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Research on the Concept Teaching of High School Mathematics Based on the 5E Instructional Model

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Abstract: *Mathematical concepts play a crucial role as the foundation in the system of mathematical knowledge. There are issues such as superficiality, excessive presupposition, and lack of analysis of essential ideas in the current teaching of high school mathematical concepts, which necessitates a transformation in the teaching approach. The introduction of the 5E instructional model can effectively address these problems and enhance teaching outcomes. The 5E model consists of five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation, aiming to guide students to deeply understand the essence and formation process of mathematical concepts through student-centered and inquiry-based activities. This paper proposes corresponding high school mathematics concept teaching strategies for each of the five phases of the 5E instructional model: introducing teaching with examples related to daily life, stories from the history of mathematics, and reviewing existing knowledge to engage students' interest; employing various inquiry methods to guide students to actively think and explore; enabling students to independently summarize and express mathematical concepts, and to analyze the essence of the concepts; applying knowledge to real-life situations and the learning of other knowledge; and using diverse assessment methods to comprehensively evaluate students' learning outcomes.*

Keywords: *the 5E instructional model; High school mathematics; Concept teaching*

1. Introduction

1.1. The 5E Instructional Model is Conducive to Reforming and Optimizing the Traditional Teaching Mode

With the deepening of education reform, the Ministry of Education of China has clearly put forward the direction of teaching reform in the "Opinions on Comprehensively Deepening the Curriculum Reform and Implementing the Fundamental Task of Cultivating Moral Education", emphasizing that teaching methods should be enlightening, discussing and participatory [1]. The new version of "Curriculum Standards for General Senior High School Mathematics (2017 Edition, Revised in 2020)" (hereinafter referred to as the "Standards") further emphasizes this point. It requires teachers to adopt diverse teaching methods such as heuristic, inquiry-based, participatory, and interactive approaches. Through various learning activities like practice, exploration, experience, reflection, cooperation, and communication, teachers can effectively cultivate students' core mathematical competencies, thus reflecting the educational value of mathematics [2]. However, in the current educational environment, although China has made progress in teaching methods, some teachers still tend to adopt traditional indoctrination teaching due to the influence of exam-oriented education, which leads to students' mechanical memory and it is difficult to deeply understand the essence of mathematics. In order to implement the requirements of curriculum reform, teachers need to actively change the traditional teaching model and explore and practice new teaching methods.

The 5E instructional model is one of the teaching modes discussed by experts and scholars many times in recent years. This model was originally applied to biology. After in-depth research and practice by experts and scholars, it has been successfully expanded to science teaching and has achieved remarkable teaching results. The 5E instructional model emphasizes the dominant position of students, encourages teachers to create situations, guides students to participate in group inquiry activities, and constantly revise, internalize and integrate the knowledge learned through interpretation and expansion, so as to develop students' mathematical literacy and ability. This model not only enriches the teaching

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methods of the teachers, improves the teaching quality, but also cultivates the students' inquiry ability, independent learning consciousness and teamwork ability, which meets the requirements of the new curriculum reform, and has obvious advantages compared with the traditional teaching model [3].

1.2. The Important Position of Mathematical Concept in Mathematical Knowledge System and Mathematics Teaching

Mathematical concepts play an important cornerstone role in the system of mathematical knowledge. Referring to the requirements of curriculum standards and combining with the transitional characteristics of senior high school, mathematics concept teaching has laid a solid foundation for students' follow-up learning. Mathematical concepts reflect the characteristics of spatial form and quantity relationships in the real world, and are an important tool to exercise students' thinking ability. Eriksson and other education experts also emphasize the core position of core concepts in subject teaching, and point out that mastering core concepts is the key to promoting the development of students' thinking and comprehensive quality [4]. In high school, students begin to be exposed to more abstract and comprehensive mathematical concepts, such as definitions, theorems, formulas, and laws, etc. Therefore, the importance of high school mathematics concept teaching is self-evident. It is not only a key node for the development of students' logical reasoning, abstract thinking, inquiry ability and innovative ability, but also a key way to realize the implementation of mathematical core literacy. As the mathematician Hua Luogeng said, "The learning process of mathematics is essentially a process of the continuous construction and deepening of mathematical concepts." [5].

1.3. The Existing Problems of High School Mathematics Concept Teaching

As the cornerstone of the subject, mathematical concepts run through the whole learning process. Although the current high school mathematics concept teaching shows some depth in some high quality courses or open courses, generally, its teaching effect still needs to be improved. High school mathematics concept teaching mainly faces the following problems: (1) the surface phenomenon of concept teaching is serious. Some front-line teachers still adopt the traditional teaching style, and pay too much attention to the direct presentation of concepts, while ignoring the formation process of concepts. This leads to students tending to memorize concepts by rote or a lot of practice, rather than actually understanding their meaning.(2) The presupposition of concept introduction and formation is too strong. Although some teachers begin to pay attention to the introduction and formation of concepts, the process is often based on teachers 'subjective experience, rather than the law of students' cognitive development. This excessively preconceived teaching method limits the opportunities for students 'independent inquiry and cooperative learning, which leads to students' vague understanding of concepts.(3) Concept teaching lacks in-depth analysis of the essence and thought. The current mathematical concept teaching mostly focuses on the analysis of the concept semantics and logic, but ignores the excavation of the essence of the concept content and the ideas behind it. Although this teaching method is helpful for students to solve mathematical problems, it is not conducive to the overall construction of students' mathematical knowledge system and the development of core literacy.

1.4. The Combination of the 5E Instructional Model and High School Mathematics Concept Teaching is Reasonable

The 5E instructional model, as an exploratory teaching model based on constructivism theory and conceptual transformation theory, is to guide students to deeply understand the occurrence and development process of concepts through self-exploration and construction. This model is highly consistent with the teaching concept of mathematical concepts emphasized in the Standard, which focuses on the process of students generation and understanding of mathematical concepts. Specifically, the 5E instructional model includes five links: engagement, exploration, interpretation, transfer and evaluation. These links are the key steps of mathematical concept teaching —— concept introduction, construction, analysis, application and summary, forming a natural correspondence relationship. This fit not only reflects the close connection between teaching model and teaching content, but also provides effective tools and methods for the improvement of high school mathematics concept teaching. At present, front-line teachers generally face challenges in teaching mathematics concepts, such as insufficient attention and time-consuming teaching design. The application of the 5E instructional model can reduce the work burden of teachers and improve the teaching effect through the phased teaching design. This model encourages teachers to guide students to conduct independent inquiry and cooperative learning, so as to deepen students' understanding of concepts and improve students' mathematical core of literacy.

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2. Research Status at Home and Abroad

2.1. Related Research on the 5E Instructional Model

In the early 1960s, Karplus designed the SCIS course by conducting Science Curriculum Improvement Research (SCIS). However, during the implementation of the SCIS curriculum, US curriculum experts found students experiencing difficulties in self-building scientific concepts. In order to solve this problem, they proposed the Atkin-Karplus learning ring teaching model, which includes three links of preliminary inquiry, concept introduction and concept application, aiming to promote students to use and consolidate the concept in new situations through students' active exploration and teachers' concept introduction [6]. In the 1980s, in order to better promote the display of students' pre-scientific concepts and the construction process of evaluating new concepts, BSCS added engagement and evaluation links on the basis of Atkin-Karplus learning ring, forming a more perfect teaching model [7]. In 1989, Based on this model, Bybee proposed the 5E instructional model supported by constructivism theory and conceptual transformation theory, including five links: introduction (engagement), inquiry (exploration), interpretation (explanation), migration (elaboration), and evaluation (evaluation) [8].

Although the engagement of the 5E instructional model in China is relatively late, many scholars have devoted themselves to the application research of this mode, and its application scope has covered different sections and subjects. Tan Juan et al. explored how to effectively apply the engagement link of the 5E instructional model in middle school biology teaching, so as to guide students to actively participate in classroom exploration and practice, promote the transformation of concepts and construct [9]. In view of the current situation that it is difficult to reflect students' subjectivity in physics teaching, Zhang Huiqing proposed to apply the 5E instructional model to physics teaching, emphasize the role of teachers as guides, respect the subject position of students, and promote the development of students' individual differences [10]. Deng Haimei used the 5E instructional model in the teaching of Graphs and Geometry, and found that it was helpful for students to construct and understand the knowledge, and also promoted the cultivation of mathematical thinking ability of students [11]. Hou Yuqun discussed the application of the the 5E instructional model in high school mathematics under the background of core literacy, and verified the positive role of this model in improving students' interest in mathematics learning, academic performance and core literacy through teaching practice [12].

2.2. Related Research on Mathematics Concept Teaching

In the field of mathematics concept teaching, He Fengbo stressed that students' cognitive characteristics should be fully considered in the teaching of mathematics concepts, and students should be guided to understand concepts from multiple angles and avoid mechanical memory. He advocated the combination of concept learning with life practice, and encouraged students to discover concepts prototypes in life to promote students' deep understanding of mathematical concepts [13]. Zhou Youshi focuses on the learning of concept change, believing that students need to go through the transformation process from former concept to scientific concept, and put forward the corresponding concept change learning model [14]. From the perspective of modern cognition, Li Shanliang puts forward three concept teaching modes: progressive mode, central diffusion model and basic expansion mode, which provides a new perspective for concept teaching [15]. Based on the psychology of mathematics education, Yu Ping put forward the teaching model of concept assimilation, concept formation and problem extension, which further enriched the theoretical system of mathematical concept teaching [16].

2.3. Literature Review

Among the many instructional models, the 5E instructional model, with its inquiry characteristics based on constructivist theory and concept change processes, has been proven effective in cultivating students' inquiry abilities in subjects such as biology. This model emphasizes student participation and autonomous exploration, guiding students in learning so that they can construct knowledge in practice and develop critical thinking and problem-solving skills. However, research and application of the 5E instructional model in mathematics teaching are still relatively few. In particular, in high school mathematics concept teaching, how to effectively integrate the 5E instructional model to enhance students' inquiry abilities, thinking abilities, and problem-solving abilities has not yet been systematically studied. Therefore, high school mathematics concept teaching based on the 5E instructional model has significant research value. This study will further explore the integration points of the 5E instructional model and high school mathematics concept teaching and continuously optimize and improve the

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teaching model to better serve the comprehensive development of students. At the same time, it is also necessary to pay attention to students' learning experiences to ensure that the implementation of the teaching model can truly stimulate students' interest and enthusiasm for learning.

3. Teaching Strategies for High School Mathematics Concepts Based on the 5E Instructional Model

3.1. Teaching Strategies for the "Engagement" Link

The "engagement" link is the starting link of the 5E instructional model, and is an important link in teaching, and its status can not be ignored. Successful engagement of concepts will quickly get students into the teaching situation. We can choose practical examples closely related to students' life and create a real problem situation with a sense of substitution. Through means such as case analysis and scenario simulation, students are placed in the context of practical problems. This guides them to identify mathematical problems, thereby stimulating their interest in learning. Alternatively, classic stories and significant discoveries in the history of mathematics can be used to provide a historical backdrop for introducing new concepts. By recounting the exploration journeys and achievements of mathematicians, students' thirst for knowledge and spirit of inquiry are sparked. Meanwhile, it enables them to understand the context and evolution of mathematical knowledge. Reviewing prior knowledge to find the connections with new concepts helps students build a knowledge network. Through methods like questioning and discussion, students are led to recall previous knowledge and uncover the relationships between old and new knowledge, laying the groundwork for learning new concepts.

3.2. Teaching Strategies for the "Exploration" Link

The "exploration" is the central link of the the 5E instructional model, and the process of students to construct mathematical concepts. In this link, the teacher guides students to think actively and carries out inquiry activities with students as the center. When encountering problems in the process of inquiry, teachers can not directly tell students, but give appropriate guidance, guide students to solve problems, so that students can get something in the process of inquiry. In the current teaching environment, there are multiple forms of mathematical inquiry. Different forms of inquiry should be adopted for mathematical knowledge of different natures. Teachers can make use of teaching aids and charts to enable students to observe and analyze, and draw conclusions through discussion. It is advocated that students explore actively through independent thinking to discover new knowledge. This can fully arouse students' interest in learning and develop their abilities in various aspects. Teachers can ask questions through stories, data or network information, and teachers and students can discuss them together, so that students can use rational thinking to reason and draw conclusions. In the process of discussion, teachers should induce students to draw conclusions in the form of questions, rather than telling them the conclusions directly. The teacher also leads the students to conduct exploratory teaching, so that the students can understand the production process of the concept, understand the meaning of the concept, and have a more thorough understanding of the concept. Experimental teaching will make the boring mathematics knowledge vivid and interesting, so it is welcomed by the majority of students, and can well mobilize the enthusiasm of students.

3.3. Teaching Strategies for the "Explanation" Link

The "explanation" link is the key link of the the 5E instructional model, which is an in-depth understanding of the essential attributes of the concept. Teachers should give the students the opportunity to express their ideas and understanding, and guide the students to summarize, and use the professional terms to express the mathematical concepts scientifically and accurately. Through the last inquiry link, students' thinking is fully active and eager for their ideas to be listened to, understood and respected. So teachers can make use of this psychology, give students fully express space and encourage students to express their ideas, teachers properly explain, correct and induction, through guide step by step, encourage students to form mathematical concept consciousness and teachers to each key words, key points to analyze, to help students understand the concept of the connotation and extension, thoroughly understanding the nature of mathematical concept, the understanding of mathematical concept is not limited to the literal meaning.

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3.4. Teaching Strategies for the "Elaboration" Link

The "elaboration" link is the strengthening link of the the 5E instructional model, but also the extension link. On the basis of concept formation, different transfer exercises are set up according to students at different levels, and knowledge is applied to real life to make abstract concepts concrete. Each student is a unique individual. Therefore, different students have different levels of understanding of mathematical concepts. In order to avoid the situation where "underachievers can't handle it while high achievers aren't challenged enough", exercises should be set at different levels according to the students' proficiency levels, so as to ensure that "high achievers are fully engaged, average achievers make good progress, and underachievers can absorb the knowledge well". Students' mastery of concepts should not merely rest on the understanding of abstract concepts and the interpretation of definitions. Instead, they should learn to apply them in practice and use the principles of the concepts to solve some actual mathematical problems. This way, students can appreciate that mathematical knowledge is close to life and has practical value.

3.5. Teaching Strategies for the "Evaluation" Link

The "evaluation" link is the reflection link of the the 5E instructional model, and also the summary link. In the teaching process, the teachers observe the students' performance in class by asking questions and listening, and make some evaluation of the students effectively, and guide the students to conduct self-evaluation and mutual evaluation. The standard of evaluation is not limited to knowledge, but also should be evaluated from the aspects of students' comprehensive ability. To achieve diversified and unified evaluation standards, so that students can achieve the joy of success in learning, and maintain a strong interest in learning, so as to promote the all-round development of students.

The 5E instructional model is developed on the basis of inquiry teaching, paying more attention to students' participation, communication and expression ability and emotional attitude in inquiry. Students' self-evaluation is a kind of cognition of students' performance of their performance in classroom learning. These indicators are diverse, such as knowledge mastery, classroom participation, interest and so on. Self-evaluation is conducive to students monitoring their learning behavior for self-reflection, improving their problem-solving ability and improving their learning initiative. Mutual evaluation of students is a kind of evaluation of the performance of group members in class. Through the objective evaluation of others, they can more accurately and clearly realize their own advantages and disadvantages, and constantly improve themselves and form a virtuous circle. Teachers are the main body of evaluation that can not be ignored. Teachers should evaluate students comprehensively and objectively, grasp the shining point of each student carefully, and evaluate students' classroom performance, learning ability and emotional attitude with concise and inspiring language. Therefore, diversified evaluation methods should be adopted for the comprehensive evaluation of students. In addition, in this link, some teachers only judge the learning effect of students by using paper tests, and regard the score as a yardstick to evaluate everything. Although scores are somewhat a yardstick of evaluation, they are not absolutely the only measure. In the process of inquiry, more attention is paid to the comprehensive performance of students, that is, whether students actively participate in inquiry activities and group discussions. Therefore, in the evaluation process, the evaluation should be conducted from many aspects.

4. Conclusion

This study focuses on the teaching of high school mathematics concepts based on the 5E instructional model. It deeply analyzes its importance and existing problems and proposes targeted teaching strategies. The organic combination of the 5E instructional model and high school mathematics concept teaching can break the deadlock of traditional cramming teaching, highlight the dominant position of students, and help students deeply understand the essence of mathematical concepts in each link of exploration, explanation, transfer, and evaluation, build a sound knowledge system, and improve their core mathematical competencies. Diversified teaching strategies, such as creating situations in the engagement stage, conducting multiple explorations in the exploration stage, providing precise guidance in the explanation stage, setting hierarchical exercises in the transfer stage, and implementing multiple evaluations in the evaluation stage, fully consider individual differences among students and stimulate their interest and enthusiasm for learning. In future teaching practices, continuously optimizing the application of the 5E instructional model will inject new vitality into high school mathematics concept teaching and promote students' all-round development to a new level.

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