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A Review of Research on High School Mathematical Modeling Teaching Models under the Concept of STEAM Education

Yanzi Chen*

Hangzhou Normal University, Hangzhou 311121, China

**Corresponding author: Yanzi Chen, E-mail: 2365233500@qq.com.*

Abstract

In recent years, the research on the STEAM education concept and mathematical modeling has become an academic hotspot. With continuous advancements in education policies, the teaching model of high school mathematical modeling under the STEAM framework has shown new development trends. This paper analyzes how this teaching approach can theoretically align with curriculum standards and support the ongoing reforms in basic education. STEAM education emphasizes interdisciplinary integration, hands-on inquiry, and innovation, making it highly compatible with mathematical modeling, which serves as a crucial practical component of mathematics. Integrating STEAM principles into mathematical modeling instruction can enhance students' core competencies, promote subject integration, and improve their ability to apply mathematical concepts in real-world contexts. In terms of practical research methods, this paper identifies three key approaches: a multi-stage and multi-mode research framework, the establishment of competency-based evaluation criteria, and project-based learning (PBL) applications. Additionally, two strategic improvement plans are proposed: first, engaging five key groups—students, teachers, school administrators, policymakers, and parents—to collaboratively refine the teaching model; second, drawing insights from international teaching practices to expand the depth and scope of localized implementation. Finally, the paper suggests that future research should focus on diversifying methodologies, designing comprehensive teaching cases, and extending research durations to provide valuable references for innovative practices in mathematics education.

Keywords

STEM education, mathematical modeling, high school students

1. Introduction

The STEM education concept emphasizes the organic integration of science, technology, engineering and mathematics, aiming to develop students' comprehensive literacy and innovation ability. Mathematical modeling refers to transforming problems encountered in real life into mathematical problems and using mathematical models to solve these real-life problems. The specific process includes posing a problem from a real-life situation, searching for a model to build, solving the model and checking the results, conforming

to the actual results if the results are realistic and re-building the model if they are not, and finally evaluating whether the solution is effective or not.

There are many similarities between mathematical modeling and STEM education concepts. Mathematical modeling is based on mathematical ideas and aims at solving real problems. In the process of modeling, we need to pay attention to the actual background of the problem and apply interdisciplinary knowledge to solve the problem, and this process helps to develop our practical ability and innovative thinking. Coincidentally, this process complements the emphasis of STEM education on the development of application and innovation skills. In addition, STEM education can help students master the methods and techniques of mathematical modeling more quickly and improve their learning efficiency. Therefore, integrating STEM education into mathematical modeling activities is a very feasible approach.

2. Main Elements of the Study

Based on the principle of bibliometrics, the author searched and analyzed the data on Chinese Journal Network and Scientific Research Publishing with the subject terms “STEAM education”, “high school mathematical modeling” and “teaching mode of high school mathematical modeling under the concept of STEAM education”, respectively. “High school mathematical modeling teaching mode under the concept of STEAM education” were searched, analyzed and counted. The retrieved documents were read and analyzed one by one. The search shows that there are 29 research papers on the issue of “teaching mode of high school mathematical modeling under the concept of STEAM education”, while there are 5956 papers on “STEAM education”, 5956 papers on “high school mathematical modeling” and 5956 papers on “high school mathematical modeling”. The total number of literature on “high school mathematical modeling” is 1848. In terms of the temporal distribution of the literature, the search shows that the number of literature on the above three subject headings has increased significantly in recent years. Comprehensively analyzing these literatures, it can be found that the current theoretical and practical research on the teaching mode of high school mathematics modeling with the concept of STEAM education mainly focuses on the following main aspects.

2.1 Theoretical Understanding on the Integration of STEAM Education Concepts in Mathematical Modeling Teaching in High Schools

At present, there is not much academic research on high school mathematical modeling teaching based on the concept of STEAM education, and the statistics show that only 29 pieces of literature have been targeted to explore this, mainly focusing on STEAM emotions, attitudes, beliefs and project evaluation, and curriculum development, literacy connotation and competence structural framework related to STEAM is also a hot topic. However, the classroom design of how to combine the teaching of mathematical modeling with the concept of STEAM education at the high school level still needs to be further explored and improved, and at the theoretical level, the core problem lies in how to accurately position the role of mathematics in STEAM education. To summarize there are mainly two representative views.

One viewpoint holds that the design of high school mathematics modeling courses under the perspective of STEAM should pay attention to the characteristics of the discipline and the cognitive laws of students, and combine the basic elements of STEAM education concepts and curriculum design theories, and carry out the curriculum design from the six basic elements: curriculum concept, design principles, curriculum objectives, curriculum content, teaching methods and evaluation mechanisms. Su and Chen (2022) believes that high school mathematics modeling teaching integrating STEAM education concepts should focus on the task requirements of the students' curriculum stage and the actual development of students' thinking, so as to make a good curriculum design. Qian (2021) analyzes two STEAM cases in the United States and shows the design and implementation of the project “Birdwatching & Bird Nest Modeling”, which confirms the feasibility of STEAM in combining the curriculum standards and extending classroom teaching. Xie (2024) agreed that the integration of mathematical modeling into STEAM is a feasible way to develop relevant teaching and learning for students. It is also operable and adaptable. In this regard, Hu and Jiang (2019) also expressed similar views in their respective papers.

Another viewpoint is that in China, the integration of STEAM education into high school mathematics modeling teaching is an important means of curriculum reform in basic education. Y. Liu (2023) believes that one of the key features of Freudenthal's mathematical education proposition is the close connection to reality, i.e., the connection between mathematics and the real world internally and between mathematics and other disciplines, which is in line with the concept of STEAM emphasizing interdisciplinary learning based on authentic contexts. Moreover, STEAM education emphasizes the authenticity of the context, which usually requires students to work in teams to complete projects using multidisciplinary knowledge to enhance students' learning ability, practical ability and innovation ability; at the same time, compared with STEM education, STEAM education integrates "A", a comprehensive humanistic art, into classroom design, which can help students optimize their knowledge in different disciplines. At the same time, compared with STEM education, STEAM education integrates "A", a comprehensive humanistic art, into the classroom design, which can help students optimize the understanding and application of knowledge from different disciplines, and help to make up for the shortcomings of subject-specific teaching (Zong & Li, 2019). Zhang and Xu (2021) pointed out that the concept of STEAM education through the clarification, reconstruction, reform and transformation of the way to achieve organic integration with the teaching of mathematics education, and through the implementation of real-life situations based on the theme-based teaching. For example, "Learning in Ramen," "Planetary Distance Formula," "Summer Vacation Outing Plan," "Comfortable Neighborhood Environment ""The secret of sunflower"" and 'The secret of numbers in the Temple of Heaven' (Zhong, 2022) are good teaching cases, which shows that STEAM education is conceptually compatible with the reform of mathematics teaching.

In summary, although researchers have different starting points, there is a consensus on the understanding of high school mathematics modeling teaching mode under the concept of STEAM education, i.e., they all believe that it should be student-oriented, and at the same time, it can help the reform of mathematics education. The difference is that the former is defined more from the micro level of students' learning situation and cognitive structure, while the latter is analyzed more from the macro level of promoting the reform of mathematics teaching.

2.2 On the Practical Approach of Mathematical Modeling Teaching Mode in High Schools under the Concept of STEAM Education

In the existing research, although different scholars have different research strategies on the way of practicing the teaching mode of high school mathematics modeling under the concept of STEAM education, basically the research is conducted from three perspectives:

The first perspective is to cultivate students' modeling ability from the perspective of multi-stage and multi-mode. For example, Weng (2022) proposed a "five-stage, five-link" teaching model, which achieves the cultivation effect through five stages of analysis, design, development, implementation, and evaluation, and five links of presentation, analysis, design, production, and reporting. Each of these stages is designed under the concept of STEAM education, and scientific knowledge, technological means, engineering thinking and artistic thinking are integrated into the design of the entire senior secondary mathematics activity class. This model allows students to feel the STEAM education concepts in each stage of the mindset and learning ability to improve, such as consulting the theory of teaching models (Yao & Su, 2022) to realize the scientific rigor; use of modern educational technology such as MATHEMATIC (Xie, 2024) operation to improve the practical ability.

The second viewpoint establishes mathematical modeling literacy evaluation indexes to assess students' literacy level by quantitative means. Unlike the former view, this view is more intuitive and palpable in terms of the effect of teaching. Based on the understanding that STEAM education develops students' modeling literacy through the four major elements of establishing interdisciplinary integration, solving real-world problems, fostering students' innovative thinking, and constructing an evaluation index system (H. Liu, 2023), a multi-dimensional evaluation index system was established in Su and Chen's (2022) study. "Communication and Collaboration" and 'Transformation of Results'. And under each first-level indicator, there are corresponding second-level indicators and four different levels of level division, and the group evaluation is carried out with the mathematical modeling activity group as the evaluation object (Xing, 2022).

It can be seen that the teaching mode under this viewpoint is an organic integration of “course-activity-evaluation”, which breaks down the teaching content and is more intuitive to quantitatively assess the learning effect of students after the course.

The third viewpoint emphasizes the implementation of project-based learning. Although all of them analyze the practice of teaching mode from the perspective of project-based learning, under the premise of general consistency in content, there are also differences in research perspectives, and the focus of the research content is also different. Zhang and Ran's (2020) study explores the construction of a project-based learning model of mathematical culture as a breakthrough. Ji (2024), on the other hand, started from “creating real situations”, “reasonably penetrating the knowledge of various disciplines, cultivating students' sense of transfer, helping students establish the connection between mathematics and other disciplines”, “creating learning communities”, “showing the construction of the project”, “creating a learning community”, “creating a learning community”, and “creating a learning community”, “showing the whole process of modeling”, “focusing on multi-angle, multi-faceted, multi-subjective and diversified evaluation of student learning” four steps to carry out the study, emphasizing the standardization of the research steps. However, both studies adopted a heuristic approach to allow students to actively participate in learning, learn the project-based learning steps of identifying problems, posing problems, analyzing problems and solving problems (Ben et al., 2023), and experience the project process of initiating project activities, task planning, carrying out activities, and evaluating the presentation of their works, so as to cultivate interdisciplinary competence, critical thinking, teamwork, and innovation skills.

2.3 A Strategic Study on Improving the Teaching Model of Mathematical Modeling in High Schools under the Concept of STEAM Education

Despite the many advantages of STEAM education, there is still more room for improvement in combining it with the actual teaching of mathematical modeling in China. Improvement of this teaching mode is also the core and difficult issue of the research. In a comprehensive view, the relevant research mainly discusses from two perspectives, namely, internal enhancement and external borrowing.

First, from the perspective of internal enhancement, in general, it is mainly from the five groups of curriculum developers, textbook writers, school administrators, teachers, and students (Cheng, 2021) to provide enhancement strategies and methods. Hong (2023) believes that the main problems in building a STEAM curriculum resource base at present are the insufficient total number of courses and the lack of high-quality curriculum resources. Therefore, relevant courses should be developed to enrich curriculum resources, such as setting up a specialized STEAM curriculum development team, building a curriculum resource sharing platform, and holding a STEAM teaching competition. X. Liu (2023), on the other hand, believes that STEAM teaching materials should be written and reference materials should be standardized. At this stage, most of the concepts of utilizing STEAM education are from the cases of teaching materials of various disciplines, and there is no substantial interdisciplinary integration of teaching. Therefore, it is possible to collect cases of problem solving using multiple disciplines and prepare them in stages according to the difficulty of the problem and the academic level in which the knowledge points are located. Zhang and Ran (2020) believes that it is necessary to strengthen the localization of STEAM education and implement school-based curriculum teaching. Dai (2023) thinks that when teachers prepare lessons, they should study the teaching materials in depth, trace the source of knowledge, find the intersection of mathematical knowledge and knowledge of other subjects in mathematical modeling ideas, use STEAM education and mathematical modeling as teaching tools to teach knowledge, and build a platform for exploration and a framework for thinking for students by using inquiry-based learning and project-based learning methods. These perspectives, in common, help students to engage in meaningful learning and develop active construction of knowledge systems and problem-solving solutions.

The second, from the perspective of external borrowing, is different from the former view, which is mainly based on the current stage of the U.S. approach to the enhancement of STEAM education to supplement the domestic teaching methods. Cai and Chen (2022) pointed out that the U.S. STEAM education policy has the challenge of facing the design of the educational system, the curriculum and the synergistic operation of the educational ecosystem. For China, the revelation lies in focusing on the fairness

mechanism in the system design, integrating the concept of new liberal arts construction in the curriculum, and establishing a mechanism of multi-body participation of the government, schools and social resources in the construction of the educational ecosystem, so as to implement mathematical modeling education more effectively and cultivate talents with innovative and practical abilities. The reasonableness of Cai Hongmei's viewpoint lies in her deep insight into the differences and commonalities between STEAM education in China and the United States, and her emphasis on the importance of localized development based on national conditions.

3. Problems and Research Outlook

3.1 The Methodology of the Study is More Homogenous and Not Sufficiently In-depth

Most of the current practical research on the teaching mode of mathematical modeling under the concept of STEAM education focuses on case study and teaching activity design, and the research method is relatively homogeneous, and most of them adopt the project-based learning method to carry out practical research. Some research design projects focus on over-packaging of research content, which makes it easy for students to ignore the essence of knowledge in interdisciplinary learning and pay more attention to the novelty of disciplinary integration, which does not give feedback on good learning effects. In addition, the collaborative design of the study made students dependent on others' views in group communication, and the results of the students' post-tests in the study showed that some students still had not internalized the classroom knowledge. Therefore, the research design of the project needs to be more relevant to students' realities and emphasize the balance between presetting and generating, so as to promote students' real gains in cooperative learning.

3.2 Instructional Cases of Research Design Are More Scarce and Insufficiently Covered

Most of the studies show that there is a dearth of development and practice of instructional cases with limited coverage. Most of the scholars developed only one or two instructional cases for instructional design, failing to comprehensively cover different textbook versions and different grade levels, and the generalizability is not strong. In addition, the interdisciplinary cases studied mainly focused on physics, biology, and information technology, while other disciplines were not adequately addressed. Future research needs to continue to explore the practical ways of teaching mathematical modeling in high school under the concept of STEAM education and improve the case development to enhance the persuasiveness and generalizability of the findings.

3.3 The Study Was Conducted Over a Relatively Short Period of Time and There Were Limitations in the Sample

The short duration of the study and the limitation of the sample is another challenge for most of the current scholars in conducting such studies. The researcher usually completes the study within a week and the sample is limited to high school students in a single school, which limits the breadth and depth of the study. Meanwhile, the research practice was limited to the researcher's local school and did not take into account the effects of geographical and academic differences, which made the sample more restrictive and left room for improvement in the persuasiveness of the findings. To improve this shortcoming, future research should expand the application of empirical survey methods, increase the sample size and research time to ensure the comprehensiveness and accuracy of the findings.

4. Conclusion

In summary, the teaching model of high school mathematical modeling under the concept of STEAM education faces challenges such as single method, insufficient cases and short time. In order to deepen the research, improvements in method diversification, case comprehensiveness and time extension are needed to promote the deeper development of the research.

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