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An Empirical Study on the Impact of Augmented Reality on Students' Learning Outcomes in Teaching Product Creative Design Courses

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Abstract

Background and Aim: Augmented reality is one of the fastest developing technologies and more and more teachers are using AR to assist teaching and learning, this study aims to compare student learning outcomes of augmented reality and traditional instruction in teaching product creative design. Investigate the impact of augmented reality on learning outcomes by examining 74 students at a university in Guangdong Province, China. The learning outcomes of augmented reality teaching were compared with traditional teaching in terms of content knowledge, design process, and design outcomes through a product creative design course.

Materials and Methods: A total of 74 university students participated in this study. The participants were divided into two groups: a control group and an experimental group. The control group was taught using traditional teaching methods and the experimental group was taught using augmented reality. At the end of an 8-week product creativity design course, the course was evaluated using a course evaluation scale that has been used by the college for many years. This assessment explored the outcomes of content knowledge, design process, and design outcomes.

Results: Before the start of the course, a pre-test was administered to both groups of students using the Course Assessment Scale, which indicated that both groups had the same level of academic proficiency. At the end of the course, a post-test using the Course Assessment Scale revealed that the experimental group outperformed the control group in terms of content knowledge, design process, and design outcomes.

Conclusion: The results of the study show that the use of augmented reality technology in a creative product design course has a positive impact on students' learning outcomes. By comparing the before and after side difference analysis of content knowledge, design process, and design outcome scores of the control and experimental groups, the study found that augmented reality technology helps to enhance students' learning outcomes.

Keywords: Augmented reality; Content knowledge; Design process; Design outcomes; Learning outcomes; Product creative design

Introduction

Currently, science and technology are moving forward, education is becoming increasingly digitized, and the development of many educational technologies was boosted during and after the Coronavirus Disease 2019(COVID-19) pandemic, the rapid development of modern educational technologies inevitably enters into the learning process (Rizov & Rizova, 2015), and teachers are often faced with the use of appropriate educational technologies in teaching and learning processes to ease the process of learning for their students challenges (Kamińska et al., 2023). Nowadays, educators are introducing new technologies in the teaching and learning process to enhance the curriculum design to assist teachers in imparting knowledge and help students to better master it (Deng & Yu, 2023). For example, technologies such as virtual reality, augmented reality, and artificial intelligence can be used to enable educators and learners to teach and learn using various digital technologies (Yu, 2023).

In the 21st century, educational methods are becoming increasingly digitized and augmented reality deserves to be explored as an effective and versatile educational technology to be used in teaching and learning methods (Serio et al., 2013). Although this technology still faces associated problems in terms of ease of use, affordability, and technical skills required by users (Küçük et al., 2016), several studies have provided evidence that using augmented reality as a teaching and learning tool can improve student

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motivation and learning outcomes through increased engagement and interactivity (Ibáñez et al., 2014; Kamińska et al., 2023).

Despite the advances that have been made in augmented reality in education, there are still challenges in the widespread adoption and effective use of augmented reality, such as not having a timely understanding of the long-term impact of augmented reality on teaching and learning (Li & Keller 2018). In China, some researchers have begun to use augmented reality applications for course teaching; however, researchers do not have a deep enough understanding of AR, which makes it difficult to integrate AR into course teaching in its entirety (Wei et. al., 2015). Especially for art and design-related courses, there are fewer related studies.

Therefore, by applying augmented reality to the teaching of a design course to understand the impact of augmented reality-assisted instruction on student learning outcomes, this study informs future course design and instructional strategies, as well as provides insights for educators and policymakers to incorporate augmented reality into design education.

Objectives

1. To compare student content knowledge of augmented reality and traditional instruction in teaching product creative design.
2. To compare the student design process of augmented reality and traditional instruction in teaching product creative design.
3. To compare student design outcomes of augmented reality and traditional instruction in teaching product creative design.

Literature review

Augmented reality

The term "Augmented Reality" (AR) was coined by Caudell and Mizell (1992) to refer to a technology that superimposes a layer of computer-generated auxiliary information on three-dimensional space or the real physical world. They proposed a head-mounted display that could help Boeing engineers see virtual text and graphics while working on machinery to accomplish construction and assembly tasks more accurately and safely (Figure 1).

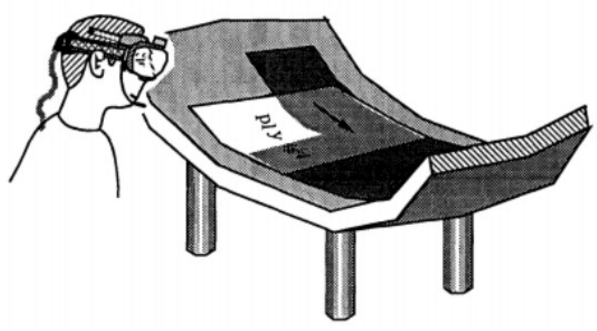

Figure 1 An application where the HUDset is used to project graphical templates for the location and orientation of composite cloth during the layup process.

There are two theories about augmented reality technology, one is based on the understanding of the concept of augmented reality from the perspective of information sources: Milgram and Kishino (1994) proposed the concept of a reality-virtual continuum, defined as a continuum between the real and virtual environments, which includes Augmented Reality (AR) and Augmented Virtual (AV), where Augmented Reality is closer to the real world, while Augmented Virtual is closer to a purely virtual

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environment, (Figure 2). Virtual Reality immerses the user in a completely virtual environment, while Augmented Reality is a hybrid of virtual and real, an extension of virtual reality technology, which can be used to simulate objects and allow learners to see virtually generated model objects in the context of a real environment.

Another theory understands augmented reality technology from the perspective of key technological components: according to Azuma (1997), augmented reality can be defined as a system that fulfills three basic characteristics:

(1): Combines real and virtual
(2): Is interactive in real time
(3): Is registered in three dimensions

The theory identifies the key components of augmented reality technology: virtual fusion technology, system display technology, user interaction technology, and tracking and localization technology.

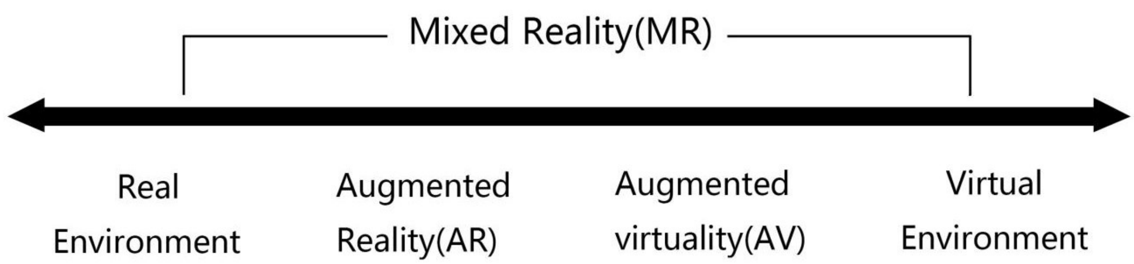

Figure 2 Milgram's virtuality continuum.

Motivation

For many years, psychologists have studied motivation in an attempt to define and explain what motivation is. Deci and Ryan (2000), based on Self Determination Theory (SDT), argued that motivation is an innate psychological need of human beings, emphasizing that the need has the requisite conditions for psychological growth, integrity, and well-being. Motivation is of both intrinsic and extrinsic types, with intrinsic motivation reflecting the natural human tendency to learn and assimilate, and extrinsic motivation reflecting external control or genuine self-regulation (Ryan & Deci, 2000). Currently, some research activities combine motivation with learner's desires. Purnamasari et. al. (2019) concluded that motivation is an important aspect of the learning process as it promotes performance goals and maintains academic achievement. Wu et. al. (2020) discussed the relationship between motivation, self-efficacy, learning engagement, and academic achievement of medical students, and concluded that motivation is significant for medical students' academic performance. Su and Cheng (2015) developed and implemented a series of gamified learning activities based on MGLS (Mobile Gamified Learning System) in an elementary school science course to increase students' motivation and to help them engage more actively in learning activities. The study found that the incorporation of mobile and gamified technologies into the learning process can result in better learning performance and higher motivation. Similarly, there is a relationship between intrinsic motivation and procrastination, during COVID-19, adolescents in Austria had to learn through distance education, which posed a great challenge to teachers, guardians, and students, some students with high intrinsic motivation to learn had a corresponding reduction in procrastination (Pelikan et al., 2021).

ARCS Motivational Modeling

Keller (1983) proposed the ARCS model of motivation, initially with the hope of finding more effective ways to understand the major influences on motivation and to find a systematic approach to identifying and solving problems in motivation. The model consists of four basic components: attention, relevance, confidence, and satisfaction. Keller (2010) systematically articulated the ARCS model of

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motivation theory, provided conceptual and theoretical knowledge of motivation, provided teachers and researchers with a systematic motivation design process and tools to support motivation design activities, and discussed the relationship between motivation design and instructional design. Currently, many researchers use motivation models to guide instruction and use IMMS to assess motivation for learning (Li & Keller, 2018). Izmirli et. al. (2015) identified motivational factors for pre-service teachers' online learning within the context of the ARCS motivational model. The study used a phenomenological model with 52 pre-service teachers in the Department of Computer Education and Instructional Technology, Faculty of Education, Canakkale Onsekiz Mart University, Turkey. Laurens and Valdés (2022) assessed the motivation of university students through the IMMS by using the Google Science Journal mobile application in their teaching to help students with kinetics, and the study showed that the implementation of m-learning favorably stimulated the students' interest in learning about kinesiology as well as their confidence in themselves. The ability of augmented reality technology to facilitate learners' mental states, which positively affects learning outcomes (Chang et al., 2019; Dhar et al., 2021; Volioti et al., 2022), is effective as a strategy to increase students' motivation (Serio et al., 2013; Low et al. 2022; Wommer et al., 2023). However, some studies have only designed the ARCS motivation model as a strategy for one phase of a course, not all phases of a course (Li & Keller, 2018). This study seeks to investigate the impact on learning outcomes by applying augmented reality as a teaching aid to all phases of a creative product design course, rather than a specific phase.

Conceptual Framework

This study is all about comparing the differences in the learning outcomes of content knowledge, design process, and design outcomes of students at a university in China after learning in an augmented technology instructional classroom and a traditional instructional classroom. According to the needs of the study, the researcher used purposive sampling to select 74 students to be divided into two classes, with T1 as the control group and T2 as the experimental group. The T1 control group was taught using the traditional teaching method and the T2 experimental group was taught using augmented reality technology. The Pre-test was conducted before the beginning of the course, and the Post-test was conducted after the end of the course to analyze and compare the effects of the two different teaching environments on the student's learning outcomes. And compare the effects of the two different teaching environments on student learning outcomes.

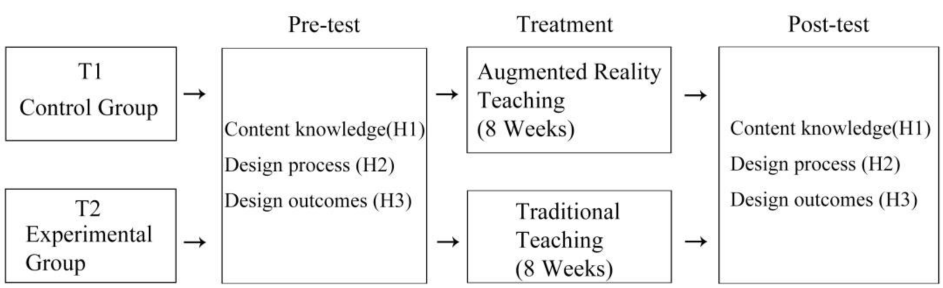

Figure 3 Visualization of the Research Framework

Hypotheses

$H_0$1:There are no differences in content knowledge of the control group between the pretest and posttest.

$H_0$2:There are no differences in the design process of the control group between the pretest and posttest.

$H_0$3:There are no differences in design outcomes of the control group between the pretest and posttest.

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$H_0$4:There are no differences in content knowledge of the experimental group between the pretest and posttest.

$H_0$5:There are no differences in the design process of the experimental group between the pretest and posttest.

$H_0$6:There are no differences in design outcomes of the experimental group between the pretest and posttest.

$H_0$7:There are no differences in Pretest of content knowledge between control and experimental group.

$H_0$8:There are no differences in the Pretest of the design process between the control and experimental groups.

$H_0$9:There are no differences in Pretest of design outcomes between control and experimental group.

$H_0$10:There are no differences in the Posttest of content knowledge between the control and experimental groups.

$H_0$11:There are no differences in the Posttest of the design process between the control and experimental groups.

$H_0$12:There are no differences in the Posttest of design outcomes between the control and experimental groups.

Methodology

Research Design

This study utilized a quasi-experimental research methodology with an eight-week experimental period and a total of six instructional components. In this study, the control group used traditional teaching methods and the experimental group used augmented reality technology teaching methods. Students in both the experimental and control groups were required to learn the basics of creative product design and complete a product design project. In the teaching process, each student needs to choose a product for market research, analyze the problem, design discussion, design sketch, and 3D model steps. There was a significant difference between the students in the control group and the experimental group in terms of teaching in weeks 4-7, especially in the teaching of the design process in the third part of the study, where the students in the experimental group needed to learn extra about the AR online authoring platform (45 minutes) and use it to produce AR works (45 minutes), which is the main augmented reality teaching technology used in this study. The students in the control group only needed to use design drawings and 3D models to express product design works, and did not need to produce AR works. Figure 4 below illustrates the treatment.

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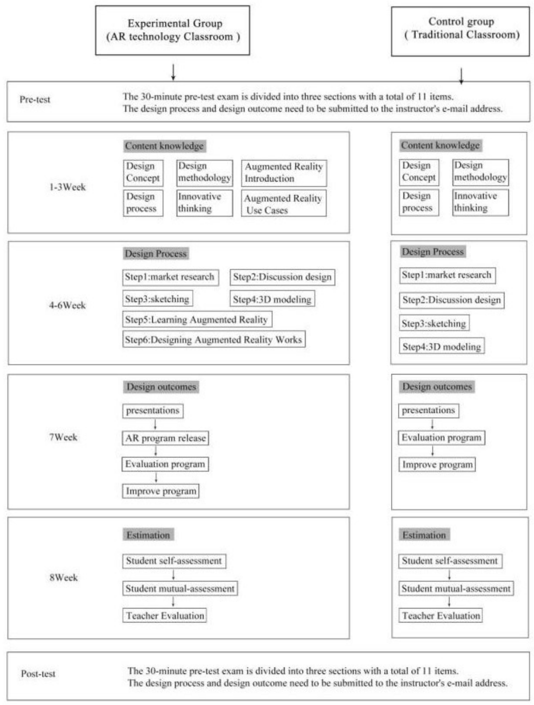

Figure 4 Teaching Program

The first part was a pre-test, before the start of the course, the students in the control and experimental groups were asked to take a test, which consisted of a complete product design proposal that each student needed to submit, and the students were required to complete this test and send it to the instructor via email within 24 hours. The instructor graded and assessed the test according to the evaluation criteria of the Zhanjiang University of Science and Technology Product Creative Design Course.

The second part is the learning of pedagogical content knowledge, and the teaching time is 3 weeks. In the learning of pedagogical content knowledge, both the control group and experimental group students need to learn the knowledge of design concepts, design methods, design processes, creative thinking, etc., but the experimental group students need the knowledge of Augmented Reality technology to ensure that they can use Augmented Reality technology in the course. Therefore, the control group and the experimental group use different teaching methods, the control group uses traditional teaching methods, and the experimental group uses augmented reality technology application cases to learn the knowledge related to product creative design. The use of augmented reality technology can stimulate students' attention and increase learning motivation (Erbas & Demirer, 2019).

The third part is the product design process, with an instructional design of 3 weeks, which is the main part of the experimental treatment in this study. This part focuses on developing student's ability to design creatively, guiding them to think about the potential impact of the design on the user or society, and the design is closely related to the practical application, highlighting the relevance of current teaching and learning to the future. There are 6 steps in the design process, the first 4 steps are the same for the experimental and control groups, however, students in the experimental group need to additionally complete steps 5 and 6.

Step 1, Market Research, students need to conduct market research on the product to help them identify problems.

Step 2, Design Discussion, students think about the identified problems and come up with solutions to solve them.

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Step 3: Design Sketching, students need to transform their design ideas into design sketches and express their design solutions through design sketches.

Step 4, 3D modeling, students put the design sketches through the 3D modeling software for digital modeling, the product model is conducive to showing the design scheme.

Step 5, Students in the experimental group learn the basics of the AR online production platform (45 minutes), and the researcher explains in detail the operation steps of the AR online production platform to ensure that every student in the experimental group can use the AR online production platform to produce AR works. There are three steps in the production of AR works, the first step is the preparation stage, and the students need to prepare 3D models, animation, text, video, and other materials in advance. Files; the second step is the development stage, where students need to log in to the AR online production platform, complete the operation steps of registering an account, creating an interface, importing materials, editing materials, and releasing content; the third step is the stage of releasing the work, after students complete the production of the AR work, they can choose the two platform ports of Web or WeChat for the release of the work.

Step 6: Students in the experimental group conduct AR work production (45 minutes), in which students in the experimental group, under the guidance of the researcher, upload the prepared materials to the AR online production platform. At the same time, students can import audio, animation, and other materials to enrich their AR works, and they can also use background music to enhance the effect of AR works.

The fourth part is the presentation and optimization of the design results, the teaching time is 1 week, and the presentation of the design results can help improve students' confidence. Students need to show their work through pictures, words, videos, etc. Students in the experimental group need to publish their AR works through WeChat or the Web and evaluate and optimize their works.

In the fifth part, Evaluation, and Feedback, the teaching time is 1 week, during which students evaluate and optimize their design work through a diverse range of exchanges, and a comprehensive project evaluation mechanism ensures that students receive recognition and satisfaction with their designs, with both the experimental and control groups undergoing the same evaluation and feedback process.

The sixth part is the post-test, which was administered by the researchers to two groups of students at the end of the course and consisted of a 30-minute test of content knowledge and a 48-hour test of the design process and design outcomes.

Population and Sample

For the sample of this study, considering the convenience and compliance of the study, the researcher used purposive sampling to select a purposive sample of 74 students from the students in the middle of the second year of product design at Zhanjiang University of Science and Technology. The sample for this study needed to be the same grade level and major to ensure consistency of expertise, if there were students in the sample who were repeating a grade in a higher grade, were denied participation in this study, and there were no requirements for the gender or age of the sample.

The sampling technique is an integral part of research methodology, and it is a very convenient and useful technique for selecting samples from the field of study. The sampling technique is considered very important because it helps the researcher to collect data from the right element or unit of the study (Kessler et al., 1994). Otzen and Manterola (2017) argued that the purpose of sampling is to study the relationship between the distribution of a variable in the target population and the distribution of the same variable in the sample of the study, which can be generalized to the results observed in that accessible population and to generalize from it to the target population. Sampling techniques are divided into two types: probabilistic sampling and non-probabilistic sampling, non-probabilistic sampling can generally be used in quasi-experimental research, non-probabilistic sampling methods can save the cost of the survey, and purposive sampling is one of the non-probabilistic sampling techniques (Ayhan, 2021). Therefore, the purposive sampling technique is used in this study.

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Ayhan (2021) argues that in purposive sampling, participants are selected by the researcher in parts. The selection is based on the judgment of the researcher. Respondents are not randomly selected but are drawn based on the judgment of the interviewer. Therefore, the probability of inclusion of any selected sample unit is unknown. Putri et. al. (2020) used purposive sampling and snowball sampling techniques in their study to discuss the impact of trust and convenience on making purchase decisions using online loans. Ntona et. al. (2023) discussed that the application of purposive sampling methodology provides reliable results regarding groundwater evolution results and provides lower costs for water resource management and control in the basin.

To obtain a reliable sample for the study, purposive sampling was used to select 74 students from the second year of product design at Zhanjiang University of Science and Technology to participate in the study.

Research Instruments

This study was conducted based on two research tools. The first research tool is a pre-test, in which students need to complete a product creative design work within 24 hours and send it to the instructor via email, and the pre-test mainly examines students' product design ability. The second research tool was a post-test, in which students needed to submit a product creative design work within 48 hours after the end of the course, which mainly tested the students' learning outcomes. The pre-test and post-test in this study are the same in terms of content and method, and the test adopts the test items and assessment criteria of the product design program of Zhanjiang University of Science and Technology.

Results

In this study, the demographic samples were taken from 74 students in the second year of the product design program at Zhanjiang University of Science and Technology, of which 36 were in the control group and 38 in the experimental group. In the gender demographics, there were 13 male students in the control group, accounting for 17.6% of the total population, and 23 female students, accounting for 31.1% of the total population. In the experimental group, there were 16 boys (21.6% of the total population) and 22 girls (29.7% of the total population). As shown in Table 1.

Table 1 Demographic Information of Gender.

Gender	Group	Frequency	Percentage	Percentage of Total
Male	Control	13	17.6%	39.2%
	Experimental	16	21.6%	
Female	Control	23	31.1%	60.8%
	Experimental	22	29.7%	

In the age statistics of the students, the age range of the sample students was from 18 to 24 years old. The number of 18-19-year-olds was 8 or 10.4% of the total, 20-22-year-olds was 65 or 86.8% of the total, and 23- 24-year-olds was 1 or 1.4% of the total. As shown in Table 2.

Table 2 Demographic Information of Age.

Age	Group	Frequency	Percentage	Percentage of Total
18-19 years old	Control	4	5.4%	10.4%
	Experimental	4	5.4%	
20-22 years old	Control	31	41.9%	86.8%
	Experimental	34	45.9%	
23-24years old	Control	1	1.4%	1.4%
	Experimental	0	0%	

Differences Between the Pre-test Scores

Before the beginning of the study, pre-test scores were collected for comparison to ensure that the two groups of students in the experimental and control groups had comparatively the same abilities.

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Descriptive statistics were used to compare the content knowledge, design process, and design outcome scores of the two groups of students. As shown in Table 3.

Table 3 Means Summary for Students' Pre-test Scores

Variability	Group	Mean	SD	N	Minimum	Maximum
Content Knowledge	Control	46.0	5.35	36	32	56
	Experimental	42.2	5.22	38	30	53
Design Process	Control	51.6	4.80	36	43	65
	Experimental	50.4	5.43	38	40	60
Design Outcomes	Control	54.0	4.29	36	45	61
	Experimental	52.4	4.90	38	42	60

Independent samples t-tests were used to compare the pretest scores of content knowledge, design process, and design outcomes between students in the control and experimental groups. First, the t-test for content knowledge scores was not significant, Mean Difference = 1.84, p = 0.138. the results indicated that there was no difference in students' content knowledge scores. Second, the t-test for the design process was not significant, Mean Difference = 1.21, p = 0.312. the results indicated that there was no difference in students' design process scores. Finally, the t-test for the design outcome was not significant, Mean Difference = 1.58, p = 0.145. the results indicated that there was no difference in the students' design outcome scores. Therefore, it is concluded that the academic level seems to be similar between the two groups. As shown in Table 4.

Table 4 T-tests for Pre-test Scores Between the Two Groups

Variability	Mean Difference	Sig.
Content Knowledge	1.84	0.138
Design Process	1.21	0.312
Design Outcomes	1.58	0.145

Descriptive Statistics of Content Knowledge

Descriptive statistics were used to analyze the content knowledge pre and post-test scores of students in the experimental and control groups. The results of the experiment surface that there is a difference between the scores of the two groups of students in the pre-test and post-test of content knowledge competence. The mean content knowledge score of the control group was 46.0 in the pre-test and increased to 82.7 in the post-test.On the other hand, the mean content knowledge score of the experimental group was 42.2 in the pre-test and significantly increased to 91.7 in the post-test. As shown in Table 5.

Table 5 Means Summary for Students' Content Knowledge Score in the Control and Experimental Group

	Group	Mean	SD	N	Minimum	Maximum
Pre-test Score	Control	46.0	5.35	36	32	56
	Experimental	42.2	5.22	38	30	53
Post-test Score	Control	82.7	3.51	36	75	90
	Experimental	91.7	2.64	38	78	96

Descriptive Statistics of the Design Process

The results of the experiment surface that there is a difference between the scores of the two groups of students in the pre-test and post-test of design process competence. The mean design process score of the control group was 51.6 in the pre-test and increased to 83.7 in the post-test.On the other hand, the mean design process score of the experimental group was 50.4 in the pre-test and significantly increased to 87.9 in the post-test. Meanwhile, the mean scores of both groups increased after the intervention. As shown in Table 6.

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Table 6 Means Summary for Students' Design Process Score in the Control and Experimental Group

	Group	Mean	SD	N	Minimum	Maximum
Pre-test Score	Control	51.6	4.80	36	43	65
	Experimental	50.4	5.43	38	40	60
Post-test Score	Control	83.7	3.19	36	78	90
	Experimental	87.9	2.18	38	85	93

Descriptive Statistics of Design Outcomes

The results of the experiment surface that there is a difference between the scores of the two groups of students in the pre-test and post-test of design outcomes competence. The mean design outcomes score of the control group was 54.0 in the pre-test and increased to 87.4 in the post-test.On the other hand, the mean design outcomes score of the experimental group was 52.4 in the pre-test and significantly increased to 90.8 in the post-test. As shown in Table 7.

Table 7 Means Summary for Students' Design Outcomes Score in the Control and Experimental Group

	Group	Mean	SD	N	Minimum	Maximum
Pre-test Score	Control	54.0	4.29	36	45	61
	Experimental	52.4	4.90	38	42	60
Post-test Score	Control	87.4	2.64	36	83	94
	Experimental	90.8	2.73	38	87	96

Difference Analysis of Content Knowledge

The results of the experiment surface that there is a difference between the scores of the two groups of students in the pre-test and post-test of content knowledge competence. The mean content knowledge score of the control group was 46.0 in the pre-test and increased to 82.7 in the post-test.On the other hand, the mean content knowledge score of the experimental group was 42.2 in the pre-test and significantly increased to 91.7 in the post-test. Meanwhile, the mean scores of both groups increased after the intervention. The average score of the control group increased by 36.6 points and the average score of the experimental group increased by 47.6 points.$p < 0.001$, the t-test was significant. From the results of the experiment, it is known that the mean score of the experimental group improved more significantly. As shown in Table 8.

Table 8 Means Summary and T-tests for Students' Content Knowledge Pre and Post-test Score

Group	Test	Mean	SD	N	Mean Difference	Sig.
Control	Pre-test	46.0	5.35	36	36.6	0.001
	Post-test	82.7	3.51	36		
Experimental	Pre-test	44.2	5.22	38	47.5	0.001
	Post-test	91.7	2.64	38		

Improvement Between the Control and Experimental Group

The independent samples t-test was used to compare the performance of students in the control and experimental groups on the post-test of content knowledge. The post-test score of the control group was 82.7 and the experimental group was 91.7, mean difference = -9.07,$p < 0.001$, t-test was significant. The results showed that there was a difference in content knowledge between the control and experimental groups in the posttest and the students performed better in the posttest in the experimental group than in the control group when they had the same academic level. As shown in Table 9.

Table 9 Means Summary and T-test for Content Knowledge.

Variable	Group	Mean	SD	N	Mean Difference	Sig.
Content Knowledge	Control	82.7	3.51	36	-9.07	0.001
	Experimental	91.7	2.64	38		

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Difference Analysis of the Design Process

The experimental results showed that there was a difference between the scores of the two groups of students in the pre-test and post-test of the design process competence. The mean score of the control group in the pre-test of design process competence was 51.6 and the post-test score was 83.7, and the mean score improved by 32.1 points,p < 0.001, t-test was significant. The mean score of the experimental group in the pre-test of design process competence was 50.4 and the post-test score was 87.9, and the mean score improved by 37.5 points,p < 0.001, t-test was significant. It was concluded from the experimental results that the mean scores of both groups were improved. As shown in Table 10.

Table 10 Means Summary and T-tests for Students' Design Process Pre and Post-test Score Improvement

Group	Test	Mean	SD	N	Mean Difference	Sig.
Control	Pre-test	51.6	4.80	36	32.1	0.001
	Post-test	83.7	3.19	36		
Experimental	Pre-test	50.4	5.43	38	37.5	0.001
	Post-test	87.9	2.18	38		

Between the Control and Experimental Group

The independent samples t-test was used to compare the performance of students in the control and experimental groups on the post-test of the design process. The post-test score of the control group was 83.7 and the experimental group was 87.9, mean difference = -4.17,p < 0.001, t-test was significant. The results showed that there was a difference in the design process between the control and experimental groups in the posttest and the students performed better in the posttest in the experimental group than in the control group when they had the same academic level. As shown in Table 11.

Table 11 Means Summary and T-test for Design Process.

Variable	Group	Mean	SD	N	Mean Difference	Sig.
Content	Control	83.7	3.19	36	-4.17	0.001
Knowledge	Experimental	87.9	2.18	38		

Difference Analysis of Design Outcomes

The mean score of the design outcomes ability pre-test of the control group was 54.0, and the post-test score was 87.4, the mean score increased by 33.3 points,p < 0.001, t-test was significant. The mean score of design outcomes ability pre-test of the experimental group was 52.4, and the post-test score was 90.8, the mean score increased by 38.4 points,p < 0.001, t-test was significant. From the results of the experiment, it is concluded that there is a difference between the scores of the two groups of students in the pre-test and post-test of the design outcomes competence, and the average scores of the two groups have been improved. As shown in Table 12.

Table 12 Means Summary and T-tests for Students' Design Outcomes Pre and Post-test Score Improvement

Group	Test	Mean	SD	N	Mean Difference	Sig.
Control	Pre-test	54.0	4.29	36	33.3	0.001
	Post-test	87.4	2.64	36		
Experimental	Pre-test	52.4	4.90	38	38.4	0.001
	Post-test	90.8	2.73	38		

Between the Control and Experimental Group

The independent samples t-test was used to compare the performance of students in the control and experimental groups on the post-test of design outcome. The post-test score of the control group was 87.4 and the experimental group was 90.8, mean difference = -3.48,p < 0.001, t-test was significant. The results showed that there was a difference in design outcome between the control and experimental groups in the

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posttest and the students performed better in the posttest in the experimental group than in the control group when they had the same academic level. As shown in Table 13.

Table 13 Means Summary and T-test for Design Outcomes.

Variable	Group	Mean	SD	N	Mean Difference	Sig.
Content	Control	87.4	2.64	36	-3.48	0.001
Knowledge	Experimental	90.8	2.73	38		

Summary of Hypothesis testing and results

Table 14 shows the summary of the results of the hypotheses testing in the study.

Hypotheses	Statement	Result after Analysis
$H_0 1$	There are no differences in content knowledge of the control group between the pretest and posttest.	Reject
$H_0 2$	There are no differences in the design process of the control group between the pretest and posttest.	Reject
$H_0 3$	There are no differences in design outcomes of the control group between the pretest and the posttest.	Reject
$H_0 4$	There are no differences in content knowledge of the experimental group between the pretest and posttest.	Reject
$H_0 5$	There are no differences in the design process of the experimental group between the pretest and posttest.	Reject
$H_0 6$	There are no differences in design outcomes of the experimental group between the pretest and the posttest.	Reject
$H_0 7$	There are no differences in Pretest of content knowledge between control and experimental group.	Retained
$H_0 8$	There are no differences in the Pretest of the design process between the control and experimental groups.	Retained
$H_0 9$	There are no differences in the Pretest of design outcomes between the control and experimental groups.	Retained
$H_0 10$	There are no differences in the post-test of content knowledge between the control and experimental groups.	Reject
$H_0 11$	There are no differences in the Posttest of the design process between the control and experimental groups.	Reject
$H_0 12$	There are no differences in the Posttest of design outcomes between the control and experimental groups.	Reject

Discussion

The impact of augmented reality technology on the product creative design course is mainly reflected in three aspects: content knowledge, design process, and design results. Content knowledge is knowledge related to the discipline, which in this study mainly includes the basic knowledge of the discipline, such as design fundamentals, design knowledge, and other related basics (Harpe et.al., 2010). Through the study, it was found that augmented reality technology-assisted teaching was more effective than traditional teaching in the product creative design course. This partially validates the findings of Wei et al. (2015).

The design process is a complex process, a series of activities and stages of design (Deković et. al., 2000), in the creative product design program, students are required to perform the design process through design conceptualization, design sketching, and detailing. The use of different tools during the design process had an impact on the outcome (Raisa 2020), Currently, AR has been used in many fields to achieve a complete and effective low-cost design process (Carmigniani et al., 2011), in the study, the

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proposed teaching program combined with Augmented Reality technology, so that the students can experience the complete design process, the students can use Augmented Reality technology to accurately and accurately design the product, the students can use Augmented Reality technology to experience the complete design process. Students can accurately observe the internal details of the object through augmented reality technology and understand the changes in model, color, and size during the product design process, and then modify their work according to these changes, the students in the experimental group use augmented reality technology to participate in the design process and improve the efficiency of the design process, which is the same as the results of the study by (Chang et al., 2019). Through the results of the study, it is shown that the experimental group using augmented reality has a higher design efficiency than the traditional group, which helps the students experience the creative product design process, so the experimental group outperforms the traditional group.

Augmented reality was introduced in the product creative design course to improve the innovativeness and learning outcomes of the final design outcome, which refers to the result of the process, with the main emphasis being on the outcome rather than the process (Harpe et. al., 2010).In the experimental group, by allowing the students to create AR scenarios, the students were able to place 3D models of virtual objects on the design layout floor plan, and mobile devices to interact with these models, augmented reality allows users to perceive the fusion of the real world with the virtual scene. Compared to the traditional group, the experimental group's students' design results were more innovative through the presentation of augmented reality technology. The results of the study showed that the experimental group using augmented reality technology as a learning aid demonstrated higher learning efficiency than the control group. Therefore, augmented reality technology did improve the students' ability to learn product design and the design results were more accomplished. This is consistent with the findings of Safin et al. (2021) and Chang et. al. (2022).

Conclusion

The results of the study show that the use of augmented reality technology in a creative product design course has a positive impact on students' learning outcomes. By comparing the before and after side difference analysis of content knowledge, design process, and design outcome scores of the control and experimental groups, the study found that augmented reality technology helps to enhance students' learning outcomes.

Comparing the augmented reality technology classroom with the traditional classroom, the application of augmented reality technology can help students understand the content knowledge of the product model, size, color, space, and other aspects. In the product design process, AR technology can improve students' learning process experience, and help students experience the changes in the augmented reality environment, model, and space so that students can more realistically observe the details of the design work and make timely adjustments, which improves the design efficiency. In terms of design results, students produce personal AR scene works through the AR online production platform, which stimulates students' motivation and interest in learning, and students enrich the form of displaying design results by adding models, videos, sounds, and other elements to the AR scene, and the display of AR works enhances students' confidence in learning.

In conclusion, according to the results of the study, the application of augmented reality technology in teaching is more positive and effective than traditional teaching in improving students' learning outcomes, and students show positive learning enthusiasm and confidence in learning, which indicates that the application of augmented reality technology has potential advantages in improving students' learning ability in various aspects, and augmented reality technology can be applied to the teaching of no subjects in the future.

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Recommendation

The results of the study suggest that AR technology is a promising motivational learning tool that can better help students improve their learning outcomes compared to traditional teaching methods, and in future work, the researcher can implement larger educational scenarios and continue to expand the scope of the study, such as applying it to the teaching and learning of architectural, graphic, and apparel design, and evaluating it through extensive user research on the operation and accuracy of instructional design systems.

The current study, is limited to one university among the students of a certain major, so the results of the study are limited, in future research, the diversity of the study population can be expanded, and the study can be carried out in different schools or different stages of education. At the same time, researchers have paid less attention to individual factors, and in future studies, the effects of individual and environmental factors on learning outcomes can be taken into account, even including age and gender factors.

The results of the current study were only for an 8-week teaching quasi-experiment, and researchers could consider analyzing the long-term effects of augmented reality technology applications on learning outcomes. Finally, the instructional model of augmented reality technology could be extended to distance education, which is now well established, and distance education technology could allow more students to experience the innovative nature of AR technology.

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