The Analysis of Application for 3d Printing Technology in the Teaching of Stage Art Design

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Abstract

The research objectives were to 1) To determine the impact of applying 3D printing technology on student performance in the teaching of stage art design courses; 2) To identify the effectiveness of 3D printing technology when it is used in the teaching of stage art design courses.

The population of the study was undergraduate students majoring in theatre, film, and television art design at Shanxi Communication University in China. The sample size of 60 students were drawn from the population. The sample was divided into two groups, which 30 of them were purposely assigned to the experimental group to receive a 5-week 3D printing teaching and learning intervention. The other 30 students were assigned in the control group, which has been taught in the traditional teaching method. A quasi-experimental research design was used in this study to compare the differences in proportion, design, quality, total score, and performance between 3D printing technology and traditional teaching modes in the stage art and design course. The performance test on the skills was developed by the institution, which has been used across the institution has been applied. In addition, a questionnaire was used to measure student' attitudes towards 3D printing technology after the experimental group completed the course.

The results revealed that the independent sample t-test indicated that the students taught by using 3D printing technology showed statistically significant improvement in the scores of proportions, design, quality, total score, and performance compared to the traditional teaching method. Additionally, the experimental group students expressed positive attitudes towards the use of 3D printing technology in learning. In conclusion, the use of 3D printing technology in the stage arts design course promotes progress in students' practical skills and knowledge acquisition. This investigation provides empirical insights into blended learning in a university stage art design course.

Keywords: 3D Printing Technology; Educational Technology; Stage Art Design.

Introduction

Technology and education are two crucial factors in a person's existence. The purpose of education is to assist individuals in discovering and understanding who they are (Pavlova, 2008). More recently, with the arrival of the Fourth Industrial Revolution age of hyperconnectivity and hyperintelligence, there has been an increase in interest in changes in teaching techniques because of new technologies like artificial intelligence, the use of computers, and 3D printing (So, Lee, & Kye, 2017).

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3D printing is the use of 3D models in a digital environment and is the ability to transform a file into a physical object (Krassenstein, 2015). Academic experts think that 3D printing classes are crucial to improve scientific instruction and expanding educational opportunity (Ishutov, Hodder, Chalaturnyk, & Zambrano-Narvaez, 2021).

Furthermore, educators are considering how 3D printers may help their teaching in a variety of subject areas (Gonzalez & Bennett, 2014; Moorefield-Lang, 2014; Ryan & Grubbs, 2014). This covers instruction in the arts (Gentili, 2016).

More recently, 3D printing technology has been incorporated into academic curricula across a number of design disciplines (Dimitrov, Schreve, & de Beer, 2006; Johnson, et. al., 2009; Modeen, 2005; Tennyson & Krueger, 2001).

The application of 3D printing technology in teaching has become a trend, but the current teaching content using 3D printing technology remains at the level of relatively simple physical reproduction or copying, tends to be based on students' interests and hobbies of 3D printing technology as a learning tool, the use of 3D printing technology and design-related course content is less (So et al., 2017).

Few experimental studies have been conducted to show that the impact of 3D printing technology models have a positive impact on the design curriculum compared to models made using traditional manual methods such as paper structural models, sculptural models, foam core models and ceramic molding models (Greenhalgh, 2016).

In conclusion, based on the above information, the intersection of technology and education is becoming increasingly important, and the emergence of 3D printing technology has led to a re-evaluation of teaching methods. As a result, researchers have studied 3D printing technology and applied it to theatre arts and design courses, and by using 3D printing technology for learning in stage art and design courses, students can be better equipped to deal with the challenges and individual needs of modern education (Menano et al., 2019).

The aim of this study was to determine the effects of using 3D printing technology in the stage arts design course. The study analyzed the results of learning using 3D printing technology, which included improving the proportion of learners, design, quality, total score, performance grades and student attitudes towards the use of 3D printing technology.

Research Objectives

The research objectives have been formulated as follows.

1) To determine the impact of applying 3D printing technology on student performance in the teaching of stage art design courses.

2) To identify the effectiveness of the 3D printing technology when it is used in the teaching of stage art design courses.

Literature Review

Constructivism Learning Theory

Papert & Harel (1991) and informed by Ackermann (2001), which highlights the customized production of knowledge objects as well as the social element of the learning process.

Constructionist learning involves students arriving at their own conclusions through creative experimentation and the making of social objects; the teacher plays a mediational rather than instructional role and assists students in understanding and helping each other with problems through an interactive process (Harel& Papert, 1991).

Constructivism emphasises the active participation of learners in the process of knowledge construction. In the stage art design course, students can participate in all stages of creation through 3D printing technology, from design concept to actual production, gradually transforming abstract ideas into tangible works.

Constructivism holds that learning is most effective when students are able to create works using real, actionable materials and tools (Sinha, Rieger, Knochel, & Meisel, 2020).

Design-oriented training corresponds to the process of technological innovation from inspiration to concreteness; this method involves two stages—creative design idea and practical product development (Huang & Wang, 2022). The pedagogical focus of the stage arts design course in this study is simultaneously design-orientated learning content.

Constructivism Theory in Arts

Constructivism Theory in Arts has many possible aesthetic and formal relationships with materials, color, composition, and attitudes towards society and art history (Battcock, 1979).

Constructivism Theory in Arts is a theoretical framework for art that focuses on the constituent elements in a work of art, such as shape, proportion, space, and structure. In stage art design courses, constructivism can provide a useful reference and standard for proportion, quality, and design (Bowlt, 1977).

Constructivism Theory in Arts emphasizes the structure and form of works of art, and the proportion of the model is one of the structures involved in stage art design. By applying the principles of constructivism, students can learn how to examine and control the proportional relationship of stage models. Proportion is an important factor in determining the relative size of each element in the stage design model, which directly affects the perception and experience of the stage space. When designing stage art, the correct use of proportions can help the audience see the elements on the stage clearly from all angles, and proportions are the key elements to ensure the visual and artistic effects of stage art design (Čučaković & Paunović, 2016).

In Constructivism Theory in Arts, material and form play an important role in the performance of a work of art design. Constructivism highlights the importance of visual representation in a work of art through structure and form (Bannister, 2012).

Aesthetic theory

Aesthetic theory is the study of art and beauty. This theory is dedicated to exploring the essence and value of art, as well as people's understanding and reflection on the experience of beauty and aesthetic attitude. Through the study of artistic creation, artistic works, and artistic appreciation, aesthetic theory explains the emergence, evolution, and influence of artistic phenomena and explores the relationship between art and other disciplines and cultural and

social phenomena. Through the theoretical exploration of aesthetics, people can have a deeper understanding and appreciation of the connotation and extension of art (Josal, 1961).

The aesthetic viewpoints followed in stage art design include the following aspects: space, time, semiotics, integration of art, and balance of illusion and reality.

First, stage design is seen as an art form that creates space, similar to painting, sculpture, or architecture, which obeys the principles of spatial art. At the same time, stage design is also a part of drama, and its contribution and participation in drama must be considered (Josal, 1961).

Secondly, stage design is related to space and time in art, exploring the possible unity and different manifestations of space and time in art. Stage designers need to consider how to use the elements of space and time to present dramatic effects (Josal, 1961).

By using these aesthetic viewpoints in the process of stage art design, designers can create artistic stage works (Josal, 1961).

There are seven principles of design contained in the principles of aesthetics: balance, emphasis, movement, pattern, proportion, rhythm, and unity and variety (Kim, 2006). These seven design principles need to be followed throughout the process of stage arts design. These elements and principles are common to art and design education and have been incorporated into the visual arts standards for art and design curricula due to their importance (Spratt, 1987).

Research Methodology

Research design

In this study, a quantitative research approach was used where students were divided into two groups, the experimental group and the control group, both of which received a five-week course in stage art design, with the experimental group being taught using 3D printing technology and completing 3D printed models. The control group was taught using traditional methods and completed handmade models. At the end of the course, the experimental group completed a questionnaire about their attitudes towards 3D printing.

The applicability of using 3D printing technology in the stage art design course was determined by comparing the differences between the experimental group and the control group in terms of variables such as proportion, design, quality, performance, and total score, as well as the students' attitudes towards the use of 3D printing technology.

Population and Sample

The research population of this study was a total of 120 undergraduate students majoring in theatre, film, and television art and design at Shanxi Communication University in China. Students majoring in theatre, film, and television art and design already had the basic ability to use 3D modelling software in their first year of university study in their basic professional courses, so they were all equipped with the basics of teaching using 3D printing technology.

The focus of the evaluation for this study was to compare whether there was a difference in proportions, design, quality, performance, and total score in a stage art design course using 3D printing technology versus using a traditional mode of delivery. Therefore, a total of 60 students in two classes of the second year of the existing theatre, film, and television art and design majors at the university were selected as the research samples for this study, 30 students in the control group using traditional teaching methods, and 30 students in the experimental group teaching with 3D printing technology.

Research Treatment

In this study, a quasi-experimental research design was used to divide the students into two groups, an experimental group and a control group. The experimental group was taught using 3D printing technology and the control group was taught using traditional methods. To ensure comparability between the groups, the course lasted for 5 weeks and consisted of 12 lessons with no significant differences. Teachers collected data from two separate groups and recorded and assessed student performance throughout the course to compare the impact of learning with 3D printing technology on student learning outcomes.

Experimental group procedures

The experimental group used a blended learning approach while maintaining a traditional teaching approach for the control group. The blended learning content of the experimental group included the following steps:

(1) The learning and use of 3D printing technology: The course content includes the concept of stage design, the principle of 3D printing in stage art design, 3DMax software applications, drawing skills, hybrid modeling, and post-processing of 3D printing.

(2) Participation in practical tasks: Students engage in practical tasks including forming design ideas, using design software, creating 3D models, submitting designs for evaluation, and optimizing the printing process.

(3) Completing and presenting the group project: The final lesson included presenting the overall design proposal and the stage model, and the course ended with a focused presentation where students received a final grade.

(4) Completion of the questionnaire: A questionnaire on attitudes towards 3D printing technology was completed at the end of the course.

Research Instrument

Performance Tests

In the study, the experimental group and the control group used different teaching methods to teach the stage design course, the experimental group used 3D printing technology to produce scenic design models, and the control group used the traditional manual method to produce scenic design models. The teaching tasks of the two groups were the same throughout the teaching process. After five weeks of teaching, the scores of the two groups in proportion, design, quality, performance, and total score were compared to see if there was a significant difference.

The scoring criteria used in the study's testing of a total of five variables, namely, proportion, design, quality, performance, and total scores, were the existing methods of evaluating the performance of students' practical courses in the Shanxi University of Communication. The details information is display in the table 1.

Table 1: Operationalization Table of “Student Proportion, Design, Quality, Total Score, Performance"

Variable	Definition	Operationalization	Measurement
Proportion	Proportion of an object is the proportional relationship between the representation of an object or whole and its prototype. In everyday	Students make models as part of their coursework. Teacher' s grade based on the proportional accuracy of the model. (The model	Score (0-100) 90 and above = Excellent 81-90= Good 71-80=Average 61-70= Normal

	life, the proportions of an object are primarily the relationship between the form of the object and the size of the object, also known as object proportions (Wu & Li, 2006).	proportion score accounts for 20% of the total score)	60 and below =Fail Medium (70-79 points) Pass (60-69 points) Fail (below 60 points)
Design	Design is a process of creating new ideas. The result of the design process is presented in the form of a physical entity or description that can be complete and detailed enough to ensure that the idea can be realized (Stumpf & Teague, 2005).	Students present stage art design plans in coursework, and teachers grade them according to the design effects presented by students. (The design score accounts for 30% of the total score)	Score (0-100) 90 and above = Excellent 81-90= Good 71-80= Average 61-70= Normal 60 and below =Fail
Quality	Quality includes not only the degree to which the item is good or bad, but also the degree to which it meets the expectations and needs of the demander (Shewfelt, 1999). Quality in this study mainly refers to the quality of the models produced by the students.	The student presents the stage model he made in the assignment, which is graded by the teacher according to the completion of the model material and the detailed processing of the model. (Model quality score accounts for 20% of the total score)	Score (0-100) 90 and above = Excellent 81-90= Good 71-80= Average 61-70= Normal 60 and below =Fail
Performance	Proportion of an object is the proportional relationship between the representation of an object or whole and its prototype. In everyday life, the proportions of an object are primarily the relationship between the form of the object and the size of the object, also known as object proportions (Wu & Li, 2006).	During the course learning process of students, teachers will grade according to the students' learning status in each class. (Academic performance is 30% of the total grade)	Score (0-100) 90 and above = Excellent 81-90= Good 71-80= Average 61-70= Normal 60 and below =Fail
Total score	The student's scored grades for the course are added together to produce the student grade, which	The teacher grades the final grade of the course.	Score (0-100) 90 and above = Excellent 81-90= Good 71-80= Average

	is the student's overall grade (Ross, 1992). The total score in this study is the sum of the Student Proportion Score, Design Score, Quality Score, and Performance Score.	61-70= Normal 60 and below =Fail

Questionnaire

In this study, a questionnaire was used to collect the content of participants' attitudes towards the use of 3D printing technology in a stage arts and design course. The questionnaire was adapted from the USIT questionnaire scale developed by Metin, Yilmaz, Coskun, and Birisci (2012), which underwent a rigorous development and validation process.

The questionnaire consists of two sections.

Section 1: Demographic information of the respondents, including gender, age, and design experience.

Section 2: Attitudes of the study towards the use of 3D printing technology. The questions included five variables. Believe regarding usage of 3D printing instructional technology in lessons, Appreciation for the usage of 3D printing instructional technology in lessons, Unappreciated using 3D printing instructional technology, Disinclination to make use of 3D printing instructional technology, Believe in the usefulness of 3D printing instructional technology.

In this study, a five-point Likert scale was used as a measurement tool to determine the scores and points for each question. The detailed information is displayed in Table 2.

Table 2: Operationalization Table of "Students' attitudes towards using 3D printing technology"

Variable	Definition	Operationalization	Measurement
Demographic Profile	Demographic information is data and information on the characteristics, size and composition of the population. (Hodgkinson, 2002).	1. Gender 2. Age 3. Experience of Learning Design (year)	
Believe regarding usage of 3D printing instructional technology in lesson	Believe regarding usage of 3D printing instructional technology in lesson refers to the degree to which individuals (e.g., students, educators, professionals, etc.) trust and approve of the application of 3D printing technology in a given context (Metin et al., 2012).	4. I enjoy using the 3D printing technologies in lesson. 5. I learn better the lesson when 3D printing technologies use. 6. I feel motivated the lesson used 3D printing technologies. 7 .I am pleased with the lesson used 3D printing technologies.	5 Levels Agreement Likert's scale (Strongly Agree to Strongly Disagree)

		8 .I can listen carefully to the lesson used 3D printing technologies. 9. I learn swiftly topics when 3D printing technologies are used.	
Appreciation to usage of 3D printing instructional technology in lesson	Appreciation to usage of 3D printing instructional technology in lesson refers to the extent to which students, as well as educators, feel, recognize and evaluate the use of 3D printing in the teaching and learning process (Metin et al., 2012).	10. I become active in the lessons used 3D printing technologies. 11. I remember the knowledge easily through lesson used 3D printing technologies. 12. Usage of the 3D printing technologies in lessons increases learning. 13. The knowledge learnt during the lessons by using 3D printing technologies are more permanent. 14. My creativity increase in lessons used 3D printing technologies.	5 Levels Agreement Likert's scale (Strongly Agree to Strongly Disagree)
Unappreciated using 3D printing instructional technology	Unappreciated using 3D printing instructional technology means that the value, importance, and potential impact of 3D printing technology as a teaching and learning method or tool is not sufficiently recognized, valued, or attended to in an educational setting (Metin et al., 2012).	15 .Usage of the 3D printing technologies is unnecessary. 16. It is a waste of time to use 3D printing technologies in lessons. 17. I dislike the topics that are told with the 3D printing technologies. 18. I lose my concentration in the lesson used 3D printing technologies.	5 Levels Agreement Likert's scale (Strongly Agree to Strongly Disagree)

Disinclination to make use of 3D printing instructional technology	Disinclination to make use of 3D printing instructional technology refers to the level of resistance or disapproval of educators or students to the use of 3D printing in the teaching and learning process (Metin et al., 2012).	19. I do not know how to use computers in my lessons. 20. I do not want to use computers and the internet in my classes. 21. I do not want to participate in lessons teaches by 3D printing technologies. 22. I am stressed in the lesson used 3D printing technologies.	5 Levels Agreement Likert's scale (Strongly Agree to Strongly Disagree)
Believe in usefulness of 3D printing instructional technology	Believe in usefulness of 3D printing instructional technology refers to the degree to which students and educators have confidence that the use of 3D printing technology will achieve the desired results in real-world teaching and learning, and that it can be used effectively in an educational setting (Metin et al., 2012).	23. It is beneficial for me to learn the usage of the 3D printing technologies. 24. Usages of the 3D printing technologies are made more prevalent in education.	5 Levels Agreement Likert's scale (Strongly Agree to Strongly Disagree)

Validity of Research Instruments

The researcher employed the Item Objective Consistency (IOC) method to authenticate the research instrument used in this study. To evaluate the content validity of the research instrument, the indicator objective coherence (IOC) method was used. This approach involves dispersing the test items and requesting education professionals with relevant practical experience in theatre arts education to assess their relevance. Subsequently, experts use empirical judgments or evaluation scales to assess the relevance of each item to the study's topic or purpose (Li & Xin, 2008). The three validators held the title of professor in theatre and film art and design, with over 10 years of teaching experience. Consistent with Turner and Carlson's (2003) findings, the validation results showed that all IOC scores exceeded 0.7, confirming the content's validity.

Reliability of Research Instruments

To test the reliability of the questionnaire on attitudes towards the use of 3D printing technology, a pre-test was administered to 30 randomly selected students from the Theatre, Film, and Television Art and Design program. The internal consistency reliability has been calculated to ensure the reliability of the questionnaire items.

Reliability analysis was performed for each factor, and Cronbach’s alpha correlation coefficients were used. According to Nunnally (1978), reliability of 0.70 or more for each section of the questionnaire is considered acceptable. Cronbach’s alpha correlation coefficients were calculated among the factors as listed in Table 3.

The table summarizes the variables, number of items, and Cronbach's alpha values, which ranged from 0.868 to 0.984. The results showed that the questionnaire items were reliable to be used for data collection.

Table 3: Results of Cronbach's Alpha of the research instruments

Variable	**Number of Items**	**Cronbach's Alpha**
Believe regarding usage of 3D printing instructional technology in lesson	6	0.967
Appreciation to usage of 3D printing instructional technology in lesson	5	0.950
Unappreciated using 3D printing instructional technology	4	0.984
Disinclination to make use of 3D printing instructional technology	4	0.971
Believe in usefulness of 3D printing instructional technology	2	0.868

Data Collection Procedures

The duration of the course is 12 sessions over 5 weeks. Throughout the course of the study, students' attendance in class and completion of each section of the assignment were recorded using a grade recording form, as arranged in the study. Upon completion of the course, student performance data were collected after students submitted their assignments in accordance with the requirements of the study.

At the end of the course, a questionnaire on attitudes towards the use of 3D printing technology was distributed to students in the experimental group, which was filled out by students using the Questionnaire Star software, and the questionnaire data was retrieved after all the students had submitted the questionnaires.

In order to ensure that this study followed research ethics, the researcher followed the necessary steps by first obtaining approval from the School of Arts at Shanxi University of Communication. In addition, a consent form was developed to protect the participants' personal information by ensuring that the participants were aware of anything they were agreeing to do and that the participants' privacy was respected and the participants' rights and dignity were respected.

Data Analysis

There were two main methods of data research for this study, which are the performance tests and the questionnaires.

The independent samples t-test was applied to test the effectiveness of using 3D printing technology in the classroom.

For the questionnaires, the descriptive statistics has been applied to analyze students' attitudes towards the use of 3D printing technology, which in turn determined how students felt about the experience of using 3D printing.

Research Conceptual Framework

This study compared the use of 3D printing technology in stage arts design course with 30 students in the experimental group and 30 students in the control group. The experimental group was taught using 3D printing technology and the control group was taught using traditional methods. After a 5-week course, the two groups were compared to see if there were any differences in proportion, design, quality, performance, and overall scores. At the end of the course, a questionnaire was given to the experimental group to investigate their attitudes towards 3D printing technology. The research framework presented in figure 1.

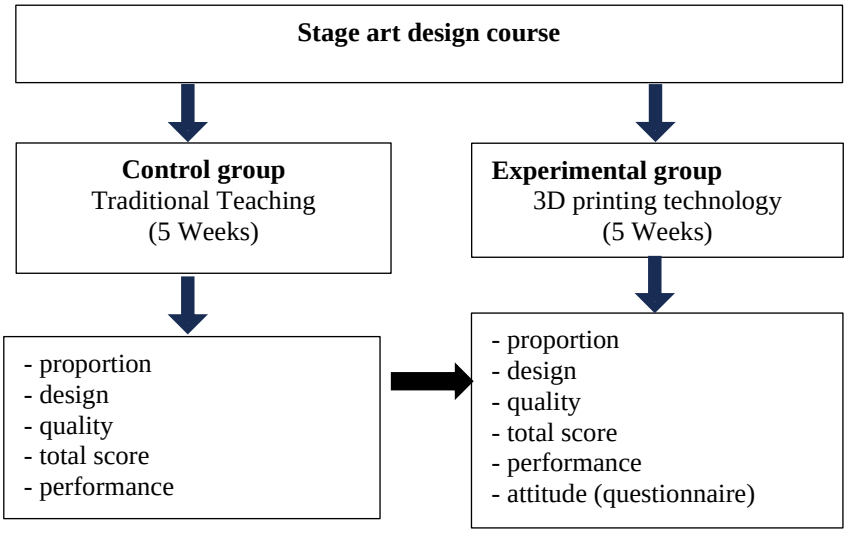

Figure 1: Research Conceptual Framework

Based on the conceptual framework, the hypotheses were developed as follows.

Hypotheses Testing

$H_0$1 : There is no difference in the proportion of students who use 3D printing technology to learn and traditional teaching.

H_a1 : There is a difference in the proportion of students who use 3D printing technology to learn and traditional teaching.

$H_0$2 : There is no difference in the design of students who use 3D printing technology to learn and traditional teaching.

H_a2 : There is a difference in the design of students who use 3D printing technology to learn and traditional teaching.

$H_0$3 : There is no difference in the quality of student who use 3D printing technology to learn and traditional teaching.

H_a3 : There is a difference in the quality of student who use 3D printing technology to learn and traditional teaching.

$H_0$4 : There is no difference in the total score of students who use 3D printing technology to learn and traditional teaching.

H_a4 : There is a difference in the total score of students who use 3D printing technology to learn and traditional teaching.

$H_0$5 : There is no difference in Performance of students who use 3D printing technology to learn and traditional teaching.

H_a5 : There is a difference in Performance of students who use 3D printing technology to learn and traditional teaching.

Research Results

Demographic Information

The research collected data from 60 students—30 for the control group and the other 30 for the experimental group.

Of these 60 students, 3 (5%) were aged 18–19, 52 (86.7%) were aged 20–21, and 5 (8.3%) were aged 22–23. There were 21 boys, or 35 percent of the total, and 39 girls, or 65 percent of the total.

Among stage art design course students, there are 2 students (3.3%) with 1 year of design learning experience, 15 students (25%) with two years of design learning experience, 28 students (46%) with three years of design learning experience, 8 students (13%) with four years of learning experience in design, and 7 students (11.7%) with 5 years of design experience.

1. Result of Data Analysis for Research Objective 1: ***To determine the impact of applying 3D printing technology on student performance in the teaching of stage art design courses.***

The results of the data analysis for research objective 1 are based on the results of the hypothesis testing test of the independent samples t-test.

The research proposed five hypotheses to differentiate students' performances between the control and the experimental group with the 3D printing technology as the intervention.

To test the hypotheses, independent sample t-tests were used to compare whether there was an improvement in student proportion, design, quality, total scores, and performance scores. The results of the independent sample t-test are shown in Table 4.

Table 4: Independent Samples T-Test

		t	df	sig.	Mean difference	SE difference
Proportion	Student's t	8.33	39	.000	11.27	1.353
Design	Student's t	11.4	44	.000	14.17	1.242
Quality	Student's t	10.32	43	.000	13.93	1.351
Total score	Student's t	8.73	42	.000	11.73	1.344
Performance	Student's t	4.37	45	.001	8.07	1.844

According to the results in Table 4, the scores of proportions, design, quality, total, and performance scores were statistically significant when comparing the two groups. Therefore, the null hypothesis was rejected. It can be shown that students in the treatment group had higher improvement scores on all variables than the control group. In addition, the largest mean difference was found in the design score, with a difference of 14.17, which was statistically significant at <.001.

Further review of the descriptive statistics of the improvement scores of the two groups also showed that the treatment group consistently scored higher than the control group. Details of these scores are shown in Table 5.

Table 5: Group Descriptive

	Group	**n**	**Mean**	**Median**	**SD**	**SE**
Proportion	Control	30	70.53	70.00	2.82	0.516
	Treatment	30	81.80	82.00	6.85	1.251
Design	Control	30	70.73	69.50	3.13	0.571
	Treatment	30	84.90	85.00	6.04	1.103
Quality	Control	30	70.17	69.00	3.31	0.605
	Treatment	30	84.10	82.50	6.61	1.208
Total score	Control	30	72.50	71.50	3.17	0.579
	Treatment	30	84.23	85.50	6.64	1.213
Performance	Control	30	77.10	75.00	4.85	0.885
	Treatment	30	85.17	88.50	8.86	1.618

In summary, all hypotheses tested for students in terms of proportion, design, quality, total scores, and performance showed that students in the treatment group scored higher after learning in the treatment condition. Therefore, all null hypotheses were rejected. As a result, all scores were statistically improved.

Table 6: Summary of Hypothesis testing and results

Statements	**Result**
$H_0$1:There is no difference in the proportion of students who use 3D printing technology to learn and traditional teaching.	Rejecting the Null Hypothesis
$H_0$2: There is no difference in the design of students who use 3D printing technology to learn and traditional teaching.	Rejecting the Null Hypothesis
$H_0$3:There is no difference in the quality of student who use 3D printing technology to learn and traditional teaching.	Rejecting the Null Hypothesis
$H_0$4: There is no difference in the total score of students who use 3D printing technology to learn and traditional teaching.	Rejecting the Null Hypothesis

$H_0$5: There is no difference in Performance of students who use 3D printing technology to learn and traditional teaching.	Rejecting the Null Hypothesis

2. Result of Data Analysis for Research Objective 2: *To identify the effectiveness of the 3D printing technology when it is used in the teaching of stage art design courses.*

The results of the data analysis for research objective 2 are based on the results of the analysis of the questionnaire on students' attitudes towards the use of 3d printing technology.

A five-level Likert scale questionnaire was used in this study to collect the attitudes of the sample towards each variable. In order to interpret the data obtained, arbitrary levels were used to interpret the mean value of each variable. According to Norman (2010), the mean value of 3.51–4.50 was interpreted as agreement.

Table 7 shows the students' attitudes towards the use of 3D printing technology. The total mean of the five dimensions in the questionnaire is 4.27, which indicates agreement. This indicates that the students have a positive attitude towards the use of 3D printing technology in the classroom and that 3D printing technology has a good effectiveness in the teaching of stage art design courses.

Table 7: Descriptive Statistics of Students' attitudes towards using 3D printing technology

Item Statement	Mean	SD	Interpretation
Believe regarding usage of 3D printing instructional technology in lesson	4.41	0.69	Agree
Appreciation to usage of 3D printing instructional technology in lesson	4.42	0.68	Agree
Unappreciated using 3D printing instructional technology	3.96	1.26	Agree
Disinclination to make use of 3D printing instructional technology	4.09	0.99	Agree
Believe in usefulness of 3D printing instructional technology	4.49	0.68	Agree
Total	**4.27**	**0.86**	**Agree**

Discussion

The study reveals a significant boost in students' learning performance with 3D printing technology in stage arts design courses compared to traditional teaching. This improvement is evident in proportion, quality, and design scores, aligning with findings from prior studies (Bøhn, 1997; Flowers & Moniz, 2002; Gibson, Kvan, & Wai Ming, 2002; Iwamoto, 2004; Greenhalgh, 2016). Integration of 3D printing allows students to explore complex stage structures, contrasting with the trend of simplification in traditional methods. Notably, those using 3D printing show a preference for intricate designs. The key finding is a significant performance increase in both individual and team projects. In individual work, 3D printing facilitates a concrete presentation of design ideas. In team projects, it promotes collaboration and communication, leading to enhanced overall performance, as evidenced by previous research (Georgiev et al., 2023). The cumulative scores for students utilizing 3D printing surpass those following traditional teaching methods, aligning with the conclusions drawn by Greenhalgh (2016). In summary, the integration of 3D printing technology significantly enhances students' learning performance in stage arts design courses.

The Overall Finding Diagram

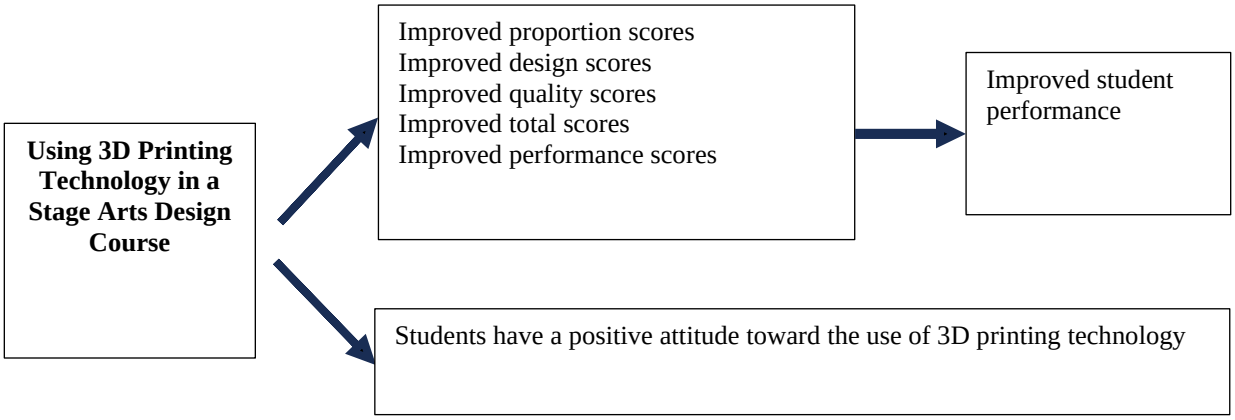

Figure 2: The overall finding

As shown in Figure 2, the utilization of 3D printing technology in the teaching of stage art design was determined by analyzing the differences between the scores of the experimental group using 3D printing technology and the control group using traditional teaching in the five aspects, which were proportions, design, quality, total score, and performance. The results revealed that the use of 3D printing technology significantly improved students' scores in all aspects. Additionally, the results showed that students have positive attitude towards using 3D printing technology in a stage arts design course.

Notable Findings

In addition to the two research questions in this study, this paper contains several other noteworthy findings that may be directly or indirectly related to the research questions listed below.

Stimulate creativity: Students may be more strongly stimulated using 3D printing technology. Through the actual design and fabrication process, students could come up with and realize unique artistic ideas.

Promote teamwork: In a teaching and learning environment using 3D printing technology that involves collaborative team projects, students may improve their teamwork and communication skills by working together to solve problems and achieve design goals.

Improved learning outcomes: student learning outcomes may be improved through the use of 3D printing technology. Assess students' academic achievement or performance abilities and compare them to learning outcomes under traditional teaching methods. The results of our study may show improved student competence and performance in a blended learning environment.

Student Practical Skills Development: students will gain practical experience in using 3D printing technology, which will help develop relevant technical and craft skills. The researchers observed students' acceptance and use of these technologies. It was found that students were able to use them proficiently to support their learning.

These additional and noteworthy findings provide a more comprehensive and integrated understanding of the use of 3D printing technology in the teaching of stage art design. It also provides useful guidance for educational practice and future research.

Recommendations

This study is expected to improve the course content on 3D printing technology in the teaching of the Theatre and Film Art and Design major at Shanxi Media College, to promote an innovative and reforming program on the basic education of the stage Art and Design major, and to promote the adoption of a blended learning approach with technological interventions in the reform of education in this major.

The researchers concluded that there is a need to create a specialized 3D printing technology curriculum module that includes comprehensive content ranging from fundamentals to practical applications to provide opportunities for in-depth learning. Secondly, more hands-on projects are recommended to provide students with hands-on experience in creating stage art design elements using 3D printing technology to enhance practical skills while stimulating creativity and design thinking. In order to better operate the 3D printing technology, it is recommended that design software training related to the technology be introduced to enhance students' technical skills. Interdisciplinary collaboration is another key recommendation. Through collaborative projects with related disciplines such as engineering and digital modelling, students can expand their knowledge areas, develop interdisciplinary skills, and improve their adaptability. To ensure that students have adequate opportunities for practice, schools should provide sufficient 3D printing equipment and related resources and establish partnerships with industry. Finally, to keep the curriculum on the cutting edge, regular teacher training is recommended to keep educators up to date with the latest developments in 3D printing technology. The implementation of these recommendations will not only improve the quality of teaching and learning in the theatre arts and design curriculum but also develop a more well-rounded skill set in students, making them more adaptable for the future.

Recommendations for Future Research

In order to further deepen the understanding of the applicability of 3D printing technology in the teaching of stage art design, future research on this topic could be continued.

Firstly, the timeframe could be extended to observe the long-term effects of integrating 3D printing technology into stage arts design education. This could help to provide a more complete picture of the long-term development of students' skills and attitudes. Secondly, given the rapid development of 3D printing technology, future research should include an ongoing evaluation of the technology to ensure that findings are consistent with the latest technology.

In future research, more focus needs to be placed on specific applications of 3D printing technology in stage arts design, such as set design, costume making or prop making, to increase the depth of the research. In addition, comparative studies could be used to assess the relative effectiveness of 3D printing technology in stage arts design education compared to other emerging technologies or traditional methods. Such comparisons can help identify the unique strengths and potential weaknesses of 3D printing technology.

In order to gain a more comprehensive understanding of learning outcomes, subsequent studies could delve into learning outcomes related to the use of 3D printing technology, including technical skill outcomes, the development of student creativity, and an increased understanding of stage arts design principles as a whole. Student diversity is also an important aspect to consider in subsequent studies. The responses of different student backgrounds and

experiences to 3D printing technology could be explored. Future research could build on the current study to provide a more comprehensive and in-depth understanding of the use of 3D printing technology in stage arts and design education.

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