Research on generative AI enabling secondary school mathematics curriculum design

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Abstract. Research on the application of Generative AI to education has received wide Attention. Researchers find that the rise of Generative AI provides a technological driver for innovation in education. Researchers also found that the characteristics of Generative AI provide a theoretical foundation and practical direction for its deep integration into the secondary school intelligence education platform. However, there is very little empowerment for a particular discipline. Therefore, this paper analyzes the design of generative AI-enabled secondary school mathematics curriculum, resulting in immersive scenarios, optimizing innovative teaching models, and enhancing personalized diagnostic feedback. This paper suggests, in combination with traditional teaching methods, that the development of a human-generative AI mathematical knowledge construction system plays the interaction of mathematics teachers' learning characteristics and technical capabilities.

1 Introduction

In recent years, China's artificial intelligence technology has developed at an astonishing rate, and generative artificial intelligence as an important branch has gradually penetrated the field of education. In secondary school mathematics teaching, curriculum design plays an important role in helping teachers clarify teaching goals, optimize teaching content, stimulate students' learning interests, and improve student abilities. Some researchers found that excellent curriculum design can promote students' proactive learning ability and overall quality improvement [1]. Some researchers analyzed the curriculum design of integrated practical activities from multiple dimensions and found that it can cultivate students' sense of social responsibility and ecological civilization [2]. In the context of digital education, there is a lack of digital literacy among teachers, and students are unable to adapt to the digital model. Researchers abroad believe that Generative AI empowering curriculum design can reduce the workload of teachers [3]. Some researchers believe that unprecedented creativity is injected into the course design process [4]. The findings of scholars show that generative AI has huge potential in supporting innovative curriculum design [5]. Therefore, this paper examines the design of Generative AI-enabled secondary school math curricula to help solve these problems.

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2 The practical challenges faced by traditional mathematics curriculum design

2.1 Neglecting the cultivation of students' mathematical thinking

Traditional mathematics teaching emphasizes logic, according to a certain structure to promote the characteristics of knowledge learning. To a certain extent, this can cultivate in students a strict mathematical thinking pattern, which is gradually developed, allowing students to deepen their understanding of the relationship between mathematical concepts, definitions, etc. However, with the continuous development of mathematics teaching, the limitations of heavy knowledge and light thinking of mathematics teaching content have been shown. Previously, the purpose of the teacher's curriculum design was to play a leading role in teaching mathematical knowledge to students by explaining the difficulties of mathematical content, exploring mathematical problems, and so on, to enable students to understand and master formulas and theorems in mathematics. Huang Cuixiang's research shows that mathematics disciplines have a strong abstraction, expanding students' mathematical thinking is an important help to students' learning, which is an important task facing mathematics teachers at present [6]. Now, while these methods play an important role in the student's mastery of mathematical knowledge, students will, to some extent, ignore the essence behind this knowledge and fail to develop their mathematical thinking.

Teachers in traditional mathematics teaching have the characteristics of teaching students fragmented knowledge, allowing students with weak foundations to quickly understand mathematical concepts, and improving students' learning self-confidence. This fragmented approach to knowledge review plays an important role when students face exams. However, this course design lacks a holistic construction of the mathematical knowledge system. In the past, through the traditional mathematics curriculum design of teachers, students learned fragmented mathematical knowledge, lacking an overall construction system of mathematical knowledge, resulting in no improvement in mathematical thinking skills. For example, when teachers design traditional mathematics courses to teach sine theorems, they focus solely on the process of defining and proving sine theorems, and ignore the mathematical history of sine theorems, their applications in life, and their connections to other mathematical knowledge, which prevents students from having the flexibility to apply mathematical thinking to life.

Traditional mathematics teaching fully plays the leading role of teachers, explaining mathematical knowledge to students through teaching methods and demonstrating the thinking process and methods of mathematical learning. This greatly improves the efficiency of mathematics teachers teaching classes with a large number of students. However, traditional mathematics courses are designed with a single teaching method. In traditional courses, mathematics teachers use the teaching method, but there is a lack of communication and interaction between students and teachers. The classroom atmosphere is dull and oppressive, and students lack initiative, actively raising, analyzing, and solving problems. They lack the desire to explore knowledge, which greatly hinders the development of students' mathematical thinking. Moreover, the traditional classroom evaluation method is based on exams, which value students' understanding and application of mathematical knowledge rather than the mathematical thinking process.

2.2 Limited teaching resources

The teaching resources in traditional mathematics teaching are generally textbooks. Mathematics textbooks provide teachers with a standard teaching template for curriculum design, which can reflect the key and difficult points of mathematics teaching.

Due to the common limitations of mathematics education in various regions around the world, teachers have overlooked the diversity of teaching content and fixed their teaching content. Researchers abroad have shown that limited teaching resources make it extremely challenging for teachers to provide personalized teaching for students [7]. Both teachers and students only teach and learn knowledge from textbooks, and students not only lack understanding and application of other mathematical knowledge, but also cannot understand new ideas and cutting-edge developments in mathematics.

Due to the long time taken for textbook compilation and publication, there may be a situation where teaching resources are outdated. If traditional teaching resources are updated slowly, they cannot reflect new mathematical ideas and the latest research results to a certain extent, which affects the teaching effectiveness of teachers and hinders frontiers.

There are obvious limitations in the uneven distribution of educational resources. There are significant differences in resource allocation between urban and rural areas, regions, and schools, with only a few schools having good educational resources. This uneven distribution of educational resources results in some rural schools lacking basic teaching equipment, which greatly affects the teaching quality of teachers and the learning needs of students.

2.3 Students' personalized learning

Traditional mathematics teaching has the characteristic of adapting to students' learning pace. Traditional mathematics teaching methods are relatively stable, and students can easily adapt to the teacher's teaching pace and master their learning rhythm.

However, due to the limitations of teachers not adopting differentiation strategies, this leads to a lack of layered design for homework assignments and classroom exercises when designing middle school mathematics courses, making it difficult to balance individual differences among students and meet their personalized learning needs. The traditional mathematics curriculum design typically adopts a unified pace and standardized content. And students with different foundations have different learning needs. Chang Lingxiao's research explores that in curriculum design, students' personalized needs serve as the starting point and foothold of curriculum design. Teachers need to reflect on and innovate teaching methods to improve their ability to meet students' personalized needs [8].

In traditional mathematics teaching, teachers often use blackboard writing to demonstrate the thinking process of solving mathematical problems, increasing the visualization effect of mathematical knowledge. However, due to the rapid updates and iterations of the times, some teachers have not been able to quickly adapt to the limitations of digital technology. In the context of digitization, teachers lack the use of new technologies and equipment. This situation of limited teaching resources suppresses students' personalized learning needs and diversity in teaching, resulting in a poor learning experience for students.

3 The current status of generative artificial intelligence applications in curriculum design

3.1 Immersive scenario creation

Generative artificial intelligence serves as a tool for providing context, creating scenarios that are integrated with real-life situations to stimulate students' interest in learning. Liu Bangqi's research shows that generative artificial intelligence can be applied in classroom teaching to promote students' development [9]. The teaching process includes introducing new knowledge, explaining new knowledge, applying new knowledge, summarizing and summarizing, assigning homework, etc. Therefore, the process of introducing new knowledge is of utmost importance, as it needs to attract students' attention and serve the subsequent teaching activities. Generative artificial intelligence has played a crucial role in helping teachers improve the process of introducing new knowledge.

Generative artificial intelligence interacts with students. The vivid mathematical scenarios created by generative artificial intelligence not only provide students with an immersive experience and lively classroom atmosphere but also greatly enhance their deep learning experience.

Although generative artificial intelligence can create immersive scenarios, there are still certain limitations. Generative artificial intelligence is based on big data to construct knowledge, but to some extent lacks understanding of the causal relationship of the essence of knowledge.

3.2 Optimize and innovate teaching modes

Generative artificial intelligence leverages the functions of human-computer interaction to enhance students' thinking abilities. Generative artificial intelligence can generate answers to students' questions, stimulate their curiosity and initiative in exploring knowledge, and also cultivate their ability to organize language, obtain and organize information when asking questions to generative artificial intelligence.

When teachers carry out practical activities, they encourage students to boldly create using generative artificial intelligence. Dong Yong's research shows that empowering curriculum design with generative artificial intelligence can optimize innovative teaching models and help build high-quality teaching classrooms [10]. This approach endows students with more fun and interactivity in the learning process, enhances their ability to use generative artificial intelligence, and through step-by-step exploration, enables students to gain a deeper understanding of how to effectively use generative artificial intelligence to assist their learning.

Generative artificial intelligence can enhance students' learning experience by generating mathematical images, videos, and other teaching resources related to teaching content, making classroom content rich and colorful. For example, in a math class, the teacher presents proofs of mathematical theorems and encourages students to follow the explanation in the video. This not only deepens students' understanding of knowledge, but also stimulates their interest in learning, increases student participation, and enlivens the dull and oppressive teaching classroom.

Generative artificial intelligence has optimized and innovated teaching models, to some extent ignoring traditional teaching methods in the past, and should be combined with traditional teaching methods.

3.3 Strengthen personalized diagnostic feedback

Personalized diagnosis is a method of providing personalized learning plans and coaching measures for students who encounter difficulties in the learning process through a series of

evaluation analyses. The key is to provide personalized services based on the individual differences of students and tap into their development potential.

Generative artificial intelligence can also provide real-time feedback on students' learning progress, adjust the direction and difficulty of learning promptly, quickly adapt to students' learning changes, and enable students to steadily move forward in their own learning pace. Wang Ming's research shows that generative artificial intelligence collects a large amount of data and algorithm models, and through students' assignments, deeply analyzes their mastery of knowledge points, thereby more accurately understanding students' learning difficulties and areas that need improvement [11]. For example, after assigning relevant teaching tasks, the generative artificial intelligence provides feedback on students' mastery based on their answer situation, and generates several questions of the same type as the wrong questions or that require extrapolation to help students master key and difficult points.

Generative artificial intelligence can not only provide feedback on students' learning progress, but also help teachers optimize course design. After the teacher completes the course design, generative artificial intelligence can generate detailed reports based on the students' learning situation, allowing the teacher to gain a deeper understanding of the students' learning difficulties and modify the course design to fit the students' real learning situation.

Generative artificial intelligence can enhance personalized diagnosis and help teachers optimize curriculum design by providing feedback on students' learning progress. However, it is still necessary to leverage the leading role of teachers in curriculum design and assist with generative artificial intelligence.

4 The prospect of empowering middle school mathematics curriculum design with generative artificial intelligence

4.1 Combining with traditional teaching methods

Educators can combine generative artificial intelligence with traditional teaching methods to significantly improve students' learning outcomes, and this approach is worth promoting worldwide. Researchers abroad have shown that combining generative artificial intelligence with traditional teaching methods can supplement resources for STEM education [12].

Mathematics teachers should realize the importance of digital thinking and continuously improve their digital teaching abilities. For example, based on the mathematical content to be explained in this chapter, using generative artificial intelligence to generate visual images improves students' learning experience, presents mathematical content clearly and intuitively, and deepens students' understanding of mathematical knowledge. The relevant research results indicate that in terms of conceptual understanding, students assisted by generative artificial intelligence perform significantly better than those who receive traditional teaching guidance [12]. Therefore, in future instructional design, teachers should combine generative artificial intelligence with traditional teaching methods to help students enhance their understanding of mathematical concepts.

Teachers can use generative artificial intelligence to generate mathematical problems and quizzes, improve students' learning engagement, and enhance their initiative in learning. Some foreign researchers have suggested that teachers need to understand students' views on generative artificial intelligence to better customize the technology through this approach [13]. This can meet the personalized needs of students and enhance the teaching effectiveness of traditional teaching methods. Most students believe that generative artificial intelligence has profound implications for their discipline and future career paths, therefore they consider

the use of generative artificial intelligence as an important part of their curriculum.

4.2 Developing a human generative Artificial Intelligence mathematical knowledge construction system

At present, the development of generative artificial intelligence has received significant attention from all over the world. Undoubtedly, generative artificial intelligence has brought convenience to students' learning, but there are still urgent problems to be solved: how to construct knowledge with generative artificial intelligence, and whether generative artificial intelligence can obtain new insights with the help of humans are of paramount importance [14].

Foreign researchers have shown that knowledge construction is a principle-based teaching method [15]. This approach is feasible to a certain extent. In middle school mathematics classrooms, generative artificial intelligence analyzes mathematical theorems, concepts, and formulas, generates mathematical knowledge graphs, constructs a mathematical knowledge construction system, and connects the key and difficult points of mathematical knowledge with strong logic.

Therefore, teachers can build a mathematical knowledge graph based on their mathematical literacy. This requires teachers to have good mathematical knowledge and literacy. By clarifying teaching objectives, conducting in-depth analysis of learning situations, and designing teaching content, lesson preparation is carried out to understand the relationships between various mathematical knowledge points, thus constructing a complete mathematical knowledge graph.

4.3 Utilize the interactive effect of learning characteristics and the technical abilities of mathematics teachers

Integrating mathematical knowledge with digital tools to enhance the digital literacy of mathematics teachers. Mathematics teachers have excellent mathematical knowledge and skills and have a deep understanding of abstract mathematical concepts. Mathematics teachers can concretize abstract mathematical concepts through the combination of numbers and shapes, enabling students to learn mathematical knowledge more quickly and effectively.

Mathematics teachers need to strengthen collaboration with generative artificial intelligence. Researchers abroad have explored the interaction between multiple factors such as user engagement, technical proficiency, and the functionality of generative artificial intelligence [16]. Research has found that the collaboration between learner characteristics and generative artificial intelligence can significantly improve the ability of self-regulated learning. Mathematics teachers have strong logical reasoning abilities and are skilled at solving difficult problems. Therefore, in the context of digitization, mathematics teachers can quickly adapt to and master digital technology, cultivate and enhance their digital literacy. Mathematics teachers should cooperate with generative artificial intelligence and closely integrate it with teaching practice.

Mathematics teachers should strengthen their innovative spirit, so that they have a positive attitude towards new things. Foreign research has shown a close relationship between user engagement and generative artificial intelligence capabilities. When teachers are highly involved, they will feel more capable and effective in the process of using generative artificial intelligence, and will use it more deeply to obtain more effective feedback, thereby achieving a better teaching experience, forming a virtuous cycle, and improving the digital literacy of mathematics teachers.

5 Conclusion

This study explores the empowerment of generative artificial intelligence in middle school mathematics curriculum design, analyzing the practical challenges faced by traditional mathematics curriculum design, the current status of the application of generative artificial intelligence in middle school mathematics curriculum design, and the prospects for empowering middle school mathematics curriculum design with generative artificial intelligence.

The research results indicate that generative artificial intelligence empowers middle school mathematics curriculum design to help teachers create immersive scenarios, optimize innovative teaching models, and strengthen personalized diagnostic feedback. However, there are still certain limitations in teaching methods.

This study suggests three methods to improve the teaching effectiveness of middle school mathematics curriculum design: combining generative artificial intelligence with traditional teaching methods, developing a human generative artificial intelligence mathematical knowledge construction system, and leveraging the interactive effects of mathematics teachers' learning characteristics and technical abilities.

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