A Comparative Study of Mathematical Modeling of Senior Middle School in China, German and the United States

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Abstract. This study compares the contents of mathematical modeling in senior high school mathematics curriculum standards of China, Germany and the United States from five aspects. It is found that all countries attach more importance to mathematical modeling, but they have their own characteristics. The content of modeling in China is relatively rich, but the specific teaching implementation requirements are relatively low; the teaching requirements of the American curriculum standards for mathematical modeling are more detailed, the evaluation is more specific, and the operability is strong; the German curriculum standards emphasize the cultivation of mathematical modeling ability, and the evaluation emphasizes the compatibility of teaching content and test content. In addition, it is suggested to develop the teaching cases of mathematical modeling, supplement the curriculum standard, increase the number of mathematical modeling activities, infiltrate it into all parts of high school mathematics, promote the construction by evaluation, and fully reflect the mathematical modeling in the evaluation.

Keywords: High school · Mathematical modeling · China · Germany · USA

1 Introduction

For more than half a century, mathematical modeling has played an increasingly significant role in many fields such as engineering technology and natural science, and has penetrated into the fields of economy and finance, biomedicine, artificial intelligence, aerospace and so on at an unprecedented speed and breadth. Therefore, countries have promoted the development of mathematical modeling in primary and secondary school curriculum. The United States began to hold the High School Mathematical Contest in Modeling (HiMCM) [1] in 1999, and then added mathematical modeling to the mathematics curriculum of primary and secondary schools [2]. Germany also began to identify mathematical modeling as one of the six mathematical abilities in the mathematics curriculum standard in 2003 [3]. At the same time, the International Association for the Evaluation of Educational Achievement (TIMSS) and the Programmer for International

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Student Assessment (PISA) take mathematical modeling ability as an important evaluation content, which also promotes the promotion and development of mathematical modeling in primary and secondary schools to a certain extent [4]. Before 2000, the content of mathematical modeling rarely appeared in the mathematics curriculum of primary and secondary schools in China [5]. The mathematics curriculum standard of regular senior secondary school (experimental draft) (hereinafter referred to as "03 curriculum standard") issued in 2003 listed mathematical modeling as the content of mathematics curriculum of high school for the first time, and the mathematics curriculum standard of regular senior secondary school (2017 edition) (hereinafter referred to as "17 curriculum standard") issued in 2018 listed mathematical modeling as one of the six core qualities, mathematical modeling as the main line of curriculum content ran through the whole high school mathematics curriculum, which further strengthened the position of mathematical modeling in high school mathematics [6].

The research on mathematical modeling in senior high schools in China was earlier than the time when mathematical modeling appeared in the curriculum. The theoretical research of mathematical modeling in senior high school was still in its infancy, and the progress of practical exploration was relatively lagging behind. In the early 1990s, some researchers proposed the implementation of mathematical modeling in middle schools [7], and some researchers began to introduce the situation of mathematical modeling abroad [8]. Around 2000, with the needs of the new curriculum reform, the academic community also discussed the problems related to mathematical modeling in senior high school. The research content and perspective were slightly expanded, including the elaboration and analysis of the value of mathematical modeling [9], as well as the discussion of mathematical modeling teaching [10] and evaluation [11]. However, at this time, most of the research was theoretical assumption, with few breakthroughs at the practical level. The addition of mathematical modeling in "03 curriculum standard" had driven relevant research to a certain extent, but the overall impact was limited. Mathematical modeling had not been paid attention to in teaching, and few schools carried out mathematical modeling activities. In the process of revising "03 curriculum standard", the research on mathematical modeling gradually increased, and the research focus also began to expand, involving the historical review of mathematical modeling [12], the comparative research on the compilation of mathematical modeling content in teaching materials [13] and the investigation of the current situation of mathematical modeling ability [14, 15]. These studies provided a reference and basis for the revision of the curriculum standard to a certain extent, and also laid a solid foundation for the follow-up practical research of mathematical modeling. With the promulgation of "17 curriculum standard", the relevant researches were of more practical implications, involving the research on the cultivation of students' modeling ability [16, 17] and the research on the evaluation of mathematical modeling [18]. However, the research on mathematical modeling in senior high schools in China is still in its infancy, lack of practical experience and insufficient depth and breadth of theoretical discussion. It is urgent to make a more extensive and in-depth exploration from the aspects of mathematical modeling teaching and evaluation [19]. In contrast, the teaching research on mathematical modeling in senior high school abroad is more, and the content involved is more extensive. It has accumulated rich experience in practical teaching and formed more teaching cases [20]. This study analyzed the

characteristics and similarities and differences of the setting of mathematical modeling content in the high school mathematics curriculum standards of China, Germany and the United State, and fully explored the advantages and disadvantages of the setting of Chinese high school mathematics modeling curriculum, so as to provide reference for the teaching of high school mathematics modeling.

2 Research Contents and Methods

This study took the high school mathematics curriculum standards in China, Germany and the United States as the research objects. The high school mathematics curriculum standards in China were [6] issued in January 2018 (2017 edition); the high school mathematics curriculum standards (Bildungsstandards im Fach Mathematik für die Allgemeine Hochschulreife) [21] were issued in Germany in 2012; the Common Core State Standards for Mathematics were issued in 2010 in the United State [22]. With the help of content analysis method, this study analyzed and compared the content setting of mathematical modeling in high school mathematics curriculum standards of China, Germany and the United State from five aspects: the positioning of mathematical modeling, the goal of mathematical modeling, the content of mathematical modeling, the teaching requirements of mathematical modeling and the evaluation of mathematical modeling. The specific comparison framework is shown in "Fig. 1".

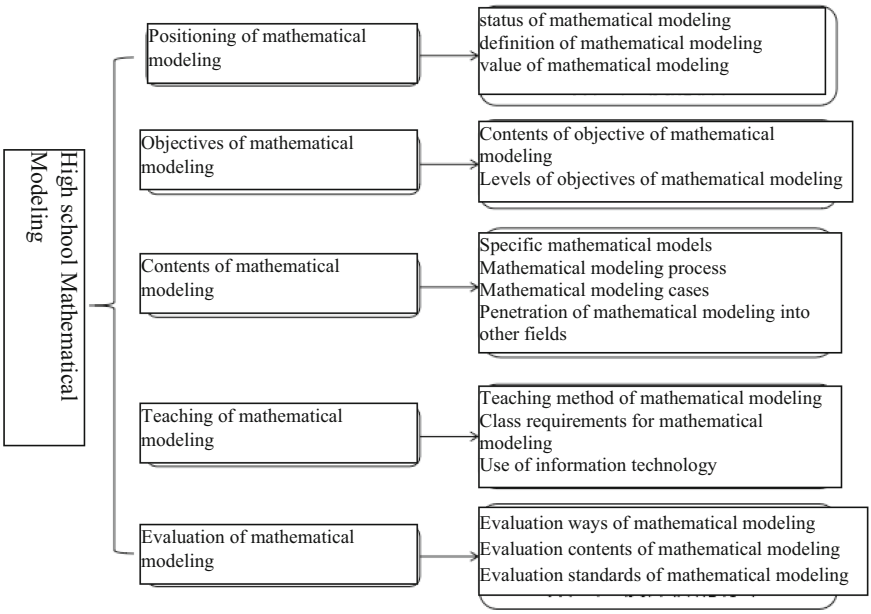

Fig. 1. Framework of mathematical modeling comparison in senior high school.

3 Research Results and Analysis

3.1 Positioning of Mathematical Modeling

The status, definition and value of mathematical modeling in the mathematics curriculum standards of the three countries are reflected in the setting of the mathematics curriculum structure of senior high school, the elaboration of the connotation of mathematical modeling and the function of mathematical modeling.

The position of mathematical modeling in high school mathematics curriculum structure shows the position of curriculum standard developers in mathematical modeling. Mathematics modeling is regarded as one of the six core qualities in the mathematics curriculum standards of senior high schools in China. Meanwhile, it is also used as a main line of content, which runs through the contents of compulsory, selective compulsory and elective courses. Mathematics modeling activities are set in the compulsory and selective compulsory courses, and the specific contents of mathematics modeling are set in the elective courses, including the models of elective class B (linear model, quadratic curve model, exponential function model, trigonometric function model and parameter variable model) and the mathematical models of class C (deposit and loan model, economic growth model, population growth model, credit evaluation model, etc.). The high school mathematics curriculum standard in Germany constructs a four-dimensional model including mathematics core competence, ability level, mathematics core thought and curriculum stratification, in which mathematical modeling is regarded as one of the six core competence levels. The high school mathematics curriculum standard in the United State takes mathematical modeling as a content module, which juxtaposes with number and quantity, algebra, geometry and probability statistics. In addition, mathematical modeling is the main content of the curriculum and is one of the eight important contents in mathematical practice. Besides, mathematical modeling and its ideas are infiltrated into other fields. The status and importance of mathematical modeling are highlighted in the curriculum standard structure of the three countries. The mathematical modeling is regarded as an important curriculum goal and curriculum content in the Chinese curriculum standard, an important ability goal in the German curriculum standard, and an important curriculum content and practical requirement in the American curriculum standard.

The definition of mathematical modeling in the curriculum standard reflects the essence of mathematical modeling. According to the Chinese curriculum standard, mathematical modeling is the ability to mathematically abstract real problems, express problems in mathematical language, and use mathematical methods to build models to solve problems. The German curriculum standards believe that mathematical modeling is the mutual transformation among the real situation and mathematical concepts, mathematical conclusions or methods. According to American curriculum standards, mathematical modeling is the process of selecting and using appropriate mathematical and statistical data to analyze the actual situation, better understand them and improve decision-making. It could be seen that there were great differences in the definition of mathematical modeling in the curriculum standards of the three countries. According to the Chinese curriculum standards, mathematical modeling is a kind of literacy. German and American curriculum standards emphasize the process of mathematical modeling.

German curriculum standards emphasize that modeling is the process of interaction and transformation between reality and mathematics, while American curriculum standards emphasize the process of model construction and improvement.

The explanation of the value of mathematical modeling in the curriculum standard also reflects the understanding of mathematical modeling. The Chinese curriculum standards believe that "mathematical modeling builds a bridge between mathematics and the external world. It is an important form of mathematical application, the basic means of applying mathematics to solve practical problems, and also the driving force to promote the development of mathematics." The American curriculum standards believe that "mathematical modeling links classroom mathematics and statistical data with daily life, work and decision-making. Quantities and their relationships in physical, economic, public policy, social and everyday situations can be modeled using mathematical and statistical methods." In terms of value, there is no clear discussion in German curriculum standards. Therefore, Chinese curriculum standards emphasize the instrumental nature of mathematical modeling. On the one hand, mathematical modeling is a tool for applying mathematics to solve practical problems; on the other hand, it is also a tool to promote the development of mathematics. American curriculum standards emphasize the media of mathematical modeling. On the one hand, mathematical modeling connects mathematics with daily life; on the other hand, it connects mathematics with other disciplines.

3.2 Objectives of Mathematical Modeling

The goal of high school mathematical modeling refers to the learning results expected of students in high school mathematical modeling teaching activities. At the same time, it is a description of the level to be achieved after students' learning of mathematical modeling content, is also the standard and basis for the evaluation of mathematical modeling teaching effect, and also plays a guiding and normative role in the teaching of mathematical modeling.

And Chinese curriculum standards explain the goal of mathematical modeling in two places. According to the "curriculum objectives", it can be concluded that through the study of mathematics curriculum in senior high school, students learn to use mathematical models to solve practical problems and accumulate experience in mathematical practice; students understand the role of mathematical models in many fields such as science, society and engineering technology, improve practical ability, and enhance innovation consciousness and scientific spirit. In the "academic quality standard", three levels of specific requirements for mathematical modeling are put forward. These requirements are distributed in different positions and show a distinct trend from being easy to being difficult (from understanding the background, significance and process of mathematical modeling to being able to choose models to go through the modeling process, and then to creatively establish models to solve problems).

German curriculum standards also put forward three levels of requirements for mathematical modeling. The requirements of the three levels are also different in degree of difficulty, but they are mainly reflected in the conditions and complexity of modeling situations, from no conditions to certain conditions, and then to their own independent

selection of conditions, from students' familiar situations to changed situations, and then to complex situations.

The goal of mathematical modeling in the American curriculum standards is as follows. Students are able to apply what they know and make assumptions and approximations to simplify complex situations, and are aware that these may need to be revised later. Besides, students are able to identify important quantities in actual situations and map their relationships using tools such as charts, two-way tables, charts, flow charts and formulas. These relationships can be analyzed mathematically and a conclusion can be drawn. In this case, it is suggested to explain their mathematical results and think about whether the results are meaningful. If the model does not achieve its purpose, it may improve the model.

It could be seen that the setting of mathematical modeling teaching objectives in the three countries were different. From the description characteristics of the goal, Chinese curriculum standards not only have the overall description, but also have the specific hierarchical description, with clear levels, highlighting the differences in the requirements of the modeling process. The goal of mathematical modeling in German curriculum standards is also in hierarchical design, highlighting the differences of modeling conditions and situations; and American curriculum standards put forward specific goals for each step according to the modeling process. From the specific content of the goal, Chinese curriculum standards involve the content and function of modeling, the process and improvement of modeling and specific models; German curriculum standards involve the type, establishment and evaluation of models; and American curriculum standards involve the process and evaluation of modeling.

3.3 Contents of Mathematical Modeling

Through the analysis of three curriculum standards, it is found that the curriculum contents related to mathematical modeling in the three curriculum standards mainly include the introduction of specific mathematical models, cases of mathematical modeling, the process of mathematical modeling and the penetration of mathematical modeling in other mathematical fields.

Among the three standards, only China's curriculum standard has set up special content to introduce the specific mathematical model. Basic mathematical models (linear model, second-order polynomial model, trigonometric function model and parameter variable model) are set in elective class B courses, and two types of mathematical models, economic mathematical models (deposit and loan model, input-output model, economic growth model, Keynesian model, production function model) and social models (grade evaluation model, population growth model and reliability evaluation model) are set in elective class C courses.

The cases of mathematical modeling in the three countries are also different. In the appendix "teaching and evaluation cases", the Chinese curriculum standards set up seven cases of mathematical modeling, such as parking distance, height of buildings inside and outside the surveying school, shoe size, packaging rope, weight and pulse, estimating the total number of candidates, and introduce and analyze the purpose of case setting, situation and modeling process in combination with specific problems. Also, four cases are listed in the fourth part of German curriculum standard "explanatory test paper for

obtaining the admission qualification of ordinary university of mathematics", such as drug treatment effect, cube, seal and air ticket reservation. Four cases are also designed in the fifth part of the standard "explanatory learning task on the selected education standard of mathematics for senior high school graduation", and three of them (inventory change, ticket reservation, cost calculation) involve the application of mathematical modeling. The American curriculum standards list eight specific cases, namely:

- How much water and food are needed for emergency relief in affected cities with an estimated 3 million people and how they are distributed.
- It is planned to hold a table tennis game for seven players in a club with four tables, where each player will compete with each other.
- Design the booth layout of the school fair to raise as much money as possible.
- Analyze the stopping distance of the car.
- Simulate savings account balances, bacterial colony growth or investment growth.
- Carry out critical path analysis, such as being applied to the turn back of airport aircraft.
- Analysis of risks in situations such as extreme sports, epidemics and terrorism.
- Link demographics to personal projections.

On the whole, the cases in Chinese curriculum standards are closer to students' real life, and the problems in the United States and Germany are more social and attractive to students. In terms of the number of cases, there is little difference among the cases in the curriculum standards of the three countries. From the detailed description of the cases, the cases in the curriculum standards of China and Germany are more detailed, and the cases in the curriculum standards of the United States only have names. From the perspective of the openness of cases, the cases in the American curriculum standards are more open, whether they are cases, or possible modeling processes or results.

Mathematical modeling cycle and mathematical modeling steps are important means to describe the process of mathematical modeling. The main steps of mathematical modeling activities in the Chinese curriculum standards include: finding problems from the perspective of mathematics in the actual situation, putting forward problems, analyzing problems, building models, determining parameters, calculating and solving, testing results, improving models, and finally solving practical problems (see "Fig. 2"). The steps of mathematical modeling in the German curriculum standards include: structuring and simplifying the real situation (finding the real model), translating the real model into a mathematical model (mathematical problem), solving mathematical problems, interpreting mathematical results in combination with the real situation, and testing the results from the perspective of consistency and appropriateness with the real situation. And the American curriculum standards list the basic modeling cycle, including: identifying the variables in the situation and selecting the variables representing the basic characteristics, establishing the model by creating and selecting the geometric, graphic, table, algebraic or statistical representation describing the relationship between variables, analyzing and executing the operation of these relationships to draw conclusions, interpreting the mathematical results according to the original situation, verifying the conclusions by comparing the conclusions with the actual situation, improving the model, or reporting the conclusion and the reasoning behind it (see "Fig. 3").

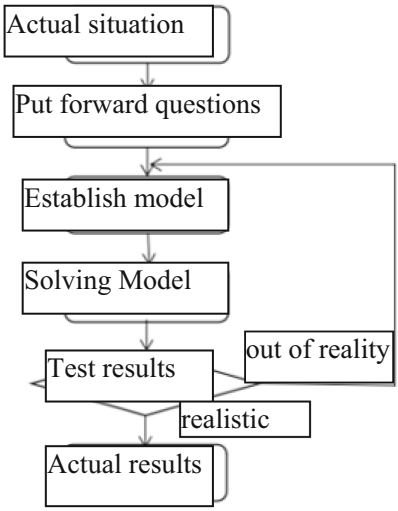

Fig. 2. Modeling process in Chinese curriculum standard.

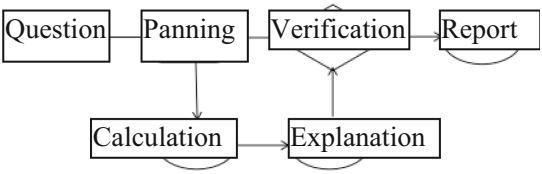

Fig. 3. Modeling process in American curriculum standard.

The three curriculum standards describe the process of mathematical modeling in detail, and China and the United States also draw flow charts. From the steps of the modeling process, the Chinese curriculum standard lists eight steps (several steps are combined in the flow chart), four steps in Germany and six steps in the United States; From the characteristics of the process content of mathematical modeling in the curriculum standards of the three countries, the Chinese curriculum standards highlight the situational nature and reflect the ideas of discovering, raising, analyzing and solving problems; the German curriculum standards emphasize the interaction between reality and mathematics. On the one hand, it is the interaction between the simplified situation model and mathematical model of the real situation. On the other hand, it is the interaction between mathematical results and the real situation. Meanwhile, the American curriculum standards emphasize the problem; the modeling process emphasizes the interpretation of the model, highlights the characteristics of mathematics, and fully presents the characteristics of mathematics from variables to the relationship between variables, and then to the application of mathematical methods and tools to establish models.

3.4 Penetration of Mathematical Modeling in Other Fields

Mathematical modeling is a special content. It cannot only be set up in the way of special topics, but also penetrate into other fields of mathematics in a decentralized way, reflecting its instrumentality and applicability [42]. Chinese curriculum standards infiltrate mathematical modeling into other contents to a certain extent. For example, in the function part, it is proposed to "use power function, exponential function and logarithmic function modeling to solve simple practical problems, and realize that trigonometric function can be used to construct mathematical model depicting periodic changes". In the application of function, it emphasizes the value and application of function model. The German standard is relatively concise. There is only one mathematical modeling in the statistical probability section of the concrete mathematical thought. The American curriculum standards believe that "mathematical modeling is not an isolated topic, but related to other standards. Making mathematical model is a standard of mathematical practice, and the specific modeling standard runs through the standard of the whole high school." In the American curriculum standard, all contents infiltrating mathematical modeling are marked with a star-shaped symbol (★). In addition to the field of mathematical modeling, the word mathematical modeling has appeared 98 times in other fields. These contents can be divided into three levels: knowledge unit, knowledge point and specific standard requirements. For example, under the knowledge unit of "the relationship among function and expression, equation, modeling and coordinates" in the function part, there is the knowledge point of "building the model of function, linear function, quadratic function and exponential function", and there is a specific requirement to "distinguish the cases that can be modeled with linear function and exponential function". The titles of many knowledge units are directly related to mathematical modeling. It can be seen that mathematical modeling in American curriculum standards completely permeates into every field. There is relatively few in China and the least in Germany.

3.5 Teaching of Mathematical Modeling

The teaching of mathematical modeling is also relatively special, which cannot be achieved by a simple lecture, but more students' independent exploration under the guidance of teachers. From the perspective of teaching, teachers play roles as mentors and collaborators in mathematical modeling. From the perspective of learning, mathematical modeling is generally carried out in the form of team exploration. According to Chinese curriculum standard, mathematical modeling should be carried out in the way of project-based learning, and students are encouraged to use information technology. One activity should be completed in the compulsory course and optional compulsory course (which can be mathematical modeling activity or inquiry activity). There are 6 class hours in compulsory course and 4 class hours in the optional compulsory course. At the same time, among the elective course contents, the contents related to mathematical modeling are set up with corresponding credits and class hour requirements, the model in class B course accounts for 1 credit (18 class hours in total), and the mathematical model in class C course accounts for 2 credits (32 class hours in total). The American curriculum standard requires the combination of mathematical modeling and other contents, emphasizes the use of information technology (such as drawing tools,

spreadsheets, computer algebra systems and dynamic geometry software), and recommends the use of charts, two-way tables, charts, flow charts, formulas and other tools in specific modeling. There is no discussion of specific modeling teaching in the German curriculum standards. It can be seen that the Chinese curriculum standard emphasizes the macro requirements of mathematical modeling teaching. There are many teaching contents, but the actual requirements are low. American curriculum standards emphasize suggestions on teaching strategies and tools, which are relatively more specific, detailed and operable.

3.6 Evaluation of Mathematical Modeling

The evaluation of mathematical modeling generally involves the tools, contents and forms of evaluation. It is proposed in the Chinese curriculum standard that the mathematical modeling results are presented in the form of reports, which can be in the form of special assignments, measurement reports, algorithm programs, produced objects or research papers. In the appendix, a case of "process evaluation of the height of buildings inside and outside the surveying school" is also set to clearly guide the mathematical modeling evaluation in the way of process evaluation. In the "academic quality standard", three levels of requirements are put forward for mathematical modeling (see "3.2 Objectives of Mathematical Modeling" of this study for details). German curriculum standard only puts forward three levels of requirements, and incorporates the high school examination standard into the standard to ensure the compatibility between the teaching content and the examination content, and emphasizes the evaluation and diagnosis of the examination for the level of mathematical ability. According to the American curriculum standard, the evaluation should focus on the explicit characteristics that can reflect students' mathematical modeling ability or performance (these characteristics are not only reflected in the process of mathematical model generation, but also in the process of model interpretation and verification). At the same time, it is suggested to use some observable and measurable behaviors as specific indicators to evaluate students' mathematical modeling ability. On the whole, the evaluation of mathematical modeling in Chinese curriculum standards is relatively macro and comprehensive, the suggestions and requirements of American curriculum standards in evaluation are more detailed, specific and operable, and the German curriculum standards emphasize the compatibility of teaching and evaluation.

4 Conclusion and Suggestions

4.1 Conclusion

The curriculum standards of the three countries pay more attention to mathematical modeling. The objectives and requirements of mathematical modeling are basically the same, but they have their own characteristics. The content of modeling in China is relatively rich, but the specific teaching implementation requirements are low, and the evaluation of mathematical modeling is relatively macro. The American curriculum standard has more detailed requirements and more specific evaluation for the teaching of

mathematical modeling, with strong operability and higher case openness. The German curriculum standard emphasizes the cultivation of mathematical modeling ability and the consistency and compatibility between teaching content and examination content.

4.2 Suggestions

By comparing the contents of mathematical modeling in three countries, this study puts forward the following suggestions for the further improvement of the contents of mathematical modeling in Chinese curriculum standards and the teaching of mathematical modeling.

4.2.1 Improving the Teaching Requirements of Mathematical Modeling

In fact, China's "regular senior secondary school mathematics curriculum standard (experimental draft)" has put forward some basic requirements for mathematical modeling. Although it is not as detailed as that of "17 curriculum standard", it has described the basic positioning, basic teaching requirements and evaluation requirements of mathematical modeling, especially requiring high school to arrange mathematical modeling at least once [23]. The "17 curriculum standard" puts forward the requirements for mathematical modeling in the compulsory courses and optional compulsory courses respectively. In the compulsory courses, it puts forward that "mathematical modeling activities and mathematical exploration activities are carried out in the form of subject-based learning. In the compulsory courses, students are required to complete one of the course case studies." In the optional compulsory course, it is proposed that "mathematical modeling activities and mathematical inquiry activities are carried out in the form of curriculum research. In the optional compulsory course, students are required to complete a subject research, which can be either mathematical modeling or mathematical inquiry." However, this requirement does not guarantee that students can complete a mathematical modeling activity. Students can choose all mathematical inquiry activities in compulsory and selective compulsory instead of mathematical modeling in high school. In addition, there are no other requirements and explanations for mathematical modeling in the "proposition suggestions for academic examination and college entrance examination" of "17 curriculum standards". In the practice of mathematics teaching in China, there has always been the phenomenon of what to test and what to teach. If mathematical modeling is not reflected in the college entrance examination, it may lead to the failure of teachers and students to carry out mathematical modeling even once in the process of three years of mathematics learning in senior high school. In other words, mathematical modeling will be a vacant course again. Therefore, it is suggested to clarify the teaching requirements of mathematical modeling in the curriculum standard, and complete mathematical modeling activities at least 1–2 times in senior high school, so as to ensure the effective implementation of mathematical modeling.

4.2.2 Strengthening the Integration of Mathematical Modeling and Other Mathematical Contents

There are two ways to present mathematical modeling in mathematics curriculum, one is thematic and the other is decentralized. Mathematical modeling in primary and junior

middle school mathematics curriculum is more combined with specific mathematical content and presented dispersedly, emphasizing the understanding of specific models, and the models involved are also relatively simple. In college mathematics courses, mathematical modeling is more related to social life, science and technology, highlighting the establishment of models through the analysis of practical problems. The models involved are more complex and the modeling process is more difficult. High school mathematical modeling is between the two. It needs not only modeling cases as simple as that of primary school and junior middle school and being related to specific mathematical content, but also relatively complex modeling cases as college mathematical modeling. The content setting needs to play a transitional role, but also infiltrate the idea of mathematical modeling into all the main contents of mathematics, so as to systematically help students understand the ideas and methods of mathematical modeling [24]. Although the idea of mathematical model is also reflected in different contents in "17 curriculum standard", and special mathematical modeling activities are set up in different versions of teaching materials. On the whole, the integration of mathematical modeling and other mathematical contents in the "17 curriculum standard" should to be improved. Therefore, it is necessary to closely combine mathematical modeling as an idea and method with specific mathematical content, highlight the role of mathematical modeling in helping students understand the process of knowledge occurrence and development, and let students experience the role and value of mathematical modeling.

4.2.3 Enhancing the Operability of Mathematical Modeling Evaluation

Compared with the "regular senior secondary school mathematics curriculum standard (experimental draft)", the position of mathematical modeling in the "17 curriculum standard" has been improved. Some evaluation requirements and suggestions are also put forward in the "academic requirements", and the process evaluation is demonstrated through case 19. On the whole, the evaluation requirements on mathematical modeling in the "17 curriculum standards" are still relatively macro, not specific enough, and need to be adjusted and improved, especially in the case of the relative lack of practical experience of mathematical modeling in senior high schools in China. In addition, the relative lack of teachers' mathematical modeling knowledge and mathematical modeling teaching experience will make mathematical modeling be restricted in practical teaching. Therefore, it is suggested to learn from the practice of the United States, develop and compile more cases and books suitable for mathematical modeling teaching and evaluation of Chinese high school students, and supplement the content of the curriculum standard through more detailed and specific cases and analysis [25]. At the same time, a complete mathematical modeling activity takes a long time, so it is not appropriate to take it as the content of the college entrance examination. Therefore, it is necessary to explore an evaluation model suitable for mathematical modeling. A set of observable and measurable specific index system and cases for evaluating students' mathematical modeling ability proposed in German and American standards can be used as an important reference [26] to further improve the evaluation and diagnosis of the examination for the level of mathematical ability [27].

Authors' Contributions. This study is independently completed by Yanwei Peng.

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