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Model Design of Art Design Teaching Reform by Integrating Virtual Reality Technology Guided by Patent Achievement Transformation

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ABSTRACT

Virtual reality technology, as a trend of the development of the new era, has a profound impact and influence on traditional art design teaching. This paper combines virtual reality technology to construct a classroom teaching interactive analysis system to help art design teaching reform. All the objects required for the art design teaching scene are modeled in 3Ds Max, the mapping of each object in the scene is beautified using Photoshop, the FBX format file with animation effect is output, and Unity3D is used for the design and development of the VR part. Subsequently, a quantitative coding form for classroom observation, methods and rules for behavioral data collection, and a classroom migration matrix for analysis were designed to analyze the teaching interaction behaviors in the smart classroom classroom from the micro level. The characteristics of the teaching model in the art and design classroom were captured at the macro level based on the S-T analysis. A teaching experiment was conducted in a school's art design program after the FIAS analysis. The improved art design classroom interaction increased for the blended teaching mode, and the average of the pre and post-test scores of the experimental class applying this model were 74.18 and 84.37 respectively, and there was a significant difference, which was a significant improvement over the control class. This study provides new ideas and methods for the teaching reform of art design majors in higher education institutions.

Keywords: virtual reality, classroom interactive behavior, coding rules, art design

1. Introduction

At the present stage, scientific research technology and theoretical achievements continue to develop to provide reference for the update and optimization of China's advanced technology, and virtual reality technology has been further developed under the demand of the market, and has made contributions in many fields that are hard to be ignored. In the field of art and design, the technology

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has achieved remarkable results by virtue of a more diversified, intuitive and intelligent presentation. In particular, the reproduction and interactive form of virtual reality technology provides art designers with more diversified creative space, which facilitates designers to show their ideas and design thoughts, and provides a more intuitive, three-dimensional display of artistic impact based on modern technology.

In the art design practical training course, the use of virtual reality technology in course teaching from different perspectives, resulting in different values. From the perspective of teaching hardware, it can effectively save practical training resources, more closely art theory and operation, effectively converted into the ability of artistic innovation [1]. From the perspective of design course research methods, it can efficiently collect participant information, provide new methods of user research, and provide strong support for design development and design evaluation [2-3]. From the perspective of the teacher's teaching session, virtual reality technology can be used in a multi-dimensional way to realize different teaching effects and enhance the interaction between teaching content and students [4]. From the perspective of students, the use of 3D demonstration and VR technology in the way of experiential teaching content, effectively realizing the combination of course theory and practice, effectively converting abstract teaching content into intuitive feeling of contextual teaching [5]. In summary, virtual reality technology has a positive effect on improving the teaching quality of art design courses and cultivating students' art design ability.

The reform of teaching information technology is changing the traditional art design teaching mode. Jin, H. et al. based on computer-aided design software for environmental art design teaching innovative teaching methods, which can optimize the professional curriculum, teachers' teaching methods and students' learning, to promote the improvement of students' professional design ability in environmental art [6]. Zhang, B. et al. use information technology to build a computer-aided design platform system, which provides a theoretical basis and practical test results for computer graphics and image-aided art design teaching by integrating network teaching resources, and utilizes digital means to cultivate students' artistic modeling ability and judgment of beauty [7]. Liu, F. et al. explored the innovative teaching mode of art design under the Internet open learning mode, and found that in the computer-aided design platform through the forming interdependence among group members, improved students' cooperation efficiency, and had a positive promotion effect on students' art design performance [8].

Teaching design based on virtual reality demonstration mode changes the traditional classroom-centered teaching mode, combines course theory with teaching practice, enriches students' learning experience, and effectively enhances the teaching effect. Gong, Y. shows that virtual reality technology, by virtue of its vividness and autonomy characteristics, helps to enrich the means of artistic creation and improve the quality of the artistic creation process, and in the field of art teaching mode and teaching design, can enhance the comprehensive teaching experience of teachers and students, and significantly enhance the teaching effect [9]. Qian, J. analyzed the role played by three kinds of virtual reality technology with different characteristics in the art design course, comparing the classroom teaching effect under image recognition, speech recognition, natural processing technology, and traditional teaching methods, and found that the effectiveness of virtual reality technology classroom is much higher than that of traditional method classroom, and the The effect of visual and image modality is higher than that of voice modality [10]. He, C. et al. designed a model of artificial intelligence computer-aided teaching system with personalized teaching and collaborative learning functions, and the digital network learning platform based on artificial intelligence provides great support for the design creativity of the teaching participants, which can effectively stimulate the learners' desire to learn in the art profession and enhance their learning effect [11]. Du, S. explores the virtual reality environment art design teaching mode from the perspective of modern educational technology, puts forward the concept of desktop VR technology intervening in the experimental modeling course, constructs a virtual learning environment that can enhance the sensory experience of students, and enhances the students' interest in learning and their own sense of creativity, so as to improve the learning effect of the students [12]. Feng, C. centers on the teaching application of art modeling design examples, elaborates the advantages of intelligent virtual reality technology into art creation design teaching, the expansion and promotion of teaching resources, the synergistic effect of teaching results, etc. [13]. Ruan, Y. puts forward an integrated three-dimensional art design teaching mode to study the application of this immersive virtual reality technology in art design teaching practice, which is able to create an immersive teaching environment, guide students in their learning and three-dimensional practice to develop creative thinking, and bring new opportunities for art and design education [14].

This paper develops a VR-based classroom teaching interaction analysis system for art design teaching reform and analyzes the practical application of the model. Firstly, we constructed the observation scale of classroom teaching interaction behavior, designed the data processing and classroom interaction behavior collection methods, and modeled the analyzed variables and drew the Rt-Ch diagram. Design interpersonal interaction rate, the interaction rate between people and media technology, the rate of silence and confusion, the rate of teacher's speech behavior, and other teaching mode judgment classification standard conditions. Finally, two classes are selected as the experimental class and control class in the art and design program of a school to carry out the teaching experiment.

2. Method

2.1. VR Interactive Contextual Art Design Teaching

2.1.1. Overall system design. This study applies VR technology to art design teaching, compiles a VR course, and realizes art design contextualized teaching using a mobile app + VR device [15]. Learners interact with characters and objects in the virtual context to improve their understanding and memorization of art design words and sentences, transforming a boring language classroom into interactive art design teaching in a simulated environment. The structure of VR interactive contextualization is shown in Figure 1.

This study is divided into two modules. Module 1 is VR classroom teaching, which is mainly based on the art design teaching objectives and course objectives, develops the corresponding VR interactive contextual art design teaching design, and adopts novel teaching methods to boost the actual classroom to complete the teaching task. Teachers based on student learning data and scoring feedback, real-time mastery of student knowledge of the class, so as to carry out targeted teaching. Module 2 is VR underclass teaching, to make up for the shortcomings of the school art design courses can not fully meet the needs of students' daily use of art design, for all kinds of common social scenes in daily life, students will be placed in the imitation of foreign language environment to learn art design. With the technical support of VR, the combination of the two modules makes the learning of art and design no longer stop at the traditional classroom, and improves the art and design level of students in an all-round way.

This study is a new learning environment design to create a three-dimensional audio-visual combined independent learning environment for learners that breaks the conventional classroom teaching environment. The main theoretical basis is as follows. Constructivist learning theory believes that learning occurs in a specific context, it is the process of constructing knowledge by the learners themselves, and the teacher should guide the learners to construct new experiences from their original experiences.The role of VR technology in art design teaching reflects the interactive process between the learners and the virtual context, and the learners can reconstruct their knowledge through personal experience in the virtual context to obtain new knowledge. Contextual cognitive learning theory that the context is the premise and foundation of learning, cognition should play the role of the learner's main body, through the setting of the context to realize the acquisition of knowledge, and ultimately the application of knowledge to practical activities.VR technology allows learners to sit in the classroom can experience simulation of the art design situation, the return to the real in the virtual interaction, in the do learning.

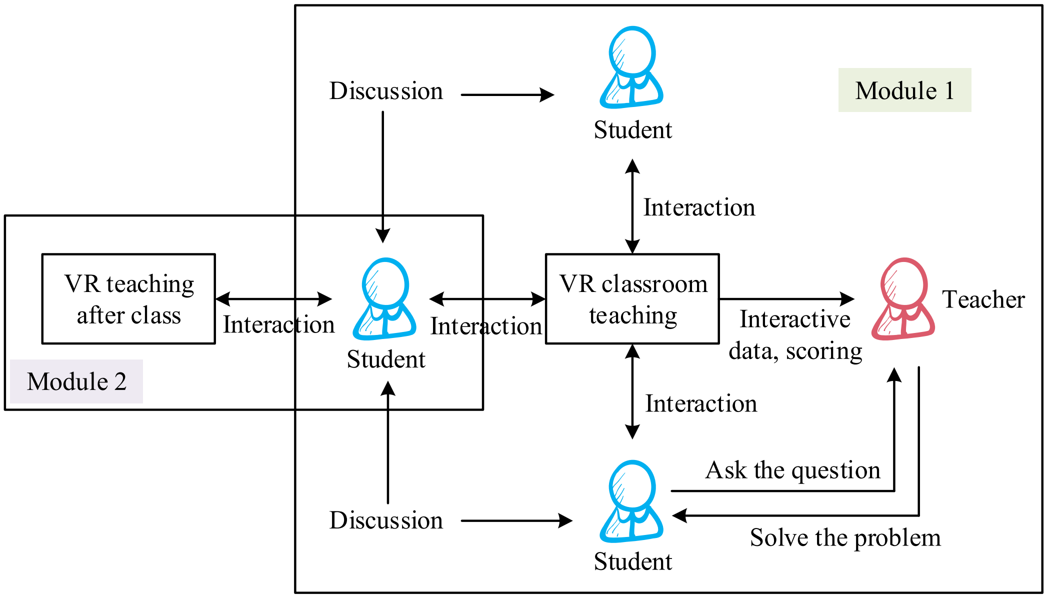


Fig. 1. ART design diagram of VR interactive situation

Cognitive flexibility theory focuses on explaining how to promote the flexible transfer and application of knowledge through the deepening of multidimensional understanding.VR interactive contextual art design teaching adopts a flexible classroom format, which promotes the learners' in-depth understanding of knowledge mastery through novel learning methods, and is able to transfer and apply knowledge. According to the above theory, VR technology is applied to art design teaching to make up for the shortcomings of traditional classroom teaching forms and provide new ideas for the development of modern education.

2.1.2. System development process. The development process is shown in Figure 2. Firstly, the scene conception is carried out, all the objects needed for the scene are modeled in 3Ds Max, the mapping of each object in the scene is beautified using Photoshop, and the FBX format file with animation effect is output. Secondly, use Unity3D to design and develop the VR part. We need to install JDK and configure environment variables, download and install MojingSDK in Magic Mirror development platform, import FBX format files, sound effects, lights, etc. into Unity3D for integration and development, and import Unity project into Android studi to continue to develop the interface and functions after the completion of the VR content production. After all the development is completed, we will test the software with the Bluetooth handle of Magic Mirror on Android platform, and finally release the Android version APK for students to use.

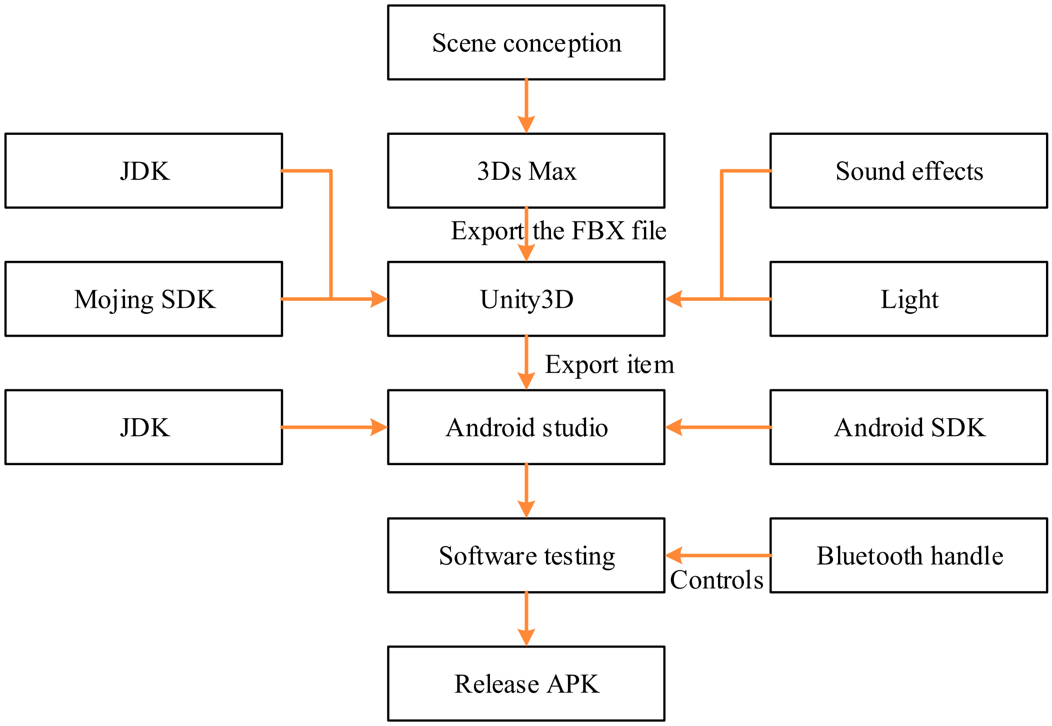


Fig. 2. Flow chart of VR interactive situational ART design

2.1.3. Virtual teaching model of art design based on VR/AR technology. The VR/AR virtual simulation experimental teaching system model designed in this paper has a high degree of immersive presence, real-time interactivity, data visualization, virtual simulation and animation design. Immersed in the sense of presence means completely immersed in the virtual world, and the real world has the same feeling, through the equipment can be with the virtual object role and reaction operation, the knowledge and the internal structure of the object has a direct perception of the visual, auditory and tactile trinity of effective integration, it is easy to invest in which to get a sense of presence of a strong learning experience; real-time interactivity includes human-computer interaction, virtual model and external data interaction, etc.; data visualization, data visualization, virtual simulation and animation design. Real-time interactivity includes human-computer operation interaction, virtual model and external data interaction, etc.; data visualization is able to show all kinds of abstract data in a variety of ways; virtual simulation and animation design includes simulation based on the physical laws of the virtual model, simulation of the operator's view, and animation simulation of the image of the abstract content. Using VR/AR technology, the school's virtual simulation experiment teaching, scientific research, management and all other information resources to carry out a comprehensive digitalization, and ultimately realize the informationization of education, improve the level of education management of the school. The application of VR/AR-based display technology in the field of virtual simulation experimental teaching has become a necessary means of online experimental teaching with its 3D stereoscopic, immersive and interactive features, the model of which is shown in Figure 3.

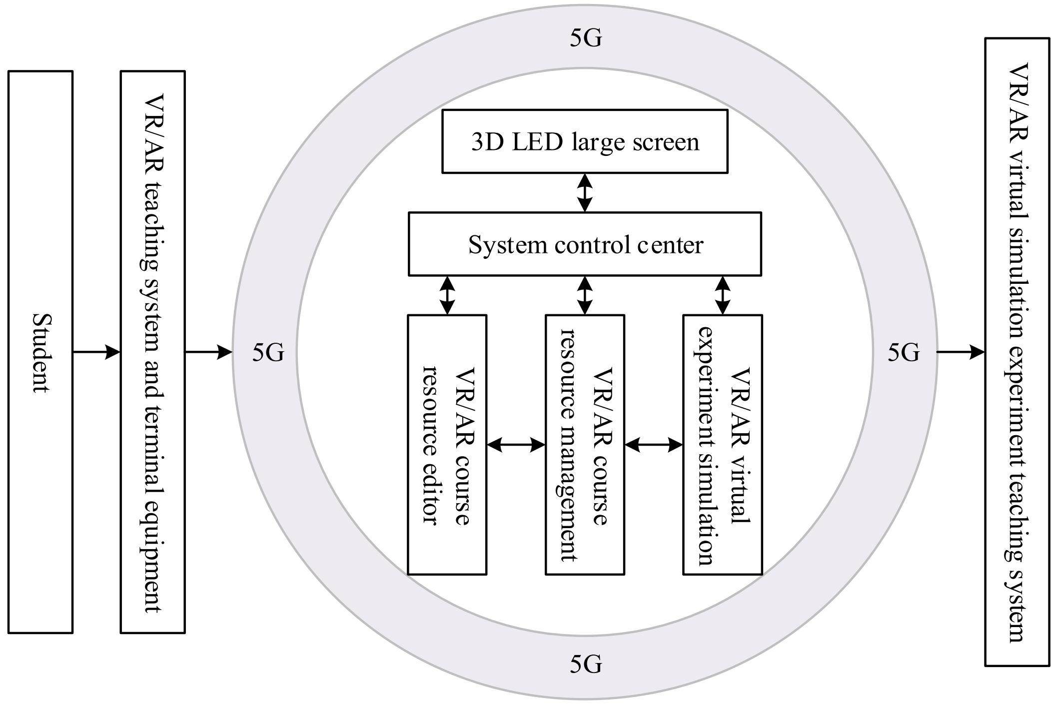


Fig. 3. Model of VR/AR virtual simulation experiment teaching system

2.2. Classroom Teaching Interaction Analysis System Based on Smart Classroom

2.2.1. Construction of the Observation Behavior Scale for Classroom Teaching Interaction. Flanders Interaction Analysis System (FIAS) is a typical and widely used research tool for classroom teaching interaction behavior, but FIAS emphasizes teachers' verbal behavior and cannot reflect information technology-supported classroom teaching interaction behavior, which is only categorized as silent speech [16]. In this paper, we adopt the Classroom Teaching Interaction Analysis Coding System (hereinafter referred to as ITIAS) in the smart classroom environment, which completely changes the classification structure of the original FIAS code in terms of teachers' speech, and cannot well describe the interaction between teachers and students in terms of their speech. Further analysis of ITIAS, OOTIAS, and ITIAS reveals that the three coding systems are more typical interaction analysis tools for IT-supported classroom teaching at different times, each of them possessing a set of categorical coding lists of teaching and learning interaction behaviors used for classroom observation, and they have more similarities in terms of the meanings assigned to the codes.

2.2.2. Behavior Collection Methods and Coding Rules. There are two common methods for data collection of interactive behaviors in classroom teaching: ① fixed-time sampling, observing classroom behaviors at certain time intervals (usually 3 seconds) and assigning them certain operational definitions, and dividing them into types of behaviors to be coded and recorded; and ② video slicing based on the transition points of behaviors and counting the durations of each type of behaviors [17]. The researcher will selectively adopt one of these methods for data collection according to the needs of the study, and this study ultimately adopts the first method for raw data collection.

2.2.3. Data Processing and Classroom Interaction Behavior Analysis Variables. According to the coding, the observer judges the classroom behaviors in the recorded video at fixed intervals (every 3 seconds) and assigns coded markers to them, forming the original observation record sheet. Drawing on the FIAS data processing method, the core idea of the coding process in this study is that each code is combined with the previous code and the next code to form an "ordinal pair", and the other codes are used twice, except for the first and last codes, which are used once each.

The migration matrix transformed from the original observation record sheet is a symmetric matrix whose rows and columns are represented by the meaning of the codes, and each cell in the matrix is filled with a number that indicates the frequency of consecutive classroom behaviors or overlapping behaviors. According to the distribution of various classroom behavior codes in the matrix and the proportionality between the frequency of behavior can make meaningful analysis of the classroom teaching situation, such as analyzing the teacher's teaching style classroom emotional climate. In order to facilitate the expression, this paper will migrate the matrix of the rows and columns of the composition of the cell elements as $cell(i, j)$, such as cell (3, 6) that the third row of the sixth column of the cell elements, the sum of the columns of $row(i) = \sum_{j=1}^{25} cell(i, j)$, the sum of the rows of $col(j) = \sum_{i=1}^{25} cell(i, j)$, and the sum of all the elements of the matrix as $total = \sum_{i=1}^{25} \sum_{j=1}^{25} cell(i, j)$. According to the coded content, referring to the FIAS method of analyzing teacher-student verbal behavior interaction variables, this paper constructed 19 classroom teaching interaction analysis variables as follows:

The interpersonal interaction rate (P_P) is:

$$\sum_{i=1}^{12} row(i) / total \tag{1}$$

The rate of human interaction with media technology (P_MT):

$$\sum_{i=13}^{23} row(i) / total \tag{2}$$

Silent Confusion Rate (C_L):

$$\sum_{i=24}^{25} row(i) / total \tag{3}$$

Teacher Verbal Behavior Rate (T_LL):

$$\sum_{i=1}^{7} row(i) / total \tag{4}$$

Teacher speech indirect to direct influence ratio (T_L(i_d)):

$$\sum_{i=1}^{s} row(i) / \sum_{i=6}^{7} row(i) \tag{5}$$

Teacher Question Rate (T_Q):

$$\sum_{i=3}^{4} row(i) \Big/ \sum_{i=1}^{7} row(i) \tag{6}$$

Open versus closed question ratio (T_L(o_c)):

$$row(4) / row(3) \tag{7}$$

Student Verbal Behavior Rate (S_L):

$$\sum_{i=8}^{12} row(i) / total \tag{8}$$

Student passive response rate (S_P):

$$row(8)/\sum_{i=8}^{12} row(i) \tag{9}$$

Student-initiated response rate (S_I):

$$row(9)/\sum_{i=8}^{12} row(i) \tag{10}$$

Student-initiated questioning rate (S_Q):

$$row(10)/\sum_{i=8}^{12} row(i) \tag{11}$$

Student Cooperative Communication Rate (S_CD):

$$row(11)/\sum_{i=8}^{12} row(i) \tag{12}$$

Student verbal evaluation rate (S_E):

$$row(12)/\sum_{i=8}^{12} row(i) \tag{13}$$

Teacher use of media technology rate (T_MT):

$$\sum_{i=13}^{18} row(i) \Big/ \sum_{i=13}^{23} row(i) \tag{14}$$

Teacher-Traditional Media Rate (T_M):

$$row(13)/total \tag{15}$$

Teacher-Modern Technology Rate (T_T):

$$\sum_{i=14}^{18} row(i)/total \tag{16}$$

Student Use of Media Technology Rate (S_MT):

$$\sum_{i=19}^{23} row(i) \Big/ \sum_{i=13}^{23} row(i) \tag{17}$$

Student-Traditional Media Rate (S_M):

$$row(19)/total \tag{18}$$

Student-modern technology rate (S_T):

$$\sum_{i=20}^{23} row(i)/total \tag{19}$$

2.2.4. Rt-Ch diagrams and instructional modeling judgments. S-T analysis features the ability to graphically represent instructional outcomes, allowing teachers to analyze and discuss the state of teaching and learning based on the visualized results. The results of the visualization generally include S-T graphs and Rt-Ch graphs, with Rt indicating the occupancy of T behaviors, i.e., the proportion of teacher behaviors in the instructional process, and Ch indicating the conversion rate of teacher-student behaviors. The results of the S-T analysis in the study were presented in the form of Rt-Ch diagrams.The general process of Rt-Ch diagramming is shown in Figure 4.

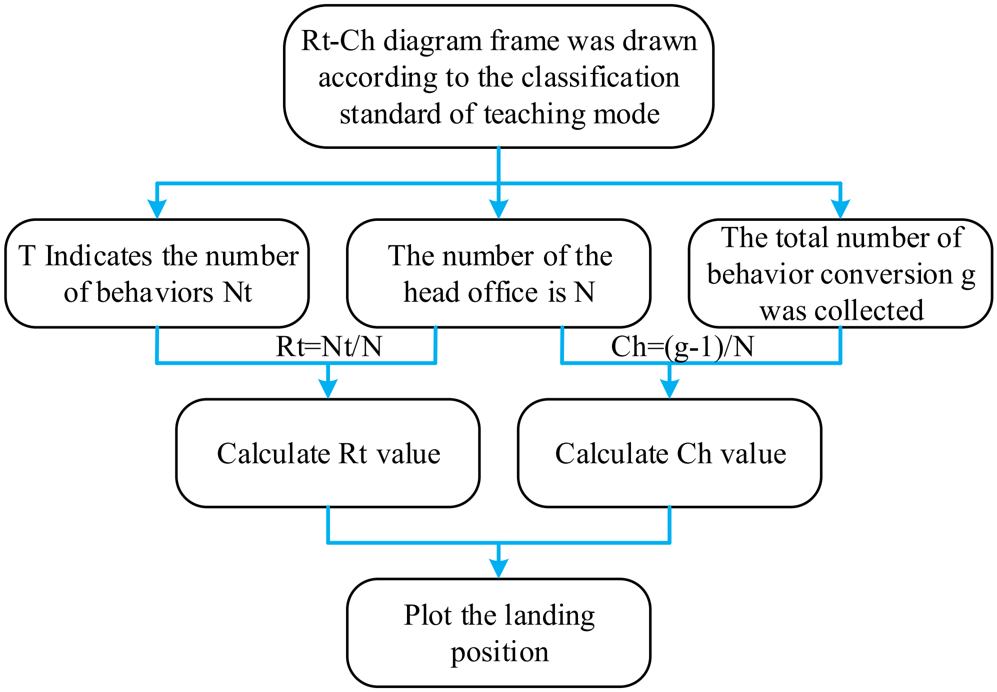


Fig. 4. Flowchart of Rt-Ch diagram drawing

The Rt-Ch diagram framework is plotted out according to the standard conditions of the teaching model classification. The Rt-Ch framework is shown in Fig. 5. Secondly, T behaviors are counted and the number of behavioral transitions g is calculated and the values of Rt and Ch are calculated according to the corresponding formulas, and a coordinate point (Rt, Ch) is obtained, and finally its coordinate point is plotted into the Rt-Ch diagram framework.

The standard conditions for the classification of teaching models are shown in Table 1.

Table 1. The standard conditions for the classification of teaching models

Teaching model	Rt-Ch Standard
Practice type	$Rt \leqslant 0.3$
Teaching type	$Rt \geqslant 0.7$
dialogical	$0.3<Rt<0.7$ and $Ch \geqslant 0.4$
Hybrid type	$0.3<Rt<0.7$ and $Ch<0.4$

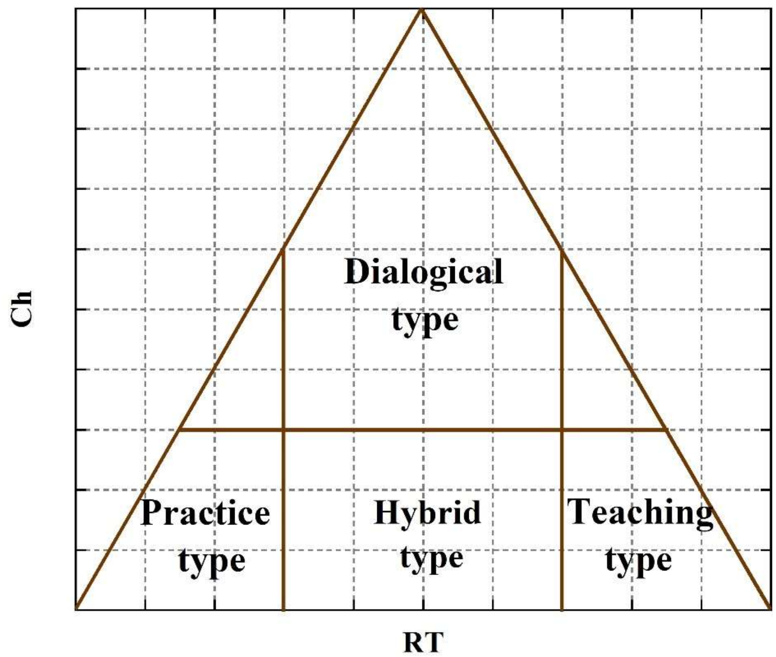


Fig. 5. Rt-Ch framework

2.2.5. Independent samples t-test and Levene's variance chi-square test:

1) Independent sample t test. In order to analyze the degree of difference between the sample data groups, the mean chi-square test as well as the variance chi-square test are often conducted. Different groups of people on the wood-plastic balcony flooring perceptual intention evaluation as a random variable, through statistical analysis to determine whether it complies with a certain probability distribution characteristics. Statistical theory generally believes that different subject objects to the same object object evaluation value of the error obeys the normal distribution, the same reasoning deduces that people on the same product samples of the perceptual intention to evaluate the degree of deviation from the evaluation score also obeys the normal distribution. If both random variables obey normal distribution with the same parameters under a certain confidence level, it can be shown that there is no significant difference between the two groups of objects in the selection.

In this paper, the independent samples t test is used to compare the degree of difference between the means of two independent groups. The principle of the test is as follows. Formulate the hypothesis: null hypothesis $H_0 : \mu = \mu_0$, alternative hypothesis $H_A : \mu \neq \mu_0$, take the level of significance a. Calculate the t statistic:

$$t = \frac{\overline{X} - \overline{Y}}{S_W \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \tag{20}$$

$$S_W = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}} \tag{21}$$

Where $\overline{X}, \overline{Y}$ is the mean of two independent samples, n_1, n_2 is the sample size of the two samples, and S_1^2, S_2^2 is the overall variance of the two samples.

Discriminative criteria: when $|t| \geq t_{a/2}(n_1 + n_2 - 1)$, then reject H_0 at the level of a, that is, the two samples are not equal to the mean; conversely, accept H_0 at the level of a, that is, the two samples are equal to the mean.

2) Levene variance chi-square test. In this paper, the Levene variance chi-square test is used to compare the degree of variance between multiple samples and is applicable to test the significance of

the degree of variance of the mean of multiple samples. The method essentially measures the degree of variation of the object by dividing the sum of squares of the variances of the sample data by the quotient of the degrees of freedom. The principle of the test is as follows. Formulate the hypothesis: null hypothesis $H_0:\sigma_1^2=\sigma_2^2$, alternative hypothesis $H_A:\sigma_1^2\neq\sigma_2^2$, take the level of significance α.

Calculate W statistic:

$$W=\frac{(n_1+n_2-2)\sum_{i=1}^{2}n_i(Z_{i^*}-Z_{**})^2}{\sum_{i-1}^{2}\sum_{j-1}^{n_i}(Z_{ij}-Z_{i^*})^2} \tag{22}$$

$$Z_{ij}=\left|Y_{ij}-\overline{Y}_{i^*}\right| \tag{23}$$

where n_1,n_2 is the number of samples in each of the two groups of samples, Z_{ij} is the value of the new variable resulting from the transformation of the original data, Z_{i^*} is the mean of the data in the ith sample; Z_{**} is the mean of the data in all the samples; Y_{ij} is the data in the ith sample, and $\overline{Y}_{i^*}$ is the arithmetic mean of the ith sample in the original data.

If the W values obey a F distribution with degrees of freedom 1, n_1+n_2-2, and $W\geq F(a,1,n_1+n_2-2)$, then H_0 is rejected at the α level, i.e., the variances of the two samples are considered unequal; conversely, H_0 is accepted at the a level, i.e., the variances of the two samples are considered equal.

3. Results and Discussion

3.1. Experiments on the application of the FIAS analysis system

According to the classification standard and operation method of FIAS analysis system, this study selects the art design class which adopts SPOC mode to carry out teaching reform as an example, video records the whole classroom teaching process of a certain chapter, and intercepts 45 minutes of it to make a complete observation record in accordance with the provisions of FIAS, and realizes the classroom analysis by using FIAS coding assistance software.

3.1.1. Data acquisition. Start the FIAS coding assistant software, in the data collection tab page, input the address of the teaching video and click “Load”, when the video loading is completed, click the video play button and the start recording button, and then according to the actual classroom situation, record the corresponding codes of the classroom teachers and students' languages every 3 seconds, each line represents 1 minute, column A represents 0-3 seconds per minute, column B represents 4-6 seconds per minute, and so on. Each row represents 1 minute, column A represents 0-3 seconds of each minute, column B represents 4-6 seconds of each minute, and so on. If it is not recorded in time, you can pause the video and make a judgment after careful consideration. When the video playback is finished and analyzed, click the Import Records button, which completes the data acquisition.

3.1.2. Statistics. Based on the data collection of 40-minute classroom teacher-student interaction behaviors, the FIAS coding assistance software makes two forms of data statistics, the instantaneous time line marker plot and the Flanders migration matrix. In the timeline marker plot, the numbers on the left side represent the category coding of classroom teacher and student verbal behaviors, while the numbers on the bottom represent the classroom instruction time in minutes, and each black cell represents the teacher or student verbal behavior that occurred during a particular minute of classroom instruction.

The time line labeling diagram is shown in Figure 6. In the time line marker plot, the numbers on the left represent the category coding of classroom teacher-student verbal behaviors, the numbers on the bottom represent the classroom teaching time in minutes, and each black cell represents a teacher or student verbal behavior that occurred during a particular minute of classroom teaching.

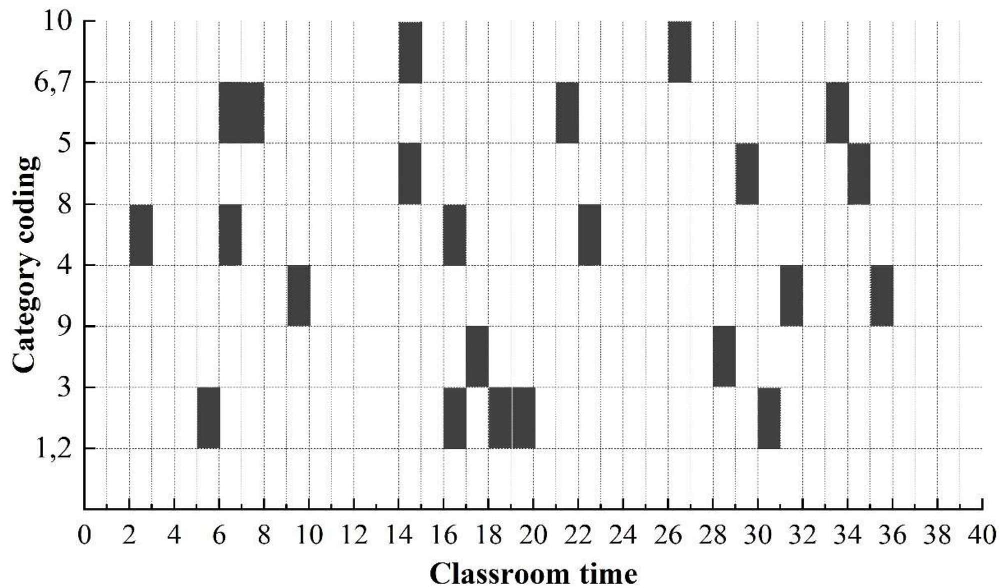


Fig. 6. Time line mark diagram

The Flanders migration matrix is shown in Table 2. Flanders migration matrix is a symmetric matrix entry, that is, all the codes recorded in the data collection, in accordance with each code and its two neighboring codes respectively, to form "ordinal pairs" to generate ordinal pairs of groups, for example, the classroom teachers and students of verbal behavior coded 8, 3, 2, 6, 1, 10, 5, 6. Then we can get (8, 3), (3, 2), (2, 6) (6, 1), (1, 10), (10, 5), (5, 6) sequential pairs of groups, each sequential pairs of numbers within the number represents the number of rows and columns, such as (6, 4) means that in the matrix of the sixth row of the fourth column counting 1, the sequential pairs of groups to complete the counting of the 10 categories of linguistic behavior constitutes the 10th-order Flanders Migration Matrix.

Table 2. Flanders Migration matrix

Categories	Categories1	Categories2	Categories3	Categories4	Categories5	Categories6	Categories7	Categories8	Categories9	Categories10	Total
Categories1	3	0	3	4	1	0	0	0	0	12	27
Categories2	0	3	3	5	0	0	1	0	9	18	41
Categories3	4	0	18	23	25	14	0	30	6	9	136
Categories4	1	0	10	16	34	55	0	47	18	13	202
Categories5	0	0	6	24	50	39	0	31	0	0	152
Categories6	0	0	0	8	45	46	0	66	30	0	201
Categories7	0	0	0	0	0	0	1	0	0	0	2
Categories8	1	2	3	13	6	0	0	76	21	9	139
Categories9	3	8	10	21	7	0	0	28	19	10	112
Categories10	0	2	3	6	2	2	0	11	3	16	50
Total	18	22	62	129	174	160	1	298	112	89	1071

3.1.3. Data analysis:

1) Timeline Marker Analysis. The timeline marker chart is a more visual record of the teacher's or student's verbal behavior that occurs in every minute of classroom teaching. From the timeline marker chart of this study, we can find that the filled part is evenly distributed. This indicates that the frequency and manner in which the teacher and students carry out interactions are more appropriate in this 40-minute classroom teaching.

2) Flanders Migration Matrix Analysis. Flanders migration matrix analysis is mainly from the size of the closed loop, rows and columns of intersecting cells, diagonal cells to observe three angles. Among them, the size closed loop refers to the small closed loop formed by the four cells 4-4, 4-8, 8-4, 8-8 and the large closed loop formed by the four cells 3-3, 3-9, 9-3, 9-9. The small closed-loop structure represents the extent of incremental questioning, i.e., a classroom in which student responses are triggered by teacher questions. The large closed-loop structure represents the extent of inquiry-based questioning, i.e., situations in which the teacher accepts or incorporates student input to guide student-initiated statements. From the Flanders migration matrix in this study, it is not difficult to find that the teacher's questioning in the classroom effectively stimulates students' thinking, and to a certain extent improves students' enthusiasm and initiative in participating in classroom teaching activities, but the teacher's effect in encouraging and guiding students to actively express their views and opinions is not obvious.

Table 3 shows the Flanders variable analysis table. We can see that the proportion of teacher's language is higher than the proportion of student's language, which indicates that the classroom is not democratic and open enough; the ratio of indirect influence and direct influence of teacher's language is higher than the norm but less than 1, which indicates that the teacher mostly adopts direct control in classroom teaching; the ratio of teacher's language's positive influence and negative influence on students is higher than the norm but less than 1, which indicates that the teacher pays attention to guiding and motivating in the classroom but the didactic language is still relatively more, and the guiding and motivating effect is less than 1. The ratio of positive and negative effects of teacher's language on students is higher than the norm but less than 1, indicating that teachers emphasize guidance and motivation in the classroom, but the didactic language is still relatively high, and the effect of guidance and motivation is not obvious.

Table 3. Flanders analysis

Variable	Analytical content	Normal mode	This value
TT	The ratio of teacher language in class	70	51.87
PT	The ratio of classroom high school language	25	39.76
SC	The ratio of quiet or chaos in the classroom	10	8.64
ITD	Teacher indirect influence and direct influence ratio	40	68.71
PTN	Teachers' positive influence and negative impact ratio	40	63.25
ATR	Student response ratio	30	37.43

3.2. Analysis of S-T Teaching Behavior

Although the classification of learning behaviors in this paper describes student behaviors, there is some correspondence between teacher behaviors and student behaviors in teaching interactions. Although it is not possible to specifically determine the exact teacher behavior based on student behavior, S-behavior and T-behavior can be roughly inferred. In the S-T teaching analysis method, teacher behaviors include the behaviors of the teacher through visual and auditory information transfer, visual behaviors such as board writing and demonstration, and auditory behaviors such as lecturing and questioning. In this paper, students' head-down reading and head-up listening behaviors can be inferred from teachers' board and lecture behaviors, students' hand-raising behaviors can be inferred from teachers' questioning behaviors, and students' teacher-directed behaviors can be inferred from teachers' demonstration behaviors. Student behavior, on the other hand, encompasses all behaviors other than teacher behavior, including student behaviors such as speaking, thinking, note-taking, completing assignments, silence, and disorganization. The five learning behaviors in this paper, writing with head down, answering while standing, turning head to look at others, abnormal state, and group discussion, are student behaviors. The S-T behaviors corresponding to the nine learning behaviors in this paper are shown in Table 4.

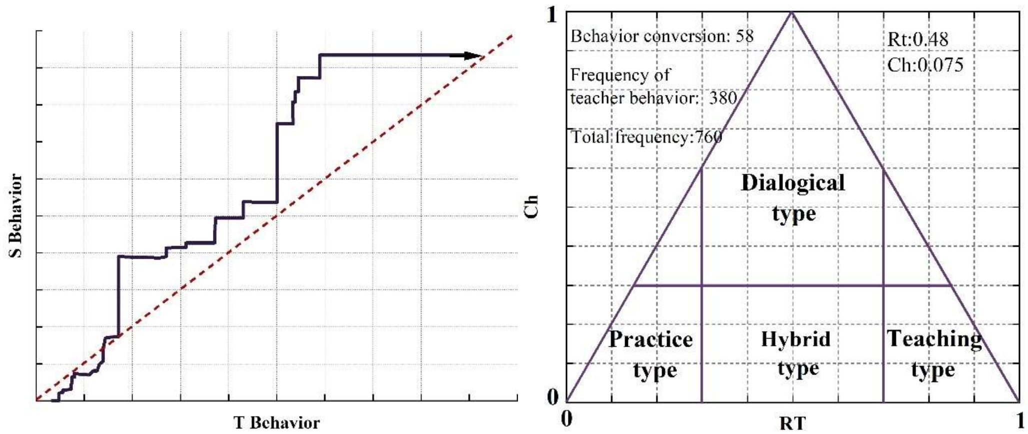
Table 4. S-t behavior classification

Dimension	Behavior classification	
	This article	S-T
S	Bend down	Students take notes
	Standing answer	Student speech
	Turn your head	Student disorder
	Abnormal behavior	Student disorder
	Panel discussion	Student speech
T	Look down	Teacher teaching
	Look up	Teacher's board
	Raise your hand	Teacher question
	Teacher guidance	Teacher demonstration

In this subsection, an art design course unit is selected for analysis, the video size is 1000 pixels × 1000 pixels, and one frame is extracted every three seconds, resulting in a total of 900 valid images. Since it is a behavioral detection of each student in the classroom, the students' behavioral actions are not consistent, some students are S-behavioral and some are T-behavioral at the same point in time. Therefore, this section follows the majority principle in the statistical analysis, i.e., according to the most behavioral categories of students at a given moment in time. For example, at the 15th second, 12 students looked down to read, 8 students looked down to write, and 4 students looked up to listen to the lesson, and the most behaviors of looking down to read at the 15th second, i.e., it is considered that the 15th second belongs to T behavior. The following rules were also followed in the statistical analysis and sorted according to the priority: ① T behavior when there is a raised hand; ② S behavior when there is a standing answer or group discussion; ③ Majority principle was followed when there is a head down writing, head down reading, head up listening, head turning to look at other people, abnormal behavior, and teacher-directed behavior.

Figure 7 shows the S-T behavioral curves with Rt-Ch results, where (a) is the behavioral curve plot and (b) is the Rt-Ch plot.

As can be seen from the S-T behavior graph, the percentage of teacher behaviors and student behaviors in the classroom are basically the same. There were more student behaviors such as standing up to answer and writing with head down in the first half of the classroom with an upward trend in the S-T curve, and there were more teacher behaviors such as raising hands to speak, reading with head down, and listening with head up in the second half of the classroom with a horizontal trend in the S-T curve. In this classroom, the number of behavioral transitions was 58, the number of teacher behaviors was 380, and the total number of teacher behaviors and student behaviors was 760, which statistically gave the classroom an Rt value of 0.48 and a Ch value of 0.075. Ch value less than 0.1 indicates that the number of S-T behavioral transitions is less in this class, i.e., less teacher-student interaction. According to the Rt-Ch value and the corresponding teaching mode table, the teaching mode of this classroom is a hybrid teaching mode.



(a) Behavior diagram (b) Rt-Ch diagram

Fig. 7. The S-T behavior diagram and the rt-Ch diagram

3.3. Analysis of teaching experiments

Two classes were selected as the experimental class and the control class in an art and design program of a school to carry out the teaching experiment. The experimental class adopts the model designed in this paper to assist teaching, and the control class teaches according to the original plan. The rest of the teaching conditions were the same for both classes. Before the beginning of the semester and after the end of the learning test exam, as a teaching experiment before and after the test.

3.3.1. Statistical analysis of data on students' reflective skills:

1) Statistical analysis of the pre-test data of the experimental and control classes. This section focuses on the statistical analysis of the overall data of the pre-test of the experimental and control classes and the differences in the four dimensions of the students' ability to reflect before the teaching experiment: habitual action, art design understanding, art design reflection, and critical reflection. The overall statistical results are shown in Table 5. The measurements of the four dimensions are shown in Table 6. It can be seen that there is no significant difference in the ability to reflect on art and design studies between the two classes before the beginning of the semester, which is suitable for the next step of the experiment.

Table 5. Test data analysis of experimental class and comparison class

		Levin variance equivalence test		Average equivalent t test			
		F	Sig.	t	df	Sig.(Double)	Mean difference
Grade	Assumed equal variance	0.481	0.028	0.568	100	0.581	0.882
	Unassuming equal variance			0.568	66.183	0.581	0.882

Table 6. Analysis of dimension data of laboratory class and comparison class

		Levin variance equivalence test		Average equivalent t test			
		F	Sig.	t	df	Sig.(Double)	Mean difference
Habitual action	Assumed equal variance	0.758	0.016	0.482	100	0.625	0.268
	Unassuming equal variance			0.516	98.551	0.626	0.266
Understand	Assumed equal variance	0.064	0.037	0.005	100	0.988	0.004
	Unassuming equal variance			0	99.548	0.988	-0.013
Reflection	Assumed equal variance	0.049	0.026	0.29	100	0.792	0.129
	Unassuming equal variance			0.287	94.332	0.793	0.159
Critical reflection	Assumed equal variance	1.037	0.035	3.606	100	0.711	1.557
	Unassuming equal variance			3.588	97.953	0.713	1.549

2) Statistical analysis of the posttest data of the experimental and control classes. This section focuses on the statistical analysis of the overall data of the posttest of the experimental and control classes and the differences in the four dimensions of students' ability to reflect after the teaching experiment: habitual action, comprehension, reflection, and critical reflection. Table 7 shows the overall statistical results of the posttest. Table 8 shows the measurement data of the four dimensions of the posttest.

In the posttest data of the experimental and control classes, the significance value of the variance equivalence test was 0.019 < 0.05, indicating that the variance was not uniform, not assuming that the results of the one-line t-test corresponding to equal variance were correct, and the sig value was 0.024 > 0.05, indicating that the differences in the two classes' ability to reflect after conducting the teaching experiments were significant; in the posttest data of the experimental and control classes in each dimension, the variance equivalence The significance values of the test are <0.05, indicating that the variance is not homogeneous, and it is not assumed that the results of the one-line t-test corresponding to the equal variance are correct, and the sig values of the four dimensions are, in order, 0.019>0.05, 0.015>0.05, 0.001>0.05, and 0.039>0.05, which indicates that the two classes show significant differences in the four dimensions of reflective ability after the teaching experiment Difference.

Table 7. Test data analysis of experimental class and comparison class

		Levin variance equivalence test		Average equivalent t test			
		F	Sig.	t	df	Sig.(Double)	Mean difference
Grade	Assumed equal variance	5.937	0.019	6.617	100	0.024	8.846
	Unassuming equal variance			6.642	97.854	0.024	8.846

Table 8. Analysis of dimension data of laboratory class and comparison class

		Levin variance equivalence test		Average equivalent t test			
		F	Sig.	t	df	Sig.(Double)	Mean difference
Habitual action	Assumed equal variance	5.637	0.024	6.244	100	0.018	2.785
	Unassuming equal variance			6.285	96.746	0.019	2.781
Understand	Assumed equal variance	5.316	0.028	6.917	100	0.015	3.51
	Unassuming equal variance			6.949	98.105	0.015	3.505
Reflection	Assumed equal variance	5.862	0.019	9.811	100	0.001	4.236
	Unassuming equal variance			9.896	99.437	0.001	4.232
Critical reflection	Assumed equal variance	4.279	0.043	6.172	100	0.039	2.26
	Unassuming equal variance			6.163	95.081	0.039	2.266

3) This section focuses on the statistical analysis of the overall data of the post-test of the experimental class and the differences in the four dimensions of students' ability to reflect after the teaching experiment: habitual action, understanding, reflection, and critical reflection. Table 9 shows the overall statistical results before and after the experimental class. Table 10 shows the measurement data of the four dimensions before and after the experimental class.

In the pre- and post-test data of the experimental class, the significance value of the variance equivalence test is 0.552>0.05, indicating that the variance is chi-square, assuming that the results of the one-line t-test corresponding to equal variance are correct, and the sig value is 0.028>0.05, indicating that the variability of the experimental class's ability to reflect is significant after a teaching experiment; in the pre- and post-test data of the experimental class in each of the dimensions of the pre- and post-tests, the significance value of the variance equivalence test is all>(0.05), indicating that variance is chi-square. 0.05, indicating variance chi-square, assuming that the results of the one-line t-test corresponding to equal variance are correct, and the sig values of the four dimensions are 0.022>0.05, 0.017>0.05, 0.021>0.05, 0.034>0.05 in order, indicating that the experimental class presents significant differences in the four dimensions of reflective ability after the teaching experiment.

Table 9. Test data analysis of experimental class and comparison class

		Levin variance equivalence test		Average equivalent t test			
		F	Sig.	t	df	Sig.(Double)	Mean difference
Total	Assumed equal variance	5.375	0.552	-11.108	100	0.028	-14.897
	Unassuming equal variance			-11.108	97.35	0.028	-14.897

Table 10. Analysis of dimension data of laboratory class and comparison class

		Levin variance equivalence test		Average equivalent t test			
		F	Sig.	t	df	Sig.(Double)	Mean difference
Habitual action	Assumed equal variance	6.879	0.367	-6.644	100	0.022	-3.32
	Unassuming equal variance			-6.63	97.134	0.022	-3.303
Understand	Assumed equal variance	5.483	0.483	-9.956	100	0.017	-5.233
	Unassuming equal variance			-9.962	98.6	0.017	-5.228
Reflection	Assumed equal variance	7.842	0.536	-10.11	100	0.021	-4.38
	Unassuming equal variance			-10.095	96.701	0.021	-4.392
Critical reflection	Assumed equal variance	4.556	0.568	-5.807	100	0.034	-3.018
	Unassuming equal variance			-5.814	96.448	0.034	-3.015

Reflective journals written by students were collected at the end of each week's teaching experiment, which ran for seven weeks, so with the addition of one before the start, there were a total of eight reflective journals submitted on by all students.

Figure 8 shows the trend of the number of people reaching different levels of reflection each week. After seven weeks of innovative teaching practice in art and design, all students became critical reflectors, and it can also be seen on the line graph that the number of both non-reflectors and reflectors showed a decreasing trend as the teaching practice progressed, and the number of critical reflectors showed an increasing trend as the teaching practice process progressed. The overall picture suggests that the vast majority of students have transformed from non-reflectors and reflectors to art and design critical reflectors as a result of their persistence in keeping a reflective journal over these seven weeks.

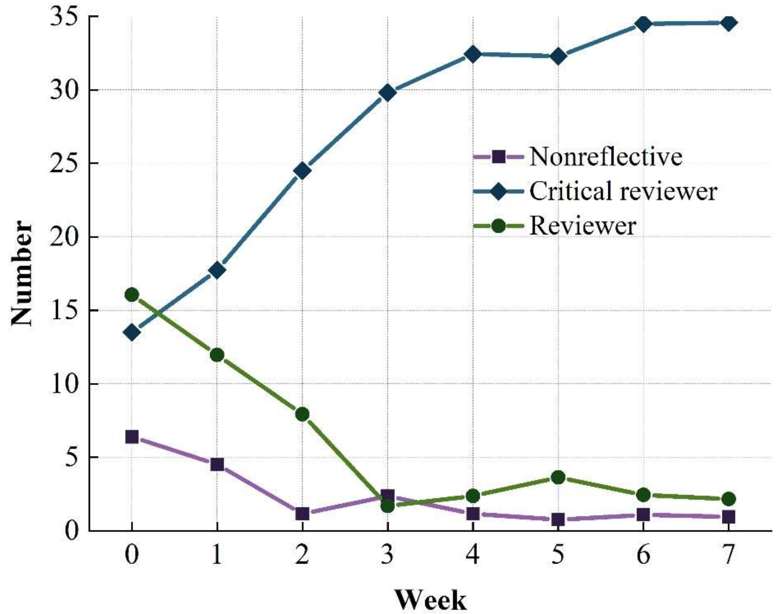


Fig. 8. Different levels of reflective levels per week

Figure 9 shows the trend in the number of people achieving each reflection dimension for each week. The number of achievers for the six dimensions of reflective level showed an overall upward trend, although the focus of the reflective dimensions varied across students at different times of the year. In the last two weeks, the number of students achieved the highest number of "association", "integration" and "reflective results", indicating that students can basically get the final reflection results after seven weeks of teaching practice.

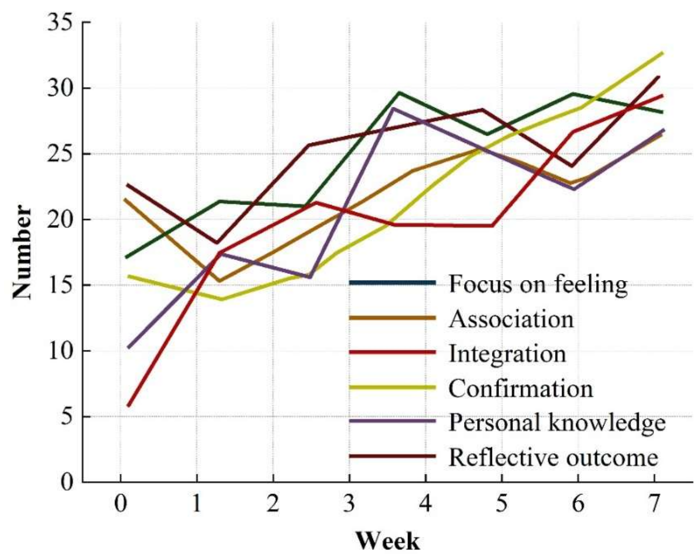


Fig. 9. The change of number of people in the reflection dimension of each week

3.3.2. Statistical analysis of academic performance. Before the beginning of the teaching experiment, the students of the two classes were tested, using the same set of test questions for both classes, which were divided into single-choice questions and fill-in-the-blank questions with a total of one hundred points, and at the end of the teaching experiment, the test papers were distributed again to the students of the experimental class and the control class, and the two classes were tested using the same set of test questions for both classes, which were divided into single-choice questions and fill-in-the-blank questions with a total of two types of questions with a total of one hundred points, and the distribution of the marks was the same as in the pre-tested questionnaire, in order to To ensure the validity of the test.

1) Statistical analysis of the pre-test data of the experimental and control classes. This part mainly analyzes the pre-test scores of the experimental class and the control class. Table 11 shows the pre-test scores of the experimental and control classes. Table 12 shows the independent samples t-test of the pre-test of the experimental and control classes.

In the pre-test scores of the experimental and control classes, the mean values of the students' scores are 74.18 and 74.66, and the difference between the mean scores of the two classes is extremely small, which can indicate that the difference between the overall scores of the two classes is relatively small before the teaching experiment. The sig value is 0.716>0.05, which indicates that the difference between the two classes' ability to reflect before the experiment starts is not significant.

Table 11. Test grade and comparison grade

	Class	N	Mean	SD	SEM
Pretest	Laboratory class	50	74.18	5.273	1.385
	Cross-reference class	50	74.66	5.606	1.647

Table 12. Test grade and comparison grade Independent sample t test

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Levin variance equivalence test</td><td colspan="4">Average equivalent t test</td></tr>
<tr><td>F</td><td>Sig.</td><td>t</td><td>df</td><td>Sig.(Double)</td><td>Mean difference</td></tr>
<tr><td rowspan="2">Pretest</td><td>Assumed equal variance</td><td>1.675</td><td>0.219</td><td>0.383</td><td>100</td><td>0.716</td><td>0.786</td></tr>
<tr><td>Unassuming equal variance</td><td></td><td></td><td>0.383</td><td>98.257</td><td>0.716</td><td>0.786</td></tr>
</table>

2) Statistical Analysis of Post-test Data of Experimental and Control Classes. This section focuses on the statistical analysis of the post-test scores of the experimental and control classes. Table 13 shows the posttest scores of the experimental and control classes. Table 14 shows the independent samples t-test of the post-test of the experimental and control classes.

In the post-test scores of the experimental and control classes, the mean values of the students' scores are 84.37 and 75.29, and the mean scores of the two classes have opened up a certain distance, which can show that the overall achievement difference between the two classes is relatively large after the teaching experiment; the significance value of the test of variance equivalence is 0.042 < 0.05, which indicates that the variance is not uniform, and it does not presume that the results of the one-line T-test corresponding to the equivariant variance are correct, the The sig value of 0.011 < 0.05 indicates that the difference in reflective ability between the two classes after the teaching experiment is significant.

Table 13. Test results for the experimental class and the comparison class

	Class	N	Mean	SD	SEM
Posttest	Laboratory class	50	84.37	6.64	1.235
	Cross-reference class	50	75.29	8.13	1.576

Table 14. After the test of the independent sample t test

		Levin variance equivalence test		Average equivalent t test			
		F	Sig.	t	df	Sig.(Double)	Mean difference
Posttest	Assumed equal variance	4.116	0.042	2.573	100	0.014	5.028
	Unassuming equal variance			2.589	98.34	0.011	5.028

3) Statistical Analysis of Pre- and Post-test Data of Experimental Classes. This part mainly focuses on the statistical analysis of the experimental class pre and post-test scores. Table 15 shows the pre- and post-test scores of the experimental class. Table 16 shows the independent samples t-test of the pre- and post-test of the experimental class.

In the pre- and post-test scores of the experimental class, the average values of the students' scores are 74.18 and 84.37, and the difference of the average scores is larger than that of the control class, which can show that the overall scores of the experimental class are on an upward trend after the teaching experiment; after the one-sample t-test on the pre- and post-test scores of the experimental class, the sig value of the pre- and post-test scores is 0.000<0.05, which indicates that there are significant differences in scores of the experimental class after and before the teaching experiment, i.e., using this paper to analyze the results of the experimental class. There is a significant difference, that is, using the model teaching in this paper can improve students' academic performance.

Table 15. Test results before and after the experimental class

	Class	Mean	SD	SEM
Pretest	Laboratory class	74.18	7.158	1.237
Posttest	Cross-reference class	84.37	7.391	1.246

Table 16. Sample t test of test in and out of experimental class

Average equivalent t test					
t	df	Sig.(Double)	Mean difference	95% confidence interval	
				Down	Up
Pretest	-14.385	0	-20.074	-22.33	-17.36
Posttest	-11.264	0	-14.159	-16.15	-11.89

4. Conclusion

This paper develops a VR-based interaction analysis system for art and design classroom teaching. A FIAS application experiment was conducted, and it was found that the proportion of teacher behaviors and student behaviors in the classroom was basically the same in the selected sample videos of teaching practice. The number of classroom behavior transitions in practice was 58, with a classroom Rt value of 0.48 and a Ch value of 0.075. A Ch value of less than 0.1 indicates that there were fewer S-T behavioral transitions in this lesson, i.e., less teacher-student interaction. According to the Rt-Ch value and the corresponding teaching mode table, the teaching mode of the classroom is a hybrid teaching mode. Two classes were selected as an experimental class and a control class in an art and design program in a school to carry out a teaching experiment. Comparing the art design academic reflective ability and academic performance of the two classes, it was found that in the post-test data of the experimental and control classes, the average art design academic performance of the experimental class of 84.37 points was 9.08 points higher than that of the control class, and the difference between the two classes in terms of art design reflective ability was significant after carrying out the teaching experiment.

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References

[1] Han, I., & Patterson, T. (2020). Teacher learning through technology-enhanced curriculum design using virtual reality. Teachers College Record, 122(7), 1-34.

[2] Hamurcu, A., Timur, Ş., & Rızvanoğlu, K. (2020). An overview of virtual reality within industrial design education. Journal of Engineering, Design and Technology, 18(6), 1889-1905.

[3] Liu, X., & Pan, H. (2022). The path of film and television animation creation using virtual reality technology under the artificial intelligence. Scientific Programming, 2022(1), 1712929.

[4] Lou, M. (2017). A Virtual Reality Teaching System for Graphic Design Course. International Journal of Emerging Technologies in Learning, 12(9).

[5] Philippe, S., Souchet, A. D., Lameras, P., Petridis, P., Caporal, J., Coldeboeuf, G., & Duzan, H. (2020). Multimodal teaching, learning and training in virtual reality: a review and case study. Virtual Reality & Intelligent Hardware, 2(5), 421-442.

[6] Jin, H., & Yang, J. (2021). Using computer-aided design software in teaching environmental art design. Computer-Aided Design and Applications, 19(S1), 173-183.

[7] Zhang, B., & Rui, Z. (2021). Application analysis of computer graphics and image aided design in art design teaching. Computer-Aided Design and Applications, 18, 13-24.

[8] Liu, F., & Yang, K. (2021). Exploration on the teaching mode of contemporary art computer aided design centered on creativity. Computer-Aided Design and Applications, 19(S1), 105-116.

[9] Gong, Y. (2021). Application of virtual reality teaching method and artificial intelligence technology in digital media art creation. Ecological Informatics, 63, 101304.

[10] Qian, J. (2022). Research on artificial intelligence technology of virtual reality teaching method in digital media art creation. Journal of Internet Technology, 23(1), 125-132.

[11] He, C., & Sun, B. (2021). Application of artificial intelligence technology in computer aided art teaching. Computer-Aided Design and Applications, 18(S4), 118-129.

[12] Du, S. (2021, April). Application analysis of virtual reality VR technology in art design teaching. In Journal of Physics: Conference Series (Vol. 1881, No. 2, p. 022056). IOP Publishing.

[13] Feng, C. (2021). An intelligent virtual reality technology in the teaching of art creation and design in colleges and universities. Journal of intelligent & fuzzy systems, 40(2), 3699-3710.

[14] Ruan, Y. (2022). Application of immersive virtual reality interactive technology in art design teaching. Computational intelligence and neuroscience, 2022(1), 5987191.

[15] Karina Aylin Gotthardt,Katrin Rakoczy,Miles Tallon,Matthias Seitz & Ulrich Frick. (2025). Can Virtual Art Touch Your Heart?—The Impact of Virtual Reality Art on Affect Considering Individual Characteristics and Aesthetic Experiences. Empirical Studies of the Arts(1),319-354.

[16] Liu Huifang & Gillies Robyn M.. (2021). Teacher Questions: Mediated-Learning Behaviors Involved in Teacher-Student Interaction During Whole-Class Instruction in Chinese English Classrooms. Frontiers in Education

[17] Valentin Stangaciu & Cristina Stangaciu. (2024). BERLib: A Basic Encoding Rules implementation. Software Impacts100677-100677.