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Comparative analysis of traditional and interactive teaching methods

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Abstract: In the face of current problems in educational practice, such as insufficient student participation in class, low efficiency in knowledge internalization, and limited development of higher-order thinking skills, this study first constructed a three-dimensional evaluation framework. Subsequently, a structured classroom observation scale was designed, along with a cognitive load scale and a delayed post-test. Finally, a standardized test was combined with an open-ended problem-solving task. The experimental results indicated that the interactive teaching method significantly improved class participation. Specifically, the frequency of questions asked in the interactive class was 2.4 times higher than in the traditional class ($p < 0.001$). The cognitive load experiment revealed that the average cognitive load during the 12th class was 53.85±3.32. Regarding knowledge transfer ability, scores for basic transfer tasks and advanced transfer tasks in the interactive teaching class were 20.49±3.67 and 20.72±7.19, respectively. These findings demonstrate that the interactive teaching method effectively promotes students' internalization and transfer of knowledge by increasing classroom interaction and reducing cognitive load, particularly in fostering higher-order thinking skills.

Keywords: *Classroom participation, Cognitive load, Educational teaching methods, Interactive teaching, Knowledge transfer ability.*

1. Introduction

In current educational practice, traditional teaching methods face problems such as insufficient student participation in class, low efficiency of knowledge internalization, and limited cultivation of higher-order thinking ability. These problems affect the overall improvement of teaching effectiveness, especially in the cultivation of knowledge transfer and critical thinking ability. With the continuous development of educational models, interactive teaching, as a new teaching method, has gradually attracted the attention of academics and educational practitioners. Interactive teaching can effectively improve classroom learning effects, reduce students' cognitive load, and improve long-term memory and transfer ability of knowledge by enhancing teacher-student interaction and stimulating students' active participation. Therefore, studying the comparison between traditional teaching and interactive teaching has theoretical value and important practical significance.

This paper compares traditional teaching methods and interactive teaching methods, and explores the differences between them in terms of classroom participation, cognitive load, and knowledge transfer ability. The paper constructs a three-dimensional evaluation framework to comprehensively measure teaching effectiveness, breaking the limitation of single performance evaluation. It adopts a multi-source data fusion analysis strategy, combined with classroom observation, cognitive load scale, delayed post-test and other methods to comprehensively evaluate teaching effectiveness. Research shows that interactive teaching has obvious advantages in improving students' classroom participation, reducing cognitive load and promoting knowledge transfer.

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The paper is divided into six parts. The first part is the introduction, which introduces the research background, purpose and significance. The second part is a literature review, which outlines the current research status of traditional teaching and interactive teaching in the world. The third part introduces theoretical foundations such as constructivism and cognitive load, as well as their application implications. The fifth part is the research method, which describes the evaluation framework, data collection and analysis methods in detail. The fourth part is the experimental results and discussion, which presents the experimental data and analyzes the difference in the effects of the two teaching methods. The last part is the conclusion, which summarizes the main findings of the study and proposes directions for further research.

2. Related Works

In recent years, scholars have proposed a variety of teaching models to address the shortcomings of traditional teaching. Active learning, defined as a variety of teaching methods that promote learner self-evaluation and personalized learning, is becoming a new educational standard. Schiel and Everard [1] aimed to evaluate how family medicine clerkship directors apply it in clerkship courses [1]. Teaching methods play an important role in the formation of educational systems. Maftunabonu [2] compared traditional and modern teaching methods and analyzed their effects on classroom dynamics, student engagement, and educational outcomes [2]. Hu pointed out that traditional classrooms have defects such as single teaching, being out of touch with reality, neglecting skill development and student participation, and are no longer able to meet learning needs. He suggested that classrooms adopt cooperative learning and use multimedia technology to improve teaching effectiveness [3]. Previous studies have focused on problem-based learning or flipped classrooms in different majors, but there are few related joint teaching methods in clinical medicine. Therefore, Wang, et al. [4] explored its impact on student ability in ocular trauma teaching [4]. Active methods are superior to traditional lectures in improving learning outcomes, but their promotion in large classes is limited. Bozzi, et al. [5] aim to promote their application innovation in large classes by integrating peer learning, technology and traditional lectures in a hybrid teaching method [5]. The COVID-19 lockdown has changed education, forcing teachers who are accustomed to face-to-face teaching to quickly switch to remote teaching. Finazzi [6] explored the impact of pre-epidemic online learning experience on this transition Finazzi [6]. Li, et al. [7] aim to compare the teaching effects of case-based learning combined with Rain classroom and traditional lectures in the undergraduate full-mouth denture restoration clinical course, and achieved good results in theory and practice Li, et al. [7]. Eli [8] investigated the views of English major students at the University of Nouakchott in Mauritania on innovative interactive teaching methods, focusing on their application in local higher education, enriching the relevant literature [8]. However, current research mostly focuses on individual interactive technologies or local teaching links, lacks systematic comparative analysis, and is difficult to comprehensively evaluate the comprehensive advantages and disadvantages of interactive teaching compared to traditional teaching.

Existing literature shows that interactive teaching methods have obvious advantages in stimulating students' initiative and improving learning outcomes. For example, Bilyk and Bardadym [9] aimed to illustrate the development of innovative, non-standard and critical thinking teaching methods in modern schools, with a particular focus on interactive learning, and made important contributions in this field Bilyk and Bardadym [9]. Tuma [10] discussed and evaluated the application of various educational technologies in medical education, focusing on interactive learning in lectures, and pointed out that although it is challenging to promote interaction in large classes, technological advances have provided effective assistance in promoting communication [10]. However, these studies also pointed out that interactive teaching faces challenges such as insufficient teacher training and complex classroom management during implementation. In response to these problems, this paper can use a mixed research method, combining quantitative data with qualitative interviews, to deeply analyze the applicability and room for improvement of interactive teaching methods.

3. Theoretical Basis

3.1. Constructivist Learning Theory and Teaching Paradigm Transformation

Constructivist theory, centered around Piaget's theory of cognitive development, advocates that knowledge is not an objective entity passively received, but rather the result of active construction by learners through interaction with the environment. This theory emphasizes the mechanisms of "cognitive conflict" and "balancing" - when new information conflicts with existing cognitive structures, learners reconstruct their cognitive structures through "assimilation" (incorporating new information into existing schemas) or "adaptation" (adjusting schemas to adapt to new information). Vygotsky's sociocultural theory further proposes the concept of the Zone of Proximal Development (ZPD), which suggests that the gap between a learner's potential level of development and their current level can be bridged through "social interaction scaffolds" such as teacher guidance and peer collaboration [11-13].

In traditional teaching, teachers, as knowledge authorities, dominate the transmission of information, while students are in a passive receiving position, making it difficult to form an active cognitive process. Interactive teaching transforms the classroom into a "cognitive community" through activities such as problem solving and group discussions. Teachers use open-ended questions (such as "Why does the law of inertia contradict daily experience") to trigger cognitive conflicts, and students verify hypotheses through collaborative debates, ultimately reaching consensus through interaction. This model directly echoes the core proposition of constructivism that "knowledge construction needs to be mediated through social interaction". For example, in science education, "inquiry based learning" allows students to construct scientific concepts through interactive activities such as experimental design and outcome reporting, which confirms the practical value of constructivist theory [14, 15].

3.2. Teaching Psychological Mechanism of Cognitive Load Theory

The cognitive load theory (CLT) was proposed by Sweller [16] and its core assumption is that the capacity limitation of human working memory (7 ± 2 chunks) directly affects the efficiency of knowledge internalization. This theory divides cognitive load into three categories: intrinsic load (determined by the complexity of learning materials), extrinsic load (caused by teaching presentation), and associative load (cognitive resources used to facilitate schema construction). The key to efficient teaching lies in reducing external load through instructional design, releasing cognitive resources to enhance relational load [17-19].

In traditional teaching, one-way teaching by teachers can easily lead to "cognitive overload": intensive information input (such as continuously playing PPTs) exceeds students' working memory capacity, external load surges, and students lack time and strategies for information processing. Interactive teaching optimizes cognitive load through two mechanisms:

(1) Task chunking and interactive processing: Breaking down complex knowledge chains into actionable subtasks, such as using the method of "teacher deducing the first half and students collaborating to complete the second half" in mathematical formula teaching to reduce internal load [20, 21];

(2) Cognitive unloading and social sharing: In group discussions, students externalize their thinking processes through oral expression, dispersing some cognitive tasks into the group (such as division of labor recording and verification), reducing individual working memory burden. The cognitive load theory provides a theoretical explanation for interactive teaching to reduce psychological burden and improve learning efficiency. Its core logic is that interaction optimizes the allocation of cognitive resources, allowing learners to invest more energy in knowledge construction rather than information storage [22-24].

3.3. Social Interaction Theory and the Dynamics of Classroom Participation

The theory of social interaction originates from Herbert Blumer's Symbolic Interactivism and Lave&Wenger's Situational Learning Theory, and its core viewpoint is that "learning is essentially a participatory process of social and cultural practice". This theory regards the classroom as a dynamic interactive system, where language and nonverbal interactions between teachers and students, as well as between students, form the situational carrier of learning. Wenger's concept of "community of practice" points out that the meaning of knowledge is generated through interaction, and learners gradually integrate into professional practice through "legitimate marginal participation".

The interactive mode of traditional teaching presents the characteristic of "one-way radiation": teachers act as the central source to output information, while students receive it on an individual basis, with low frequency and single form of interaction (such as "teacher questions individual student answers"). And interactive teaching reconstructs the interactive network through structured design (such as the "Think Pair Share" strategy):

(1) Diversified interactive subjects: shifting from a one-way chain of "teacher → student" to a multilateral network of "teacher student peer", such as students playing the roles of both speakers and evaluators during group presentations;

(2) Deepening interactive content: shifting from factual Q&A (such as "the graphical features of quadratic functions") to critical dialogue (such as "how to use functional models to explain population growth trends"), promoting cognitive leap from memory level to higher-order thinking. The social interaction theory reveals the essence of activating classroom participation through interactive teaching - by constructing equal interactive relationships and diverse participation opportunities, learning is transformed from individual cognitive activities into a process of collective meaning construction.

3.4. Logical Basis for Theoretical Integration and Teaching Evaluation Framework

The above theories together constitute the logical support of the teaching evaluation framework:

(1) Constructivism provides a theoretical basis for evaluating "knowledge transfer ability" - interactive teaching promotes students to transform declarative knowledge into procedural knowledge through contextualized tasks (such as novel problems in higher-order transfer);

(2) The cognitive load theory explains the mechanism of the "teaching efficiency" dimension - interactive teaching optimizes the allocation of cognitive resources and shortens the time required for knowledge internalization;

(3) Social interaction theory lays the foundation for evaluating the depth of classroom participation - the improvement of interaction frequency and quality is essentially a reflection of the accumulation of social capital in the learning community.

The three form a closed-loop logic: interactive teaching activates the constructivist learning process through social interaction, while using cognitive load regulation to improve learning efficiency, ultimately demonstrating the development of higher-order thinking abilities in knowledge transfer. This theoretical integration not only explains the mechanism of differences in teaching methods, but also provides actionable principles for instructional design, such as designing interactive tasks based on the "zone of proximal development", controlling task complexity based on cognitive load theory, and constructing diverse participation models through social interaction theory.

The boundary of theoretical application and the enlightenment of teaching practice in 3.5

Although the above theories provide systematic support for interactive teaching, their application is still limited by the following situations:

(1) Differences in disciplinary characteristics: Humanities courses (such as literary appreciation) are more likely to achieve meaning construction through discussion based interaction, while abstract concepts in science and engineering (such as advanced mathematics) may require the use of concrete tools to reduce cognitive load;

(2) Class size constraint: Social interaction theory emphasizes "deep interaction among small groups", and in large class teaching, interactive forms may degenerate into simple Q&A, making it difficult to form a "community of practice";

(3) Transformation of teacher-student roles: Interactive teaching requires teachers to transform from "knowledge transmitters" to "interactive coordinators", which puts higher demands on teachers' classroom management and subject knowledge integration abilities.

Future research can combine embodied cognition theory to explore the impact of physical interaction (such as experimental manipulation and gesture expression) on knowledge construction, or introduce social network analysis tools to quantify the correlation between interactive network structure and learning outcomes, and promote the continuous improvement of theoretical frameworks.

4. Methods

4.1. Construction of a Three-Dimensional Teaching Evaluation Framework

In order to comprehensively evaluate the differences in teaching effectiveness between traditional teaching and interactive teaching, this study constructed a three-dimensional evaluation framework, aiming to break through the traditional single performance evaluation method and comprehensively measure the teaching quality and effectiveness. The specific framework is shown in Figure 1:

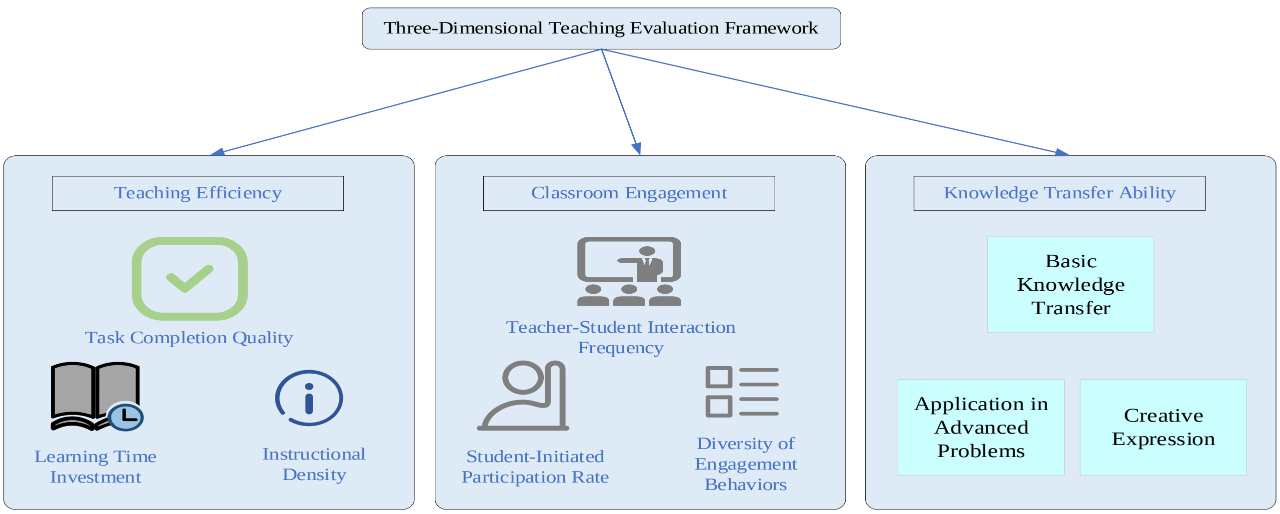

Figure 1.
Three-dimensional teaching evaluation framework.

This framework analyzes from three dimensions: teaching efficiency, classroom participation depth, and knowledge transfer ability to ensure the comprehensiveness and accuracy of the evaluation. First, teaching efficiency, as the primary dimension in the framework, mainly focuses on the relationship between the time required by students in the learning process and the learning outcomes achieved. This paper evaluates the teaching efficiency $E_{efficiency}$ of different teaching methods by measuring the time students spend on completing the same learning tasks and their progress in knowledge mastery, which can be expressed as formula (1):

$$E_{efficiency} = \frac{P_{progress}}{T_{learning}} (1)$$

Among them, $P_{progress}$ is the learning outcome and $T_{learning}$ is the learning time. This dimension helps this paper understand whether the teaching method effectively promotes students' knowledge internalization and mastery [11].

Secondly, the depth of classroom participation measures students' participation in the class, including their initiative, interaction frequency and classroom feedback. The interactive teaching method stimulates students' enthusiasm for participation by designing group discussions, teacher-student questions and answers, etc. Traditional teaching is often teacher-centered, and student participation is relatively limited. By observing and recording classroom behavior, this paper can quantify the degree of student participation and further analyze the impact of teaching methods on student classroom behavior.

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Finally, knowledge transfer ability is one of the key dimensions of this study, which assesses students' ability to apply learned knowledge to new situations. In order to accurately measure students' knowledge transfer ability, this paper designed two types of transfer tasks: basic transfer tasks and high-level transfer tasks. Basic transfer tasks require students to apply learning content to similar situations, while high-level transfer tasks examine whether students can flexibly apply knowledge to complex and novel situations. In this way, this paper can comprehensively evaluate whether students' learning outcomes can be transferred across situations.

4.2. Implementation of Multi-Source Data Collection Strategy

In order to ensure the comprehensiveness and accuracy of the teaching effect evaluation, this study adopted a multi-source data collection strategy, combining quantitative and qualitative data, and comprehensively analyzed traditional teaching and interactive teaching from multiple dimensions. Table 1 shows some key data collected during the experiment, including the frequency of classroom interaction and cognitive load of students under traditional and interactive teaching methods.

Table 1.
Frequency of classroom interaction and cognitive load of students under traditional and interactive teaching methods.

Student ID	Traditional Class Interaction (Frequency)	Interactive Class Interaction (Frequency)	Cognitive Load (Traditional Class)	Cognitive Load (Interactive Class)
1	15	30	70	52
2	12	28	72	53
3	16	35	68	50
4	18	32	71	51
5	14	29	74	54

First, structured classroom observation is one of the core parts of data collection. In order to quantify the frequency of classroom interaction, the type of interaction, and the quality of students' responses, the research team designed a classroom observation scale. By systematically observing and recording the interactions between teachers and students in the classroom (such as asking questions, answering, and discussing), as well as students' participation in the classroom (such as speaking up and participating in group activities), this paper can clearly understand the differences between interactive teaching methods and traditional teaching methods in stimulating student participation. Classroom observation provides data support for quantitative analysis and also provides valuable qualitative information for analyzing classroom atmosphere and students' emotional involvement.

Secondly, the cognitive load scale is a tool used to assess the psychological burden students bear during the learning process. This paper uses the NASA-TLX (Task Load Index) scale, which includes six dimensions: mental demand, time demand, effort, emotional burden, workload and performance. After completing each learning task, students self-evaluate according to the scale to assess the various types of load they feel during the learning process. Through this measurement, this paper can evaluate the cognitive load level of students under different teaching methods, and further analyze whether interactive teaching can effectively reduce students' learning burden and improve learning efficiency [12].

In order to examine students' long-term memory and application ability of the learning content, this study specifically introduced a delayed post-test. This test was scheduled one week after the end of the class and was designed to assess students' memory retention of knowledge points and whether they could flexibly apply what they learned to new problem situations. By comparing students' performance in the delayed post-test under different teaching methods, it can more effectively evaluate the effectiveness of these teaching methods in promoting knowledge internalization and long-term transfer.

4.3. Dynamic Grouping Control Design

In order to ensure the reliability and accuracy of the experimental results, this study adopted a dynamic grouping control method in the experimental design. The design aims to reasonably allocate students in the experimental group and the control group to ensure that the learning ability and basic conditions of the two groups are as consistent as possible at the beginning, thereby eliminating the influence of external interference factors and making the experimental results more convincing.

First, the pre-test scores are an important basis for grouping. In order to achieve dynamic grouping, each student needs to complete a basic test before the experiment begins. The test content covers the basic knowledge points related to the experimental task. The test score can be used as the standard for students to enter the group to ensure that there is no significant difference in knowledge between the traditional teaching group and the interactive teaching group. Assuming that the pre-test score of the experimental group students is $P_{pre,exp}$ and the pre-test score of the control group students is $P_{pre,control}$, the means of the two groups should be close, as shown in formula (2):

$$|P_{pre,exp} - P_{pre,control}| \leq \epsilon \quad (2)$$

Among them, ϵ is an allowable error atmosphere. In this way, this paper can control the students' initial learning level and avoid the influence of innate differences on the experimental results.

Next, based on the pre-test scores, all students were divided into two groups: the experimental group (interactive teaching class) and the control group (traditional teaching class). When grouping, it can ensure that the average scores of each group are close, and try to avoid a large gap in the academic level of the two groups of students. In addition, considering the differences in students' classroom performance and participation, this paper also takes appropriate randomization measures to ensure that students' opportunities for interaction in class can be fully distributed, and avoid students in the experimental group showing higher participation only due to personal characteristics or interests.

In addition to pre-test scores, individual differences among students are also important factors to be considered when grouping. For example, students' learning motivation, classroom participation, and cognitive style may affect their response to different teaching methods. Therefore, in the grouping process, this paper takes these factors into consideration to a certain extent, and tries to evenly distribute different types of students between the experimental group and the control group, so as to avoid the interference of certain individual differences on the results.

5. Results and Discussion

5.1. Classroom Interactive Behavior Observation Experiment

This experiment aims to compare the differences between traditional teaching methods and interactive teaching methods in terms of classroom behavior and student participation. By designing a three-dimensional evaluation framework (teaching efficiency, classroom participation depth, and knowledge transfer ability), combined with a multi-source data collection strategy, structured classroom observation, cognitive load scale, and delayed post-test were used to quantitatively record the classroom behavior distribution and student interaction intensity of the two teaching methods. In addition, the experiment also ensured the consistency of the experimental group and the control group at the baseline through dynamic grouping control and statistical analysis. The specific data is shown in Figure 2:

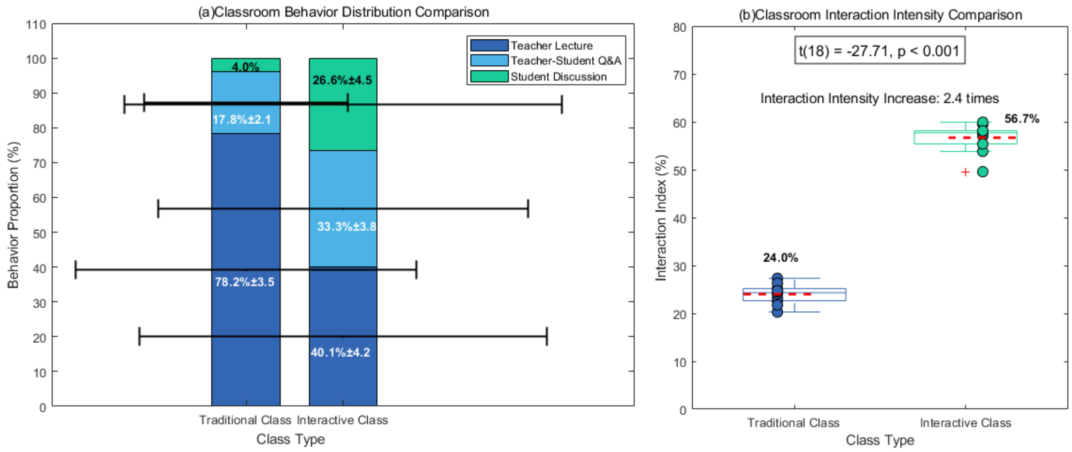

Figure 2.
Observation and evaluation of classroom interactive behavior.

Figure 2 (a-b) shows the comparison of classroom behavior distribution between traditional teaching class and interactive teaching class. The classroom interactive behavior observation experiment shows that in traditional teaching class, one-way explanation by teachers is dominant (24.00%±2.11%), while teacher-student question-and-answer and student-student discussion only account for 56.7%. In interactive teaching class, the three types of behaviors are evenly distributed (explanation 40.1%±4.2%, question-and-answer 33.3%±3.8%, discussion 26.6%±4.5%). Quantitative analysis shows that the interactive teaching class's interaction index (56.7%±3.07%) is significantly higher than that of the traditional teaching class (24.00%±2.11%), and the statistical test difference is extremely significant (t= -27.71, p<0.001). The data confirms that the interactive teaching method increases the intensity of classroom interaction to 2.4 times that of the traditional classroom through structured activity design, effectively solving the core problem of insufficient student participation.

5.2. Cognitive Load Comparison Experiment

This experiment aims to compare the effects of traditional teaching methods and interactive teaching methods on students' cognitive load. The NASA-TLX scale was used to evaluate the cognitive load levels of the two groups of students at different time points (4th, 8th, and 12th class). The experimental data came from 30 students, who were measured in traditional teaching classes and interactive teaching classes. The experiment focused on analyzing the changing trend of cognitive load under different teaching methods, especially focusing on the cumulative effect of class time on cognitive load, as shown in Figure 3.

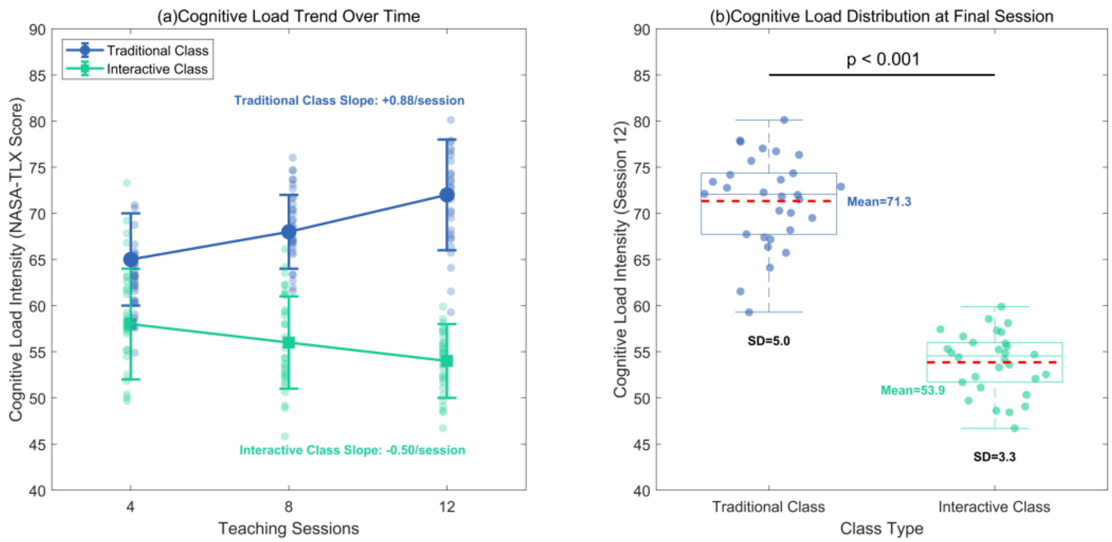

Figure 3.
Comparative evaluation of cognitive load.

Figure 3 (a-b) shows the comparison of cognitive load distribution of traditional teaching class and interactive teaching class at the last class. The experimental results show that the cognitive load of traditional teaching class gradually increases with the increase of class hours, especially in the 12th class, reaching an average score of 71.33±4.95. The cognitive load of interactive teaching class shows a downward trend, and the average cognitive load in the 12th class is 53.85±3.32. By comparing the error bar graph and the box plot, it can be clearly seen that the cognitive load of the interactive teaching class was lower than that of the traditional teaching class at each time point. Statistical analysis showed that there was a significant difference in cognitive load between the two groups at the last class. These results show that interactive teaching effectively reduced students' cognitive load and improved learning efficiency by increasing classroom interaction and structured activities.

5.3. Knowledge Transfer Ability Verification Experiment

This experiment aims to evaluate the effectiveness of traditional teaching methods and interactive teaching methods in knowledge transfer. In the experiment, students first completed the basic transfer task, and then the high-level transfer task, which required students to apply the knowledge they learned to new situations. The scoring criteria for each task included principle accuracy, logic and innovation, and different weights were assigned to each. By comparing the performance of students in these two types of transfer tasks under the two teaching methods, the experiment aims to analyze whether interactive teaching can effectively promote students' knowledge transfer ability, especially in the application of high-level tasks, as shown in Figure 4:

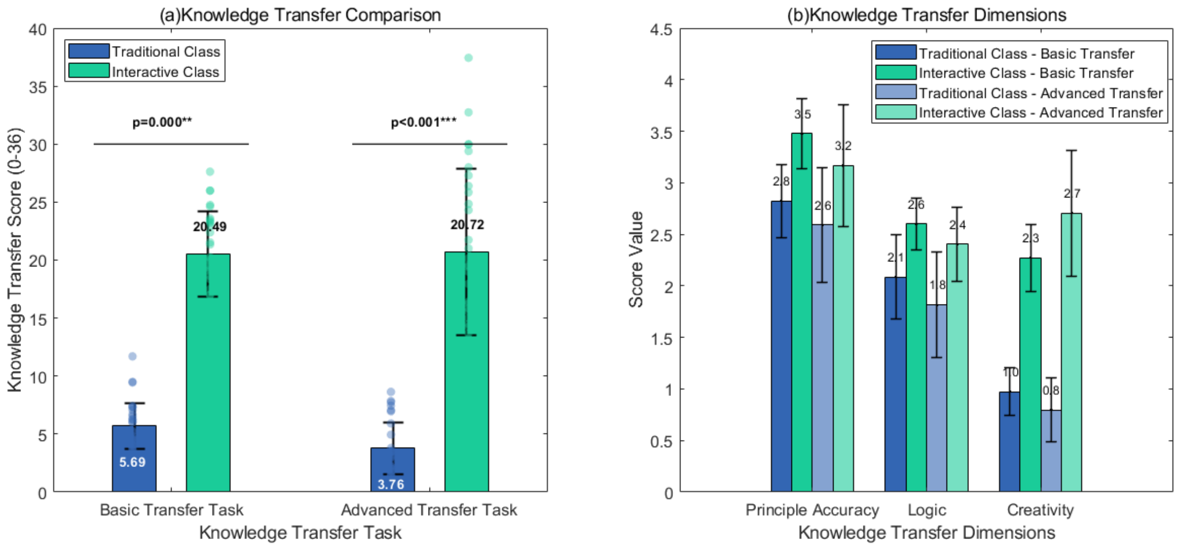

Figure 4.
Knowledge transfer ability verification evaluation.

The experimental results show that there are significant differences in the performance of traditional teaching classes and interactive teaching classes in knowledge transfer tasks. In the basic transfer task, the average score of the traditional teaching class was 5.69±1.99, while the interactive teaching class was 20.49±3.67, with a significant difference. In the high-level transfer task, the average score of the traditional teaching class was 3.76±2.23, and the interactive teaching class was 20.72±7.19, with an even more significant difference. These results show that interactive teaching significantly improves students' knowledge transfer ability, especially in high-level transfer tasks, where the scores of interactive teaching classes are significantly higher than those of traditional teaching classes. The interactive teaching class performs better in various tasks, especially in the application and innovation of knowledge.

6. Conclusions

This study compared and analyzed the effects of traditional teaching methods and interactive teaching methods, and found that interactive teaching has obvious advantages in improving classroom participation, reducing cognitive burden, and promoting knowledge transfer. The experimental results show that interactive teaching can more effectively mobilize students' enthusiasm, reduce their learning pressure, and students perform better in basic and high-level transfer tasks. This shows that interactive teaching not only helps to stimulate learning interest, but also provides support for the cultivation of high-level thinking ability. However, this study also has certain limitations, such as limited sample size and failure to explore in depth the differences in the applicability of interactive teaching in different disciplines. Future research can consider expanding the sample size, deeply analyzing the actual effects of interactive teaching in various subject backgrounds, and studying how to improve the design of interactive teaching to maximize its teaching effectiveness.

Transparency:

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

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