In this context, researchers examined various topics such as virtual technologies, creative co-creation models, digital education and classroom environments [11-13]. Furthermore, some researchers have investigated the application of information technology to enhance student engagement, interactivity, creativity and perception [14, 15]. Several obstacles still exist in spite of the fact that earlier research has explored strategies for developing innovative talent and teaching models from various perspectives as well as developing a number of new theories and technical ways. These include relatively limited teaching and learning methods and tools, students' lack of awareness of the classroom information technology environment and inadequacies in students' critical thinking and innovation capabilities [15-17]. Thus, it is clear that current teaching methods and environments still have some limitations concerning fostering creativity and learning perception in design students. Therefore, enhancing the creativity and learning perception of design students requires the effective use of artificial intelligence and information tools to improve learning environments and methodologies.

The aforementioned content serves as the foundation for this study which also uses a quasi-experimental research approach and an interdisciplinary co-creation teaching paradigm in addition to the development of a smart classroom environment. The research aims to investigate the impact of the interdisciplinary co-creation teaching model within the smart classroom environment on students' design creativity and learning perception by addressing the following two research questions:

RQ1: What are the differences in cultivating students' design creativity between the interdisciplinary teaching model in a traditional classroom environment and the interdisciplinary co-creation teaching model in a smart classroom environment?

RQ2: To what extent does the interdisciplinary co-creation teaching model in a smart classroom environment enhance students' design creativity and learning perceptions compared to the interdisciplinary teaching model in a traditional classroom environment?

2. Literature Review and Model Construction

2.1. Social Constructivist Theory and Design Education

Social constructivism theory underscores interactivity, contextuality, sociality and activeness in teaching. Learning is a process that occurs through interaction between learners and others within specific historical and socio-cultural contexts thus forming the interaction effects of teaching and learning [18]. With the development of this theory, it places even more emphasis on the comprehensive development of learners' cognition, capabilities and emotions [19]. In today's design education, nurturing students' comprehensive abilities is of paramount importance [20]. This includes not only cultivating students' professional thinking and technical skills but also highlighting emotional development.

Learning environments, tools, and approaches that are characterized by intelligence, mobility, and openness are increasingly attractive for instructional design as science, technology and artificial intelligence continue to improve [21, 22]. This new approach not only brings students and teachers closer, fostering better learning, communication and practical skills but also enhances the quality of teaching and learning. Additionally, it helps students meet the contextual and social requirements of the teaching and learning process by allowing them to shift from learning in an educational environment to learning in a social context. These modes of learning stimulate students to have positive learning perceptions. Social constructivism theory plays an important role in design education. Hence, in this study, the researchers used the social constructivism theory and employed digital information, AI technologies and relevant teaching methods to create a smart classroom learning environment that meets the current needs of design education.

2.2. Design Creativity and Design Education

Creativity is the ability to produce works that are both novel (i.e., original and unexpected) and appropriate (i.e., useful or meeting task constraints) [23]. Creativity is the manifested process of a series of skills and behaviors. It is the ability to apply these skills when faced with and solving various complex problems that represents a concrete manifestation of comprehensive abilities [20]. However, design is a complex process of addressing unknown problems, requiring the application of design thinking and practicality to resolve contradictions in various elements of the problem, ultimately leading to problem resolution and methodological innovation [24]. Therefore, creativity is an essential element in design processes influencing design realization as well as being vital to design innovation [25]. There is a great need for design creativity in society, businesses and other associated organizations particularly in the current environment of increased competition [26]. Therefore, nurturing students' design creativity is of utmost significance in higher design institutions.

In higher design education, effective teaching techniques and learning methods can stimulate and cultivate students' design creativity [27]. However, in the real educational process, there are diverse factors influencing creativity, including the environment, learning, practical, cognition, emotion, etc. Van Der Rijst, et al. [7]; Ramirez - Arellano, et al. [8] and Chakrabarti [25]. Hatchuel, et al. [28] argue that acquiring new knowledge and fostering flexible thinking are crucial for cultivating creativity and their interconnection can better stimulate creative output. Similarly, studies have shown that improving cognitive capacities is an important approach to support creativity. Learning new things is one important way to increase cognitive capacity [29]. Therefore, learning new knowledge and nurturing flexible thinking are pivotal in fostering students' creativity. Communication is a crucial aspect of the learning process especially in contemporary design education. Communication and collaboration enable students to access more new knowledge and fresh perspectives, fostering the generation of numerous novel ideas and concepts and thus offering substantial support and possibilities for creativity cultivation [30]. Similarly, research indicates that collaboration in design can prompt students to generate a greater number of design concepts. The more ideas and concepts generated during the design creation process, the more it can enhance design creativity [17, 31]. Collaboration plays a significant role in fostering design creativity.

In the context of design, practical experience holds great significance for design creativity. Students who engage in practical learning not only reinforce what they have learned but also strengthen their critical thinking skills and cognitive abilities [32]. Existing research indicates that the methods that generate original and practical solutions during practical experiences serve as important indicators of design creativity. The higher the quality and number of original proposals, the higher the degree of design creativity [17]. Therefore, these methods can directly reflect the innovative and practical value of creativity in design [33]. Simultaneously, critical thinking plays a crucial role in addressing creative problems. It involves summarizing and reflecting on various issues encountered in the creative problems-solving process, creating conflicts between new problems and existing knowledge and thereby stimulating the generation of creative thinking [34]. Critical and creative thinking can influence and change one another to some extent which can effectively foster and enhance design creativity[35]. Previous studies have confirmed that perception can influence students' learning [36]. The learning environment is a critical factor influencing student perception. It not only affects students' sense of participation and experience but also impacts their emotions [37, 38]. Hence, students' perceptions of learning also exert an influential role in their design creativity.

In a nutshell, there are relationships among the several aspects that drive design creativity in design education regardless of their diversity. Therefore, according to this study, key elements impacting students' design creativity include learning capacity, cooperation ability, practical ability, originality, critical thinking ability and learning perception. Additionally, these factors are also considered dependent variables in this research.

2.3. Interdisciplinary and Design Education

The aim of design education is to cultivate creative talents [39]. However, fostering design creativity requires a comprehensive and logical learning process. Interdisciplinary educational approaches offer design education more diverse choices to better nurture students' creativity. Interdisciplinary design education emphasizes integration which means effective communication among students, sharing of knowledge and information, decision-making and coordination of design tasks [40, 41]. Interdisciplinary learning not only addresses knowledge barriers between disciplines but also broadens the pathways and methods for students from different disciplines. It actively transforms conflicts and contradictions between disciplines into opportunities for innovation [42]. In this learning process, students' learning ability and collaboration ability can be significantly enhanced. Similarly, interdisciplinary design education plays a crucial role in enhancing students' practical abilities especially for non-practical specialist students. Interdisciplinary learning provides them with the opportunity to acquire practical exercise and new knowledge, opening avenues for generating new knowledge [43]. This learning approach not only improves students' learning ability but also hones their problem analysis and logical thinking ability, thus promoting the development of their practical ability, originality and critical thinking ability [44]. Interdisciplinary design education can cultivate students' comprehensive abilities, thereby better promoting the development of their design creativity. Therefore, it holds a crucial position within design education.

2.4. Value Co-Creation and Design Education

The higher education sector is currently implementing value co-creation techniques to boost its competitiveness in the social marketplace.[45, 46]. Efficient innovation talent development takes place through collaborative co-creation between higher education institutions and enterprises to meet the demands of society and the market for innovative talent [47]. In the process of co-creation, knowledge sharing and learning are indispensable mechanisms. Learners from diverse disciplinary backgrounds collaborate, integrating resources from both learners and relevant organizational entities. Leveraging their respective expertise and resources, they facilitate the accumulation of a series of activities and experiences, collectively realizing the practical application and innovation of knowledge [48]. Moreover, establishing an equitable interactive relationship is a key factor in co-creation [49]. Relationships that are inclusive and equal promote mutual understanding and trust between instructors, companies and students during the learning process. They contribute their utmost abilities towards the realization of common goals, thereby establishing a solid foundation for collaborative creation [50]. Therefore, value co-creation education not only plays a pivotal role in teachers, businesses, students' current learning experiences and learning processes but also has a positive impact on their future knowledge gains [47]. Furthermore, value co-creation education not only breaks down knowledge barriers between different disciplines and bridges information gaps but also connects and organizes various disciplines. It provides more opportunities for the creation of new knowledge in terms of the value, exchange, integration and interaction of knowledge [47, 51]. Value co-creation in higher design education is a crucial educational approach. It facilitates the improvement of students' communication and collaboration abilities through the integration of resources. It enhances students' ability to learn new knowledge ultimately establishing a solid foundation for enhancing the design creativity of students in the design profession by sharing resources.

2.5. Smart Classroom Environments and Design Education

Smart learning environments and smart teaching methods have become integral components of higher education. The internet, information technology and human-computer interaction technologies are essential for creating smart learning environments especially with the rise of mobile Internet and intelligent technology [52]. In recent years, with the rise of AI technologies such as ChatGPT and Mind Journey, they have brought significant changes to the current smart learning environment [10, 53]. ChatGPT as an AI-based conversational tool can generate human-like language based on human prompts creating an interactive collaborative mode between humans and machines. Currently, ChatGPT's functionality extends beyond language translation, text summarization, content generation and code creation to include many creative activities [10, 54]. Similarly, Mind Journey an AI-based drawing tool plays a significant role in creative tasks especially for students in design-related disciplines. Previous research indicates that ChatGPT can effectively be applied in design educational environments, providing technical support and assistance to students and teachers, integrating teaching resources and relationships comprehensively, enhancing design educational quality and improving the smart classroom learning environment [53, 55]. Furthermore, ChatGPT can also provide additional avenues for students and teachers to access information during the teaching and learning process, promoting personalized and complex learning and increasing the efficiency of essential processes and tasks within the learning experience [56]. Therefore, as artificial intelligence tools both ChatGPT and Mind Journey can provide high-tech support and services for learning and working in the design domain. They assist design learners in generating numerous excellent design concepts and facilitate concept evaluation [57]. In essence, they strengthen the current smart learning environment for design. In modern design education, the cultivation of creativity and students' comprehensive abilities is the ultimate goal of teaching [58] and smart learning environments can provide the necessary technical support and assurance to achieve this goal [59].

The framework for interdisciplinary co-creation education within smart classroom environments and exploring its impact on the creativity and learning perception of design students have been proposed in Figure 1 based on the aforementioned discussion.

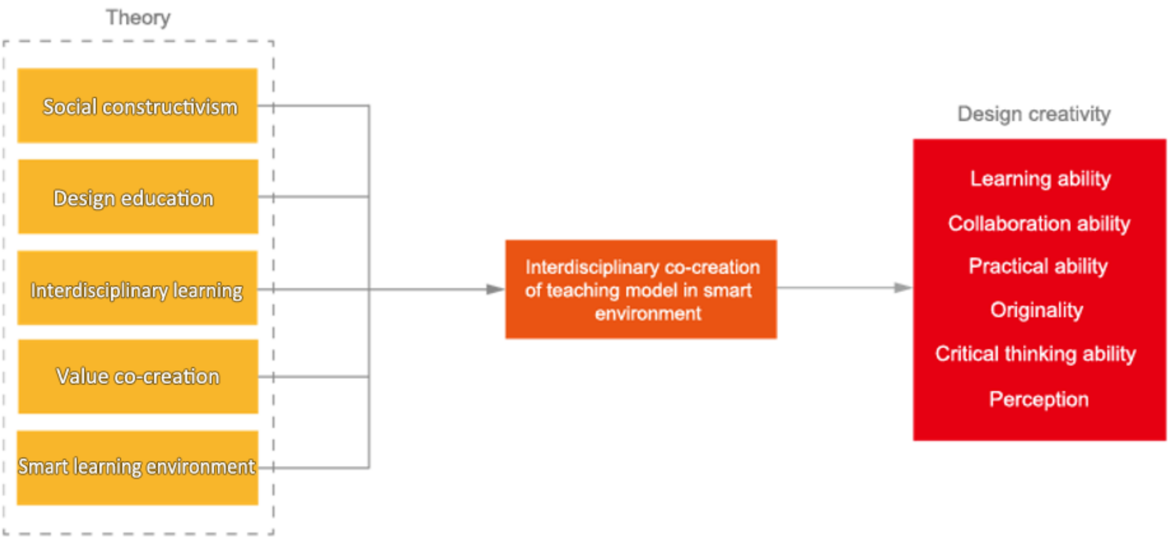

Figure 1.
Model framework.

3. Research Methodology

3.1. Experimental Design

This study adopts a quasi-experimental design with the research design groups categorized into experimental and control groups. The experimental group uses an interdisciplinary co-creation teaching model within a smart classroom environment while the control group uses a traditional interdisciplinary teaching model in a conventional classroom environment. This setup aims to verify the impact of these two teaching models on students' design creativity and learning perception.

The dependent variables include design creativity which encompasses learning ability, collaboration ability, practical ability, originality and critical thinking ability as well as learning perception. The assessment of design creativity involves testing both the experimental and control groups according to specific tasks and requirements and gathering data to measure their respective performances. The assessment of learning perception seeks to compare the differences between students in the experimental group before and after their exposure to the interdisciplinary co-creation teaching model within the smart classroom environment. Figure 2 illustrates the research design framework.

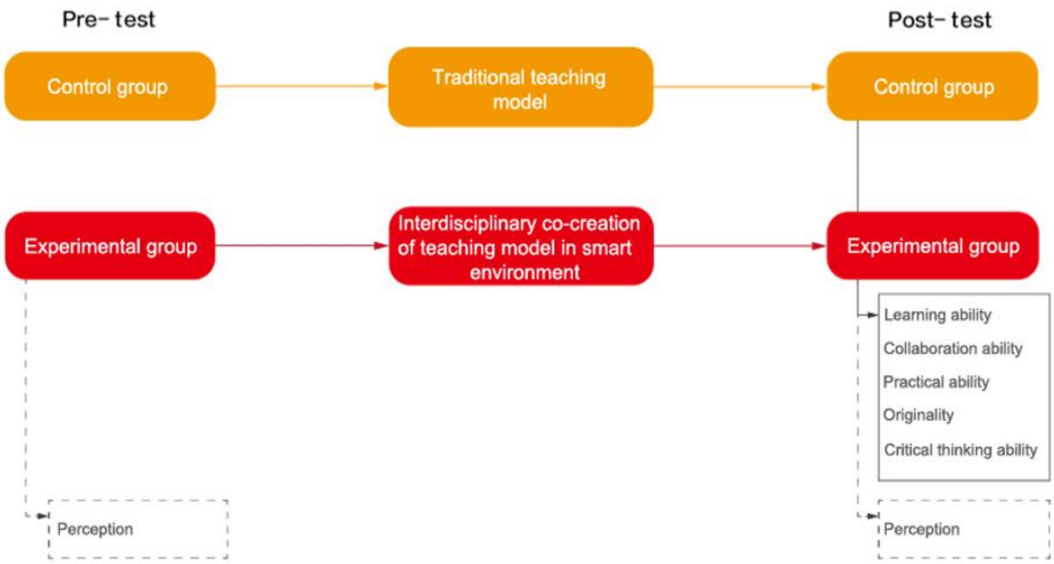

Figure 2.
Research design framework.

3.2. Population and Sampling

The sample for this study was drawn from 100 second-year students majoring in digital media arts at the Communication University of Shanxi in China. There are three main reasons for choosing this school and this subject. First, the researcher is a teacher of this subject at this school which makes it easy to collect data. The second is that the subject belongs to the first-class provincial and national subjects in China and the second-year students are representative as they have the appropriate design foundation. Third, it is more accurate to compare students in the same grade with a similar academic background. 100 students majoring in digital media were purposely sampled and 64 students were finally identified to participate in this study to achieve the purpose of the study. Meanwhile, 16 second-year students from other related majors were purposely sampled totaling 80 people who participated in this study to satisfy the requirement of interdisciplinary. These 80 students were randomly assigned to the experimental and control groups according to the ratio of male to female 1:1 in order to achieve the accuracy of the experiment.

3.3. Experimental Process

This study is based on a comprehensive creative project course in the field of digital media arts spanning 5 weeks with a total of 7 sessions each lasting 4 hours. The primary content of this course focuses on the innovative design and communication of traditional culture. The goal is to encourage students to engage in innovative design and effective dissemination of traditional culture, thereby showcasing their design creativity. During the first session, researchers spend approximately 100 minutes introducing the purpose, significance, key challenges and course content requirements of this comprehensive project course. The remaining 140 minutes are allocated for a preliminary project exercise (a pre-test for learning perception in the experimental group).

From the second session to the sixth session, researchers assign project tasks to elucidate the project's process and outcome requirements ensuring students have a clear understanding of the tasks at each step. Basic task requirements include ideation, problem definition, information retrieval, interactive communication, concept determination, idea generation, theme development, practical application, critical reflection and learning perception determination. In the final session, students are given 180 minutes to present and summarize their design projects with an additional 60 minutes allocated for the experimental group to complete the learning perception questionnaire. Subsequently, data from all participants is collected and analyzed.

3.4. Measure Tools

This study assesses students' design creativity using two main components: firstly, their performance during the learning process which primarily encompasses their learning ability, collaboration ability, practical ability, originality and critical thinking ability. Secondly, it evaluates students' perceived learning experiences. The assessment criteria for students' learning performance are derived from the evaluation system of the Digital Media Arts program at the Communication University of Shanxi to ensure the validity and reliability of the measurement tools. This evaluation system has been applied and recognized in undergraduate teaching and practical activities for several years (see Table 1).

Additionally, five professors from leading Chinese art universities were invited to review and validate this evaluation system, yielding an Index of Objective Congruence (IOC) of approximately 1 indicating the effectiveness of these assessment criteria [60]. The evaluation of students' learning perception adopts the scale developed by Fraser, et al. [61] which measures students' learning perception across eight dimensions. Each dimension's measurement items are set using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) (see Table 2). A pre-test was conducted on this scale analyzing 36 collected data points. The Cronbach coefficient alpha values for each item ranged from 0.80 to 0.89 surpassing the standard of 0.7 proposed by Nunnally [62] for reliability coefficients. This suggests that the scale shows acceptable internal consistency and stability. Hence, the measurement tools employed in this study have been duly validated.

Table 1.
Criteria for evaluating learning performance.

Variables	Operationalization	Score (0-100)
Learning ability	Learning abilities manifest through academic performance. Teachers evaluate students based on their daily assignments and final projects. The routine grade reflects the students' daily learning progress and assignment-related activities while the final grade takes into account the content and execution of the students' end-of-term projects. The overall grade is a composite score with 50% originating from the routine grade and the remaining 50% from the final grade (Total grade = 50% routine grade + 50% final grade).	90 and above = Excellent 80-89 = Good 70-79 = Average 60-69 = Normal 60 below = Fail
Collaboration ability	Students who meet the course requirements and cooperate with one another during the learning process are demonstrating their capacity to collaborate as they work together to develop a large number of useful concepts connected to the course material. Teachers assess these concepts based on both their quality and quantity.	90 and above = A lot of concepts and excellent quality 80-89 = A few concepts and excellent quality 70-79 = A few concepts and average quality 60-69 = A few concepts and poor quality 60 below = Failed concepts and bad quality
Practical ability	Practical ability is evident in the concrete manifestations of students during project-based practices. Students are required to translate their acquired knowledge into tangible forms within their works focusing on the form, content quality and distinctive practical performance of their projects. Teachers evaluate the quality of these practical elements.	90 and above = Complete performance 80-89 = Clear performance 70-79 = Basic performance 60-69 = Fuzzy 60 below = Cannot perform.
Originality	Originality is reflective of students' unique thinking abilities. Students are expected to explore innovative design expressions and distinctive problem-solving approaches from their individual perspectives during the practical process primarily emphasizing the originality and practicality of their designs. Teachers evaluate the originality (Uniqueness) and practicality (Problem-solving approach) of students' practical works.	90 and above = Completely original and practical 80-89 = More original and practical 70-79 = Originality and practicality 60-69 = Some original and practical 60 below = Completely unoriginal and practical.
Critical thinking ability	Critical thinking ability is manifested in students' reflection and summarization of their coursework. They are expected to analyze their work in five dimensions: problem identification, problem recognition, problem solving, problem expansion and creating new problems. Teachers assess students based on these dimensions in their summaries.	90 and above = 5 dimensions 80-89 = 4 dimensions 70-79 = 3 dimensions 60-69 = 2 dimensions 60 below = 1 dimension

Table 2.
The classroom environment perception scale.

Variables	Items	Source
Consolidate	My teacher takes time to summarize what I learn in the course.	Fraser, et al. [61]
	My teacher speaks to me in class about how to improve.	
	My teacher points me in the right direction to get further help.	
Challenge	My teacher asks questions that make me think.	
	My teacher encourages me to keep going when the work is hard.	
	I'm encouraged to correct my mistakes.	
Clarity	My teacher uses a variety of teaching methods to make things clear to me.	
	My teacher knows when I understand and when I do not.	
	My teacher divides the work into easy steps.	
Care	My project makes me want to learn.	
	My teacher makes me feel that he or she really cares about me.	
	My teacher gives me time to explain my ideas.	
	My teacher encourages me to do my best.	
Collaboration	When I work in a group doing a course project, we work as a team.	
	I help other group members who are having trouble doing course projects.	
	I learn from other students in my course group.	
Control	My teacher makes sure that I stay busy and don't waste time.	
	I behave well when the teacher is explaining things to the class.	
	I treat the teacher with respect.	
Motivation	The questions in this class make me want to find out the answers.	
	How the classroom looks makes me motivated.	
	My course makes me want to learn.	
Consultation	My teacher asks me questions about whether I put up my hand or not.	
	I speak up and share my ideas about the course work.	

3.5. Data Collection and Analysis

Two sets of students completed regular learning tasks and submitted final course projects which were assessed by three teachers to determine average scores reflecting design creativity. Post-tests were conducted to compare creativity differences between the treatment and control groups using an independent sample t-test for analysis. The evaluation of learning perception included pre- and post-tests conducted in a smart classroom with the experimental group using the interdisciplinary value co-creation model. Pre- and post-test scores were compared using paired sample t-tests to investigate variations in learning perception. The statistical analysis carried out with the social science statistical software package (SPSS version 26) involved both independent and paired sample t-tests. The objective was to identify the teaching model that effectively enhanced both design creativity and learning perception.

4. Results and Discussion

4.1. The Effect of Two Teaching Models on Students' Design Creativity

In this study, independent sample t-tests were conducted using the traditional interdisciplinary teaching model and the interdisciplinary value co-creation teaching model in a smart classroom environment as independent variables. These variables were analyzed against five dimensions (learning ability, collaboration ability, practical ability, originality and critical thinking ability) as dependent variables. The results of the analysis indicate significant differences between the two teaching models in terms of the dimensions of design creativity: learning ability (t=5.56, $p < 0.001$), collaboration ability (t=4.62, $p < 0.001$), practical ability (t=10.52, $p < 0.001$), originality (t=3.94, $p < 0.001$) and critical thinking ability (t=6.35, $p < 0.001$). The details are presented in Table 3.

Table 3.
Results of independent samples t-test analysis of the impact of the two groups of teaching models on the dimension of design creativity.

Design creativity dimension	Group	N	Mean	Standard deviation	t-value	p-value
Learning ability	Experimental group	40	85.27	6.27	5.56	0.000
	Control group	40	77.82	5.67		
Collaboration ability	Experimental group	40	83.87	5.83	4.62	0.000
	Control group	40	77.65	6.19		
Practical ability	Experimental group	40	86.57	3.73	10.52	0.000
	Control group	40	74.95	5.90		
Originality	Experimental group	40	82.65	5.74	3.94	0.000
	Control group	40	77.17	6.62		
Critical thinking ability	Experimental group	40	84.50	5.59	6.35	0.000
	Control group	40	75.97	6.37		

The analysis in this study revealed significant differences in the performance of the smart learning environment group compared to the traditional learning environment group. The smart learning environment group showed significantly higher levels of learning ability (85.27 ± 6.27 vs. 77.82 ± 5.67, $p < 0.001$), superior collaboration ability (83.87 ± 5.83 vs. 77.65 ±

6.19, $p < 0.001$), enhanced practical ability (86.57 ± 3.73 vs. 74.95 ± 5.90, $p < 0.001$), better originality (82.65 ± 5.74 vs. 77.17 ± 6.62, $p < 0.001$) and improved critical thinking ability (84.50 ± 5.59 vs.75.97 ± 6.37, $p < 0.001$) compared to the traditional learning group. Figure 3 clearly illustrates design creativity scores in terms of five dimensions for both groups.

The results indicated that the interdisciplinary value co-creation teaching model in a smart classroom environment can enhance students' learning ability, collaboration ability, practical ability, originality and critical thinking ability based on the above information. These improvements ultimately contribute significantly to enhancing students' design creativity.

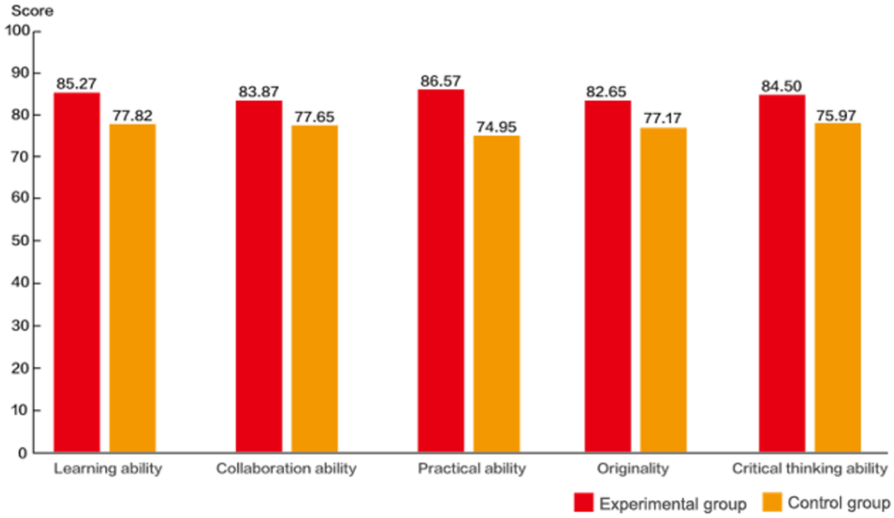

Figure 3.
Design creativity scores of the experimental and control groups.

4.2. The Effect of a Two-Teaching Model on Students' Perceptions of Learning

The paired-sample t-test was employed to analyze the pre- and post-test scores of students' perceived learning abilities in the interdisciplinary co-creation teaching model within the smart classroom environment. The results of the analysis reveal that there is a significant difference in students' learning perception abilities before and after participating in the interdisciplinary value co-creation teaching model in a smart classroom environment ($t=24.08$, $p < 0.001$) (see Table 4). The post-assessment scores were notably higher than the pre-assessment scores (4.07 ± 0.10 vs. 3.50 ± 0.10, $p < 0.001$). Figure 4 clearly illustrates scores for perception.

The results indicated that the interdisciplinary value co-creation teaching model in a smart classroom environment significantly enhances students' learning perception abilities based on the above information.

Table 4.
Learning perception in a smart classroom environment: two paired sample t-test results.

Design creativity dimension	Pre-test		Post-test		N	t-value	p-value
	Mean	Standard deviation	Mean	Standard deviation			
Learning perception	3.50	0.10	4.07	0.10	40	24.08	0.000

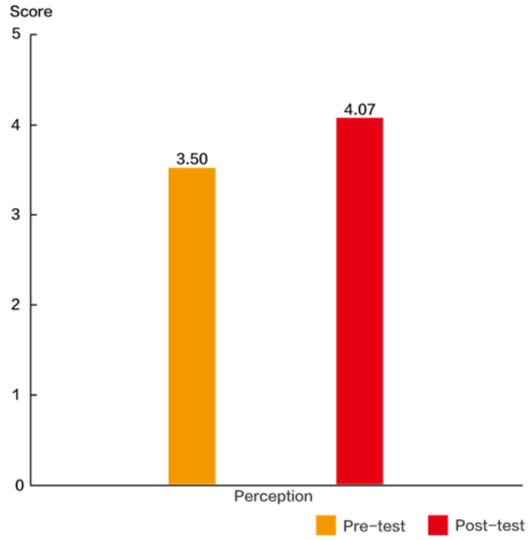

Figure 4.
Perception scores of the pre- and post-tests in a smart classroom environment

4.3. Discussion

The experimental results demonstrated that there are significant differences in the impact on students' design creativity between traditional interdisciplinary teaching methods in a conventional classroom environment and interdisciplinary value co-creation teaching models in a smart classroom environment. Compared to traditional interdisciplinary teaching methods, the interdisciplinary value co-creation teaching model in a smart classroom environment effectively enhances students' design creativity across several dimensions, including learning ability, collaboration ability, practical ability, originality, critical thinking ability and learning perception.

In terms of learning capacity, the multidisciplinary value co-creation teaching model of the smart classroom environment integrates a variety of knowledge resources, broadens students' learning settings and channels and increases their level of autonomy and flexibility in their learning. This approach effectively stimulates students' enthusiasm for learning and enhances their learning abilities [54, 59]. In terms of collaboration ability, the smart classroom environment's interdisciplinary value co-creation teaching model transcends spatial and temporal constraints enabling the sharing of new knowledge. It facilitates communication and teamwork among students by reducing distances between them and removing barriers to knowledge. It increases the chances for students to share information which improves their capacity for teamwork [56].

On the subject of practical ability, the smart classroom environment provides students with a wealth of digital information tools and artificial intelligence technologies (such as ChatGPT and Mind Journey). Students can use these tools for practical creative work while also benefiting from intelligent dialogue and evaluation [63]. This process helps them identify shortcomings in their work, learn from the feedback provided by intelligent tools and improve their thinking and practical skills. Regarding originality, intelligent tools in the smart classroom environment can help students gather a substantial amount of knowledge and work beyond textbooks for their learning, communication, and to derive new inspiration. Students from various knowledge backgrounds collaborate to generate, integrate and expand knowledge through the added dimension of value co-creation [42] which increases the opportunities for ongoing creativity and originality.

In terms of critical thinking ability, the smart classroom environment, tools and co-creation process not only offer strong technical and methodological support but also provide intelligent and artificial assessment and feedback tools. Students learn about, identify and consider their own and related challenges over time through ongoing exchanges, learning and interaction. This iterative process broadens their thinking from a single dimension to multiple dimensions and encourages deeper contemplation of content [9].

In terms of students' learning perception, the interdisciplinary value co-creation teaching model in a smart classroom environment effectively enhances students' learning perception. In this study, the smart classroom learning environment's interdisciplinary value co-creation teaching model not only provides students with an excellent smart learning environment, improving students' learning perception from a physiological sensory level but also enhances the technologies and methods they use during the learning process. It elevates students' learning and emotional experiences during the learning process [38]. The interdisciplinary value co-creation teaching model in smart classrooms is extremely important because it improves student-teacher interaction, communication and learning while also meeting students' emotional needs and perceptions of learning in a smart learning environment. This improvement spans various dimensions including learning, care, collaboration and motivation.

It is clear from the information above that the interdisciplinary value co-creation teaching approach in a smart classroom setting has a major impact on a number of variables that affect students' design creativity. Therefore, this model effectively promotes the enhancement of students' design creativity and learning perception.

5. Conclusion

The smart classroom learning environment with an interdisciplinary value co-creation teaching model effectively establishes an efficient teaching and learning environment. Students can develop and improve their teamwork and communication skills in this environment. They can use information and artificial intelligence tools for continuous design practices and evaluations. In this process, their practical ability, creativity and critical thinking capabilities are further developed. Furthermore, this new model enhances students' learning experiences, subsequently improving their learning perceptions. This encourages them to become more proactive in their learning efforts ultimately leading to an enhancement of their design creativity. Furthermore, this research also gives some suggestions for the development of design education in the future.

First, accelerate the development of smart classroom learning environments and interdisciplinary co-creation models. This will enable more teachers in design education to become familiar with interdisciplinary co-creation models and recognize their significance in design education. Second, integrate information technology and artificial intelligence tools into existing curricula. This will help cultivate awareness of cutting-edge technology and practical ability among design teachers and students. Proper utilization of advanced technological tools will enhance their overall capabilities. Third, strengthen collaboration between educational institutions, businesses and government bodies. Provide students with more opportunities for practical experience, communication and co-creation. This will help students realize the importance of learning and enhance their learning perceptions.

5.1. Implications

This study is grounded in social constructivist theory integrating the domains of design education, design creativity, interdisciplinary education, co-creative value education and smart learning environments. It establishes the interdisciplinary value co-creation teaching model within a smart classroom learning environment aimed at exploring its impact on students' design creativity. This investigation reveals that this innovative pedagogical approach effectively enhances students' design creativity, offering new perspectives and directions for future design education. Furthermore, critical factors influencing students' design creativity are identified through a comprehensive review of relevant literature. The study verifies the significance of these factors in cultivating students' design creativity within the context of design education, enriching the body of research related to design education. Lastly, it is emphasized that the cultivation of students' design creativity extends beyond instructional methods and tools. It also requires innovation in the learning environment while organically connecting these components (learning methods, tools, emotion, etc.). This approach not only enriches the framework of existing models for fostering design creativity in design education but also provides theoretical and practical references for future design education.

5.2. Limitations

Although this study yielded valid results, there are some limitations to it. In future studies, researchers should explore combining more different disciplines and various smart tools to include a larger group of students. This will further validate the role of interdisciplinary approaches and smart tools in promoting design creativity.

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