Research on Mathematics Teaching Based on VR (*virtual reality*) in China

ABSTRACT:

VR (*if possible don't start with an abbreviation*) (Virtual Reality) is of great relevance in improving the teaching quality of mathematics and students' interest in learning mathematics. In recent years, some scholars have conducted research on mathematics teaching based on VR in China, but there has not yet been any literature that summarizes and sorts out them. This paper adopts the method of literature analysis to read, summarize, and organize the previous related studies, and draws the following conclusions: (1) Previous research mainly focuses on five aspects, namely, the advantages and significance of VR in mathematics teaching, suggestions for mathematics teaching based on VR, strategies for VR-based math(*mathematics*) classes, shortcomings and challenges of VR-based teaching, as well as practical explorations of VR-based teaching. (2) The methods of research are relatively single, mainly qualitative research and less quantitative research. (3) There are some blank spots in the research. First, Most of the research on VR-based classes is based on the content of the curriculum compulsory education, with less research based on senior high school, middle collegesand university. Second, the research focuses mainly on the teaching of the Geometry section, with less coverage of other curriculum sections. Third, although some scholars have put forward specific teaching ideas for the use of VR in math classes, most of them have not yet been implemented in practice.

Keywords:VR (Virtual Reality), Math(mathematics) teaching, Immersion, Quality

1. INTRODUCTION

VR (Virtual Reality), as a new type of teaching means, allows teachers to impart knowledge to students in limited space and time, increasing class capacity, bringing students a brand-new learning experience, and better meeting the needs of student learning [1]. Currently, immersive learning by using VR is increasingly emphasized by various parties, and in the Learning Trends Report 2018 published by the Open University in the UK, immersive learning is listed as an important direction for future learning trends [2]. In the subject of mathematics, an "immersive" class can use VR and other technologies to let students visualize the connotation of mathematics so that students actively participate in class teaching, which can deepen students'

understanding and awareness of mathematical knowledge [3]. Therefore, it is necessary to study VR-based mathematics teaching. In recent years, VR has gradually come into the field of education, and some studies on related topics have appeared, but the number of studies on teaching using VR specifically for the subject of mathematics is relatively small, and there has not yet been a generalized study on VR-based mathematics teaching. In order to systematically analyze the current research status, this paper intends to review and sort out the current research and provide an overall overview of the previous research. The value of this study is that, on the one hand, it can provide ideas and directions for the implementation of VR in mathematics teaching and help VR to be used more effectively in mathematics teaching. On the other hand, it is more capable of identifying the gaps and shortcomings in it, so as to push scholars to conduct more in-depth research.

The study was guided by the following questions:

(1)……

The research questions in this paper are: (1) What are the aspects included in the current research on VR-based mathematics teaching? (2) What are the shortcomings and gaps in the current research on VR-based mathematics teaching?

Objectives of the study

The following were objectives of the study

1) To establish the aspects included in the current resources on VR-based mathematics teaching
2) To find out the short comings and gaps in the current research on VR-based mathematics teaching

2. LITERATURE SOURCES

2.1 Source of Materials

The literature involved in this paper comes from the China Knowledge Network (CNKI) database. CNKI is the most authoritative literature search tool for academic journals in China, which basically includes all the contents of journals in China in a complete manner, including various subject areas, so the selection of this database in this paper can guarantee the persuasiveness and reliability of the research.

2.2 Data Collection

In order to avoid omissions, four different keywords, namely, "VR", "virtual reality",

"immersion", and "mathematics teaching", were inputted in the process of literature review, and a total of 21 papers on VR-based mathematics teaching were mentioned through advanced search. Therefore, this paper analyzes these 21 papers in depth.

2.3 Data Sorting

Reading the literature carefully and taking notes, we summarized and sorted out the research results, research methods, and information on the samples.

3. RESULTS

Most of the scholars launched the research of VR-based mathematics teaching for different stages of mathematics courses. Eight scholars studied the use of VR in elementary school math classes, eight scholars studied the use of VR in middle school math classes, and two scholars studied the use of VR in high school math classes. Jiang, Zheng, and Zhang (include ***year of publication***) discussed the scope and prospect of VR application in mathematics teaching in the context of different stages of math courses, pointing out its application in elementary school, junior high school, senior high school, and university mathematics teaching, respectively [4]. The scholars' research direction is divided into theoretical and practical research.

3.1 Theoretical Research

Regarding the theoretical research on VR in mathematics teaching, scholars have focused on four aspects: the advantages and significance of VR in mathematics teaching, suggestions for teaching VR-based mathematics classes, strategies for VR-based mathematics classes, and shortcomings and challenges of VR-based Teaching.

3.1.1 The Advantages and Significance of VR in Mathematics Teaching

A number of scholars have discussed the significance of VR in mathematics teaching, and scholars such as Guan and Li (***include year of publication***) have compared VR-based teaching with traditional teaching, pointing out the advantages of VR-based teaching.

Regarding the significance of VR in math classes, Wang, He, Li, Liu, Yu, and

Jiang(*include year of publication*)think that it can enhance students' interest in mathematics learning and stimulate their motivation to learn [5-13]. Guan thinks that VR can promote the transformation of education and teaching methods [14]. Liu, Wang, Yu, and Jiang (*include year of publication*) point out that VR can optimize teaching and improve the quality(*competence*) of teachers' teaching [8,9,12,15].Regarding the advantages of VR in math(*mathematics*) classes, Wang, Liu, Liu, Jiang, and Chai(*include the year of publication*) point out that it can materialize abstract knowledge [7,8,10,12,13,15,16]. Wang, Li, Mu, Ji, Jiang, and Chai (*year ofpublication*)point out that it can create "immersive" classes and optimize students' learning experience [3,4,6,8,13,16,17]. He and Li think that VR can enrich the content of math(*mathematics*) classes and create an active atmosphere [5,6]. In addition, Jiang, Zheng, and Zhang (*year of publication*) believe that VR is conducive to cultivating students' habits of independent learning and inquiry in class, establishing a correct concept of innovation, which can make education no longer limited by spatial practice, and also can maximize students' learning efficiency and enhance students' independent learning ability [4]. Liu and Li (*year*) believe that VR can be integrated into the core literacy of senior high school mathematics, which facilitates students' independent investigation [7]. Jiang and Huang(*year*) think that VR can avoid danger in experiments [10]. Wang believes that VR can help students better absorb and consolidate the knowledge related to graphic geometry, which facilitates the breakthrough of key points in the teaching of the key points of three-dimensional geometry [13]. Min believes that VR can make students more deeply realize that mathematics comes from life [18].

3.1.2 Suggestions for Teaching VR-based Mathematics Classes

For the implementation of VR in math(*mathematics*) classes, scholars have proposed principles to be followed in using VR for teaching as well as pedagogical recommendations for schools and teachers. Wang points out that teaching using VR needs to follow the principle of depth of knowledge, the principle of student body and the principle of teacher body orientation, and the principle of educational diversity [13]. Liu points out that teachers should establish a scientific concept and systematic teaching thinking [15]. Mu (year)thinks that it is necessary to cooperate with various parties to actively build an "immersive" smart classroom; to explain stories to lead students to perceive mathematical knowledge with interest; to actively reform teaching and learning, and to classify the degree of difficulty of mathematical knowledge; to teach cases to stimulate students' in-depth thinking and explorations;

and to teach students according to their abilities for the benefit of all students [3]. Liu and Li(*year*) believe that VR should be used for the parts that are difficult to realize in teaching, and the frequency and timing of VR use should be grasped. It is suggested that teachers can make reasonable use of VR resources according to their teaching needs, and try different teaching experiences brought by the new technology [7]. Wang and Liu(*year*) point out that teachers should create a relaxed and pleasant class situation, guide students to carry out an independent investigation, strengthen the guidance of students' learning skills, organize rich extracurricular practical activities, break through the important and difficult points in mathematics teaching, and build a dedicated courseware material library [8]. Yu (*year*)believes that it is necessary to update the concept of education and improve teachers' information literacy, to stimulate the interest of interested students in learning virtual reality technology, to use virtual reality technology to change the way students learn, to use virtual reality technology to develop curriculum resources; to use virtual reality technology to improve the level of research on the subject; and to optimize the class evaluation method [9]. Jiang(*year*) thinks that, firstly, it is necessary to clarify what impact and influence technology has on learning, and secondly, according to the role and influence of technology on learning, combined with the corresponding learning theory to introduce the corresponding theory of technology application [12]. Wang and Sun(*year*) think that it is necessary to understand the educational value of knowledge, to establish a scientific concept of education, to have systematic thinking about teaching, and to have apt teaching methods [19]. For the requirements of using VR in math*(mathematics*) classes, Wang(*year*) points out the need to improve the teaching infrastructure, and teachers' and students' information literacy [13]; Chai(*year*) points out that teachers must be proficient in the design and application of virtual reality technology, have sufficient preparation time and adequate program design and development skills, and carefully design teaching procedures, etc*(and so on*) [16].

3.1.3 Strategies for VR-basedMathematics Classes

Regarding how to use VR effectively in math class and how to implement it effectively, scholars have proposed specific situations for using VR. Wang and Hao(*year*) believe that VR should be used in irreplaceable teaching situations, thematic situations that transcend time and space, content situations about space and graphics in textbooks, scenarios in which mathematics is closely related to life, and situations that help students build abstract mathematical concepts [20]. Min thinks that VR should be used to build a virtual world and stimulate interest, to restore the

real world and make the abstract concrete, and to interact with the real world and make the concrete abstract [18].

In addition, some scholars have proposed VR-based teaching strategies for math (***mathematics***)classes by combining teaching examples. Zhang and Ding propose a VR-based teaching model of three-dimensional geometry [21]. Lu, Qian, and Chen (***year***)construct a secondary school mathematics teaching design model with the assistance of a VR all-in-one computer based on many class practices, including the selection of VR mathematics teaching resources, the interactive design of VR-based mathematics teaching, and the extension of VR mathematics creator education [22]. Taking "projection and view" as an example, Liu proposes a teaching strategy for math class in middle school based on VR, and puts forward the three major steps of observing geometry from multiple angles, mastering the principle of three views, and returning to abstraction from intuition [15]. Liu and Li (***year of publication***) integrate VR into three-dimensional geometry in a mathematics class in high school and carried out the teaching design of a "plane divided into space" [7]. Jiang and Huang (***year ofpublication***) take "the unfolding and folding of three-dimensional shapes" as an example to develop a narrative of the application of VR in the class strategy. Wang used the concept of numbers and geometry problems as examples to illustrate the use of VR in math(***mathematics***) classes in elementary school [10]. Chai ***(year***)combines VR with math class in junior high school, and carries out the teaching design of the lesson "How ants walk closer" [16]. Wang and Sun(***year***) take the lesson of "three views" as an example and carried out a VR-based math experiment teaching design [19].

3.1.4 Shortcomings and Challenges of VR-based Teaching

While analyzing the advantages of VR application in mathematics classes, some scholarsput forward the shortcomings of VR technology as well as the challenges it is currently facing. Jiang believes that, on the one hand, the application of virtual reality technology to actual teaching will put forward higher requirements on the professional level of front-line teachers and their ability to apply emerging technologies, and the difficulty of lecturing and lesson preparation will be further enhanced.On the other hand, before the technology is thoroughly popularized, virtual imaging technology will reduce the number of practices for each student, as well as reduce the opportunity to repeat the process of learning about the operational experience [12]. According to Zhang and Ding, (***year)*** firstly, if teachers'teaching

emphasizes too much virtual reality but ignores actual teaching, it will lead to a thin teaching structure, and the overall teaching effect is not good. Second, the creation of virtual learning environments is detached from the teaching objectives, leading to a great deal of randomness and counterproductive student participation in the learning process. Third, the virtual learning environment is so different from the real environment that teaching evaluation is difficult [21].

3.2 Practical Research

Wei, He, Ji, and other scholars have practically explored the practical use of VR in math classes. Wei learned through a questionnaire survey that teachers and students have a positive attitude towards the use of VR in math classes in elementary school and applied the experimental research method to design a VR-based class that can be used to teach elementary school mathematics three-dimensional geometry [23]. Ji, Liu, and Ye(***year***) used VR to model and interact with the three exhibits of "Rolling out a straight line", "Möbius ring", and "Three-dimensional four-dimensional chess" in the "Phantom of Mathematics" theme area of the China Science and Technology Museum (CSTM) and added text, sound, and other navigational methods to build a mathematical immersive learning environment [17]. He took the example of "solving quadratic equations using the properties of equations" to carry out VR-based secondary school mathematics teaching in the ninth grade. After one year's practice, he found that students would get the freshness of playing the game upgraded, and feel a very novel experience for the flipped smart class. The class based on VR improves the learning ability of students while improving their academic performance [5].

4. DISCUSSION

Through the search and statistics of the above research, we can find that scholars have carried out research on VR-based mathematics teaching in different aspects and to different degrees. Currently, most of the scholars' research is based on math classes in compulsory education, and a few scholars have researched the application of VR technology in senior high school and university. The main research content of scholars focuses on two major directions: theoretical research and practical research.

The theoretical research mainly focuses on the advantages and significance of VR in mathematics teaching, the suggestion of VR-based math classes, strategies for VR-based math classes, the shortcomings of VRand the challenges it faces. According

to the discussion of scholars on the significance of VR in mathematics teaching, it can be found that VR has the role of materializing abstract knowledge, enhancing students' interest in mathematics learning, and optimizing teachers' teaching in mathematics. Therefore, it is necessary to further explore the effective use of VR in mathematics teaching. For the effective use of VR in mathematics classes, some scholars have proposed specific application scenarios, and some scholars have combined teaching design with examples, which are mainly focused on the geometry part. In addition, some scholars also analyze the shortcomings of VR and the challenges it faces. So how to effectively use VR in mathematics teaching is still worthy of the thinking of the majority of educational researchers.

Practical research mainly centers on interaction design and classroom practice. On the one hand, some scholars have carried out interaction design, but the development of VR-supporting teaching software only involves individual examples of numbers and algebra, and three-dimensional geometry. On the other hand, only a small number of scholars have applied VR to actual math classes for practical exploration.

According to the above summary, it can be seen that there are some shortcomings in the previous research. On the one hand, regarding the research methods of the predecessors, the predecessors mostly adopt the method of theoretical discernment, with qualitative research as the main focus, and less quantitative research is adopted. On the other hand, in terms of research content, the number of studies on this topic is small, and the depth of research needs to be expanded, which also indicates that there are some blank spots in the research on this topic. It is specifically manifested in the following three aspects: First, most of the research on VR in mathematics teaching is based on the content of the curriculum at compulsory education, with less research at senior high school and university. Second, the current research focuses mainly on the teaching of the geometry section, with less coverage of other mathematics curriculum sections. Third, although a number of scholars have put forward specific pedagogical concepts for the use of VR in math classes, most of them have not yet been implemented in practice.

5. CONCLUSION

In this study, the following conclusions are obtained by reviewing, combing, and analyzing the relevant literature on VR-based mathematics teaching:

(1) Research mainly focuses on five aspects, namely, the advantages and significance of VR in mathematics teaching, suggestions for mathematics teaching based on VR, strategies for VR-based math(***mathematics***) classes, shortcomings and challenges of VR-based teaching, as well as practical explorations of VR-based teaching.

(2) The methods of research are relatively single, mainly qualitative research and less quantitative research.

(3) There are some blank spots in the research. First, Most of the research on VR-based classes is based on the content of the curriculum compulsory education, with less research based on senior high school and university. Second, the research focuses mainly on the teaching of the geometry section, with less coverage of other curriculum sections. Third, although some scholars have put forward specific teaching ideas for the use of VR in math classes, most of them have not yet been implemented in practice.

Therefore, the current research on VR-based immersive learning in the field of mathematics is still relatively sparse and monotonous, and there is still a wide range of prospects for the application and exploration of teaching methods using VR technology in the field of mathematics. It is necessary for future research to conduct deeper research on VR-based mathematics teaching with more diverse research methods on the basis of existing research, so as to encourage experts and scholars to make suggestions on the effective use of VR technology in mathematics teaching and learning, so as to optimize the mathematics classroom and improve students' interest in mathematics learning.

REFERENCES

1. Institute of Educational Technology, Open University, UK.Learning Trends Report 2018[J]. Contemporary Vocational Education,2018,(4):96-101
2. Anthes C, García-Hernández R J, Wiedemann M, et al. State of the art of virtual reality technology[J]//2016 IEEE aerospace conference. ieee, 2016: 1-19.
3. MuXY. In-depth analysis and discussion on the construction of high school mathematics "immersive" wisdom classroom[J]. Friends of Mathematics,20 23,37(02).
4. JiangHL., Zheng Y., Zhang XN. et al. Application of virtual reality technol

ogy in the field of mathematics teaching[J]. Journal of Higher Education Science,2020,40(09):51-53.
5. He CJ. Exploration of Smart Classroom Teaching of Rural Secondary School Mathematics Based on VR Microteaching--Taking Solving Quadratic Equations Using the Properties of Equation as an Example[J]. Education Information Technology,2021(Z2):87-90.
6. Li XD.The use of AR/VR in the teaching of graph and geometry in elementary school mathematics[J]. Literature and Science Navigation (Late),2020(10):10+13.
7. Liu G., and Li L. The application of VR technology in high school mathematics teaching[J]. Secondary School Mathematics Teaching Reference,2020(Z3):149-151.
8. Wang LL., and Liu MH.The use of VR technology in middle school math teaching[J]. China Education Technology Equipment,2018(11):25-26.
9. Yu SX. Virtual Reality Technology Applied to Elementary School Mathematics Teaching Research[C]// Guangdong Teachers' Continuing Education Society. Proceedings of the Fifth Teaching Seminar of Guangdong Teachers' Continuing Education Society (IV). [Publisher unknown],2022:5.
10. Jiang J., and Huang WQ. Application of virtual reality technology in math teaching[J]. China Education Technology Equipment,2021(24):23-24+27.
11. Wang CN. Research on the use of virtual reality technology in elementary school mathematics teaching[J]. China Journal of Multimedia and Network Teaching (Lower Decade),2021(04):129-130.
12. Jiang DR. Brief analysis of the significance of virtual reality technology in junior high school mathematics teaching[J]. Curriculum Education Research,2015(20):143-144.
13. Wang ZQ. Effective use of AR/VR in elementary school math graphics and geometry teaching[J]. Elementary school students(middle periodical),2022(06):73-75.
14. Guan Z. Example of the application of virtual reality (VR) technology in math teaching[J]. Research on Elementary School Teaching,2022(08):32-33.
15. Liu T. Thinking about middle school math classroom teaching based on VR technology[J]. China Education Technology Equipment,2020(05):26-28.
16. Chai LY. Application of virtual reality technology in junior high school math class[J]. Journal of Jiaozuo Normal College,2012,28(03):72.
17. Ji HL.,Liu YR.,Ye XY. et al. Design and implementation of an immersive learning environment for mathematics[J]. Computer Simulation,2022,39(12):3

23-329.
18. Min YY. The use of virtual reality technology in elementary school math t eaching[J]. Teacher,2015(11):34.
19. Wang L., and Sun CR. Mathematics experiment based on "VR" - "three vi ews" of the understanding of teaching materials, teaching confusion, and ch ange attempt[J]. Elementary and Middle School Mathematics (Middle Schoo l Edition),2017(Z2):78-81.
20. Wang RH., and Hao ZH.VR technology, makes abstract math more interesti ng[J]. Sichuan Education,2021(12):36-37.
21. Zhang YQ., and Ding YG. Exploration of three-dimensional geometry teach ing mode based on virtual reality technology[J]. Software Guide(Education Technology),2017,16(08):33-34.
22. Lu JJ.,Qian YY., and Chen ZH.Secondary school mathematics teaching desi gn mode and its practice with the assistance of VR all-in-one machine[J]. Teaching Monthly-Middle School Edition(Teaching Reference),2021(06):3-6.
23. Wei KL. Research on the application of VR technology in elementary scho ol mathematics auxiliary teaching[D]. Lanzhou Jiaotong University,2023.