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Research on Teaching Design for Cultivating Middle School Students' Geometric Intuitive Ability Based on Virtual Reality Technology

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Abstract: *With the development of information technology, digital technology assisted teaching has become an important direction of teaching reform. To solve the difficulties in cultivating students' geometric intuition ability in traditional teaching, such as teachers' "cramming" and low student participation, this article, based on the guidance of TPACK theory, takes the three views of junior high school mathematics as an example and builds a teaching design framework of "problem orientation element analysis integrated design teaching implementation feedback evaluation". Students use virtual reality(VR) mathematical models,adopt group collaborative exploration forms,integrate interdisciplinary teaching concepts, improve the accuracy of mathematical models, construct a student-centered teaching environment, enhance students' spatial thinking and geometric intuition abilities, and promote the development of students' mathematical core literacy.*

Keywords: *virtual reality; Geometric intuition; TPACK; Junior high school mathematics*

1. Problem posing

The "Mathematics Curriculum Standards for Compulsory Education (2022 Edition)" emphasizes the "three skills" ability, which refers to the ability to observe, think, and express the world from a mathematical perspective. Among them, "geometric intuition" as a key manifestation of "mathematical vision" is a necessary basic literacy for junior high school students[1]. The new curriculum standard clearly states that cultivating students' geometric intuition ability is an important goal of mathematics teaching and a key way to enhance core mathematical literacy. During the internship, I found that middle school students often feel confused and lack thinking when facing complex mathematical problems. Even after being explained by the teacher, some students still find it difficult to truly master. This understanding is often short-lived, and when faced with similar problems, students are still helpless. At the same time, some teachers pay more attention to the cultivation of logical reasoning, application awareness, and innovation awareness in mathematics teaching, but often neglect the cultivation of geometric intuition literacy.

The author found through literature review and combined with internship experience that currently, middle school students face some challenges in cultivating geometric intuition ability[2]. For example, the teaching methods of middle school mathematics teachers are often traditional and lack diversity, mainly relying on the combination of chalk, blackboard, and PPT. When encountering complex or dynamic geometric shapes, traditional teaching methods are difficult to quickly and accurately draw and display, which not only increases the difficulty of students' understanding, but also occupies valuable classroom teaching time. In addition, many middle school mathematics classrooms are still teacher led, with low student participation and a lack of opportunities for hands-on operation. These deficiencies in classroom teaching undoubtedly hinder the development of students' intuitive imagination ability.

Based on the issue of cultivating middle school students' geometric intuition ability, it is imperative to change the educational methods and approaches. With the continuous development of information technology, virtual reality technology assisted teaching is considered an effective means of educational reform. In 2018, the Chinese Ministry of Education made a further understanding and interpretation of educational modernization, proposing the "Education Informatization 2.0 Action Plan", which requires promoting the deep integration of information technology and education, promoting the evolution of educational informatization towards innovative development, and enhancing the information literacy of teachers and students[3]. In July 2021, ten departments issued a notice on the "Action Plan for 5G

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Application 'Sailing' (2021-2023)", which explicitly mentioned "accelerating the research and development of 5G teaching terminal equipment and AR/VR teaching digital content, realizing scenario based interactive teaching, and creating immersive classrooms".

Virtual reality, as an emerging technology, can intuitively overlay virtual 3D graphics onto real scenes, providing students with an immersive experience[4]. Through this technology, students can immerse themselves in virtual interactive environments and apply relevant programs in real-time. When students are immersed in real situations, they are able to interpret real-time observations with greater flexibility, making complex mathematical knowledge concrete and vivid. This not only helps cultivate students' abilities in graphic perception, analysis, representation, and spatial imagination, but also helps them better understand abstract mathematical concepts, find problem-solving strategies, and enhance their geometric intuition skills.

In addition, teaching software developed based on virtual reality technology can greatly promote learners' learning enthusiasm. By providing rich interactive functions and intuitive operation interfaces, it effectively stimulates students' learning motivation, enhances their understanding and absorption of knowledge. In the constructed virtual environment, students can actively participate in the course and become the main body of the classroom, thereby improving the participation and effectiveness of the course. This student-centered teaching model not only enhances students' interest in learning and understanding of cutting-edge technology, but also promotes their ability to learn independently and solve problems, laying a solid foundation for cultivating high-quality talents.

2. Construction of teaching mode for cultivating middle school students' geometric intuition ability through virtual reality technology

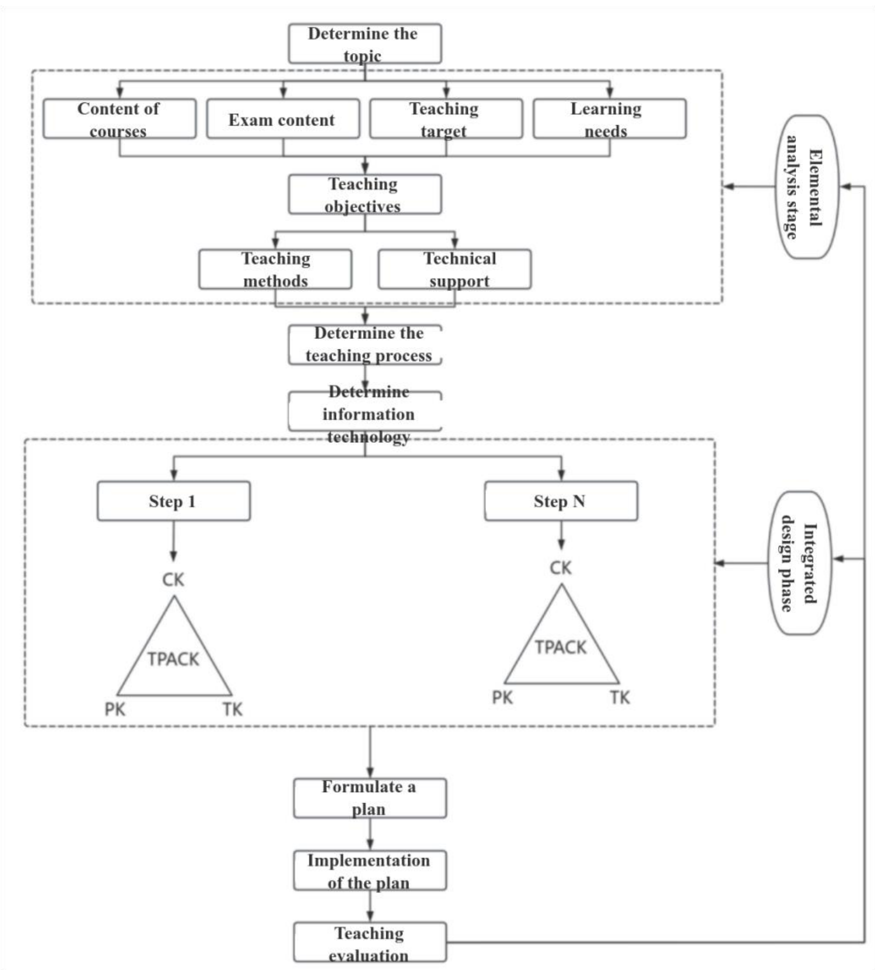

Figure 1 Teaching Design Flow Chart

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According to statistics from 2019, the proportion of campus networks equipped in junior high schools in China was 99.0% [5]. The learning environment and multimedia devices basically meet the requirements for conducting digital teaching, providing sufficient resources and environment for the application of virtual reality technology in primary and secondary school teaching activities. However, teachers lack understanding of virtual reality technology, and even more so, they lack the theory and framework for integrating virtual reality technology, namely educational information technology, with curriculum.Therefore, how to effectively integrate disciplinary knowledge with information technology and truly apply it in classroom teaching is an urgent challenge that needs to be addressed. The TPACK theoretical framework elucidates the subject knowledge, teaching knowledge, and technical knowledge that teachers should integrate, providing guidance for the integration of information technology and teaching.

2.1. Teaching Design Framework

Taking middle school graphics and geometry modules as the main content, guided by TPACK theory and new curriculum standards, virtual reality as the main information technology, and combining with traditional teaching design processes, a teaching design framework based on TPACK perspective integrating virtual reality technology to cultivate students' geometric intuition ability has been designed, as shown in Figure 1.

2.2. Analysis of Teaching Design Elements

CK,Subject content knowledge, specifically in the teaching of the "Graphics and Geometry" module, such as the concept of graphics as subject knowledge, is also part of the teaching content. This requires teachers to deeply study the textbook, familiarize themselves with the knowledge points of each part and the connections between them, in order to better control the key and difficult points of teaching. This article selects the relevant content of Chapter 5 Views in the first volume of the ninth grade of Beijing NPK, In the teaching of "Shape and Geometry" in junior high school mathematics, teachers should first understand students' existing experience in "Shape and Geometry" and then choose appropriate teaching methods based on the teaching content. Timely and effectively evaluate the teaching process and students' learning process after the teaching is completed.

TK, Technical knowledge refers to various information technologies that can assist teaching, such as geometric drawing boards. This article mainly uses virtual reality technology.

PCK, The knowledge of subject teaching methods refers to the ability of teachers to choose teaching methods that are suitable for students based on the characteristics of the teaching content of "graphics and geometry" and their specific situations, in order to help students learn and develop, thereby enhancing their understanding of "graphics and geometry" knowledge. In this article, the content of the views is mainly explained through visual presentation and teaching methods. During the teaching process, teachers not only need to evaluate whether students can correctly draw the three views, but also evaluate their thinking process and operational ability.

TCK, Integrating disciplinary knowledge of technology. It is the integration of technical knowledge and subject content knowledge, mainly referring to teachers being able to choose appropriate information technology based on subject content knowledge. In the view class, students can take the stage to hands-on operate, experience the process of object changes, understand the drawing process of three views, and make their images profound. Therefore, teachers not only need to understand the teaching content, but also need to choose appropriate information technology based on the characteristics of the teaching content, and be able to effectively apply it to the teaching process.

TPK, Integrating teaching methodology knowledge with technology. It is the integration of technical knowledge and pedagogical knowledge, mainly referring to the knowledge that teachers can use corresponding information technology to support teaching. In the View class, the main focus is on utilizing virtual reality technology to reproduce basic graphics, ancient artifacts, and architecture. Through visual displays and group discussions, students are motivated to learn.

2.3. Integration Process Design

This article mainly takes the third view section of the seventh grade mathematics textbook at Beijing Normal University as an example to design a teaching case that integrates virtual reality technology to assist in cultivating students' geometric intuition ability from the perspective of TPACK theory.

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Teaching objectives

Knowledge objective: 1. Master the principle of orthographic projection, understand the definitions and projection relationships of front view, left view, and top view; 2. Able to accurately identify the correspondence between geometric shapes and three views, and clarify the projection rules of "length aligned, height aligned, and width equal".

Ability objective: To cultivate students' geometric intuition ability and spatial concept.

Emotional goal: To inspire students' love for life and mathematics through the application of the "three views" in their learning.

content of courses

Teaching focus:

1. Understand the basic concepts and projection rules of three views.

2. The painting principle of three views.

Teaching difficulties:

1. Abstract transformation from 3D to 2D.

teaching process

Step 1: Create a scenario and introduce new knowledge

Situation introduction

Teacher: Today, the teacher wants to use VR technology to lead everyone into ancient Chinese gardens. Following the camera, we can see mountains, water, and bamboo forests. The building that comes into view now is the ancient Chinese garden architecture: "Zhai". Zhai, with a simple and elegant style, is located in a secluded and secluded area. Zhai is mostly used for meditation, reading, and rest in gardens, and can be a complete small garden, such as the Jingxin Zhai in Beihai, Beijing; It can also be a courtyard, such as the Dian Chun Gui in Suzhou Wangshi Garden, or more often a small house. Entering the studio, we can see various objects placed on the display counter, as shown in Figure 2.

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Figure 2 Landscape Display

Design intention: To introduce the living scene of ancient Chinese architecture in the garden - Zhai, to preliminary cultivate students' ability to abstract actual objects into mathematical graphics, and guide students to think about how to use flat graphics to depict three-dimensional graphics, thus naturally introducing new course content; At the same time, let students feel that mathematics comes from life and history.

Step 2 New Knowledge Learning

Collaborative exploration

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Problem: Using projection to explore complex ancient buildings may be difficult and may be explored in the fourth class, but we can first explore the interior of ancient buildings. As shown in Figure 3, when we enter the studio, we will find that there are many unique cultural relics placed inside, and they are carried by exhibition stands. We can abstract the exhibition stands into rectangular columns (click on the columns), and together we will explore what shape this rectangular column and the orthographic projection on the horizontal projection plane are?

Activity: As shown in the picture, the side edges of the rectangular prism are perpendicular to the horizontal projection plane. Please explore the following questions with the teacher.

Question 1: What are the orthographic projections of the four edges of this rectangular prism on a horizontal projection plane?

Question 2: What is the shape obtained by drawing the orthographic projection of a rectangular prism on a horizontal projection plane? What is the relationship between it and the bottom of the rectangular prism?

Question 3: Can the orthographic projection on a horizontal projection plane fully reflect the shape and size of the object?

Teacher: A orthographic projection drawn on a horizontal projection plane may reveal certain features of a rectangular prism from a specific angle, but it cannot fully reveal its entire shape and size. In order to present the shape and size of an object more comprehensively and accurately, in addition to the horizontal projection plane, we usually choose two other angles - front and side - to draw the orthographic projection of the object. This multi angle projection method can provide more comprehensive and detailed object descriptions, helping us to more accurately understand and analyze the shape and size of objects.

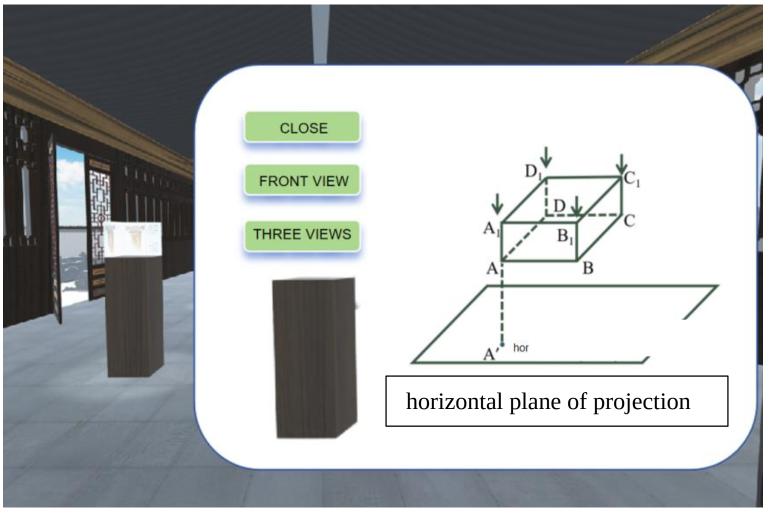

Figure 3 Cuboid software display diagram

Explore new knowledge

Teacher: As shown in the picture, we can see that a rectangular cylinder is projected onto three mutually perpendicular planes. We call the plane facing us the orthographic projection plane, the plane below it the horizontal projection plane, and the plane to its right the lateral projection plane. By projecting a rectangular prism into three perpendicular projection planes, three views are obtained: the projection in the front projection plane is called the main view, the projection in the side projection plane is called the left view, and the projection in the horizontal projection plane is called the top view. These three views are collectively referred to as three views. Among them, the main view is obtained through the projection line in the main viewing direction (i.e. the direction perpendicular to the orthographic projection plane).

Teacher: If the side projection plane and the horizontal projection plane are rotated 90 degrees to the right and down respectively, so that the three orthographic projections are on the same plane, it can be seen that the positional relationship of the three views is: the left view is on the right side of the main view, and the top view is below the main view, as shown in Figure 4. What are the characteristic features of a rectangular prism reflected in the front view, left view, and top view?

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Student: Size, volume, length.

Teacher: My classmates are observing very carefully!

Design intention: VR animation demonstrates the orthographic projection of three projection surfaces of objects, allowing students to intuitively understand and remember the view names. By rotating the side projection plane and the horizontal projection plane to the same plane, students can clarify the positional relationship of the three views. Set question one, use a projection diagram to help students intuitively grasp the drawing principles of "length aligned, height aligned, and width equal".

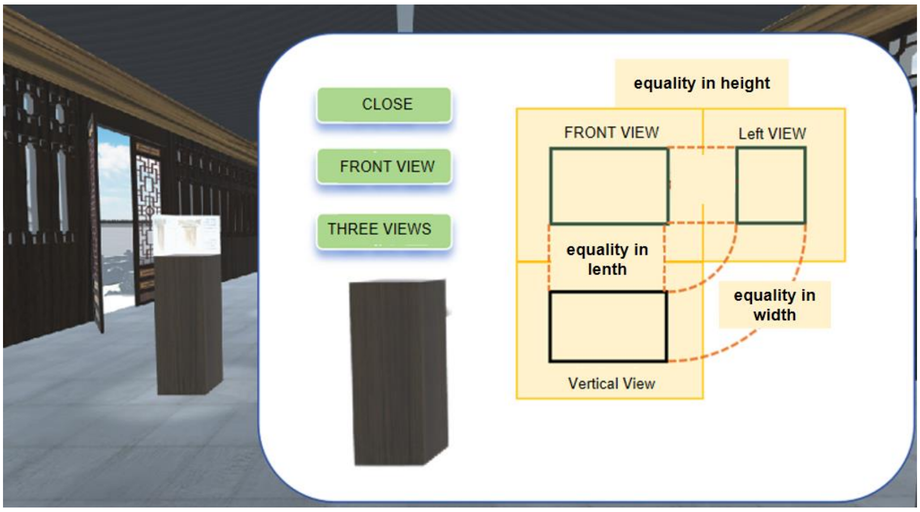

Figure 1

2.4. Teaching Evaluation Design

This article adopts a diversified teaching evaluation system, covering dimensions such as diagnostic evaluation, formative evaluation, teacher evaluation, student self-evaluation, and peer evaluation, aiming to verify the practical effect and theoretical value of virtual reality technology assisted teaching in cultivating middle school students' geometric intuition ability from multiple perspectives. In the implementation process, diagnostic evaluation serves as the starting point of teaching. Through geometric thinking pre-test and learning situation investigation, the system analyzes students' spatial cognitive foundation, graphic representation ability, and learning pain points, providing accurate data support for the design of VR situational teaching activities and the development of differentiated teaching strategies in the future. Formative evaluation runs through the entire teaching implementation stage. Teachers use VR classroom interactive data tracking, dynamic practice feedback, and periodic ability assessments to capture students' real-time mastery of core concepts such as 3D geometric transformations and spatial relationship reasoning. Based on visual data analysis, teachers optimize the presentation and interaction logic of VR teaching modules in real time, forming a closed-loop teaching mechanism of "evaluation feedback improvement".

3. Summary and Reflection

This article is based on the TPACK theoretical framework and integrates virtual reality technology into the cultivation process of middle school students' geometric intuition ability, aiming to optimize the effectiveness of mathematics teaching through technological means. The TPACK theory emphasizes the deep integration of technology, teaching methods, and subject knowledge, while virtual reality technology, with its immersive, interactive, and intuitive characteristics, provides new possibilities for geometry teaching. Through VR technology, students can directly observe and manipulate three-dimensional geometric shapes in a virtual environment, transforming abstract concepts of solid geometry into intuitive visual experiences, thereby reducing students' cognitive burden, improving their understanding of spatial relationships, and cultivating their geometric intuition ability. For example, when learning about the unfolding and folding of three view and three-dimensional graphics, VR technology can dynamically display the process of generating geometric shapes, helping students better understand the projection rules of "length aligned, height aligned, and width equal", while stimulating

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students' interest in learning and exploration desire.

However, despite the enormous potential of virtual reality (VR) technology in mathematics teaching, its application is still in its early stages and faces several critical challenges that require urgent attention. Firstly, the accuracy and detail representation of virtual models remain insufficient, particularly in rendering complex geometric shapes. For instance, subtle geometric properties such as curvature, symmetry, or spatial relationships may not be precisely visualized in current VR environments, potentially leading to misconceptions among students. Secondly, the pedagogical integration of VR technology presents difficulties, as many educators lack the technical training to effectively manage VR-based lessons. This can result in inefficient classroom control, where the teaching pace becomes inconsistent or students become distracted by the novelty of the technology rather than focusing on learning objectives. Furthermore, the high production costs of high-quality VR content and the substantial hardware expenses create significant barriers to adoption. Most educational institutions, especially in underfunded regions, cannot afford the initial investment or ongoing maintenance costs. Additionally, the current generation of VR devices often suffers from technical limitations such as motion sickness, limited battery life, and bulky hardware, which further reduce their practicality for daily classroom use. These multifaceted issues—spanning technical, pedagogical, and economic dimensions—highlight the need for collaborative efforts among educators, developers, and policymakers to optimize VR's implementation in mathematics education through improved technology, teacher training programs, and cost-reduction strategies. Only by addressing these challenges systematically can VR realize its full potential as an effective mathematical learning tool.

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