

Thoughts on the Cultivation of Mathematical Modeling Competence of Pre-service Mathematics Teacher in Local Universities

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Abstract: To ensure the effective delivery of mathematical modeling courses in universities, it is necessary to fully understand the current status of freshmen's mathematical modeling competence. This study conducted a mathematical modeling competence test among 148 freshmen from the School of Big Data of Tongren University, and analyzed the collected data via SPSS. The results indicate two major conclusions. First, insufficient attention has been paid to mathematical modeling training in secondary education, resulting in an overall low level of mathematical modeling competence among university freshmen. Second, students' mathematical modeling ability shows no significant correlation with their hometown or gender. Accordingly, great importance should be attached to the cultivation of mathematical modeling competence for pre-service mathematics teacher.

Keywords: local universities; mathematical modeling competence; pre-service teacher training

1. Introduction

As the concept of core competencies gains traction worldwide, it has become a universal consensus that mathematical modeling ability is an essential component of core mathematical literacy. Research on mathematical modeling occupies a prominent position in the Programme for International Student Assessment (PISA), as well as the curriculum standards and teaching syllabus of various countries. Cultivating students' mathematical modeling ability is far more than enabling them to comprehend the abstract mathematical principles behind modeling algorithms. The ultimate goal is to help students break free from the confines of textbooks, and turn abstract theories and methods into a powerful tool for solving real-world problems. They are expected to sort out complex problems with logical thinking and resolve them in a proper, concise, straightforward and efficient way. This is the true essence of mathematics education and where the vitality of mathematics lies [1]. In recent years, China has successively issued the Curriculum Standards for Senior High School Mathematics and the Curriculum Standards for Compulsory Education Mathematics. Educational authorities at all levels have required primary and secondary school mathematics teachers to study these documents thoroughly, distinguish their changes and continuities, so as to clarify the orientation of teaching. Serving as the guideline for mathematics teaching at corresponding school stages, these curriculum standards also provide clear guidance for the training of pre-service mathematics teachers in universities, whose career is dedicated to primary and secondary mathematics education. Existing studies generally indicate that middle and primary school students are relatively weak in mathematical modeling ability, and many teachers lack proficiency in delivering modeling-related instruction. To improve students' mathematical modeling capabilities fundamentally, priority must be given to fostering teachers' mathematical modeling literacy and teaching competencies. Accordingly, testing and analyzing the mathematical modeling ability of university freshmen can reflect two realities: first, the state of mathematical modeling proficiency that mathematics majors have acquired during their primary and secondary schooling; second, the actual implementation of mathematical modeling teaching in basic education. The findings will offer insights for local universities to optimize the training of pre-service mathematics teachers.

2. Test on Freshmen's Mathematical Modeling Competence

Mathematical modeling has been widely applied in the Internet, finance, aerospace and many other fields. Introducing it into university classrooms conforms to the trend of the times and the requirements

of educational reform. Mathematical modeling courses were first launched in Chinese universities in the 1980s. With the efforts of scholars including Ye Xiaoqi, Jiang Qiyuan and Xie Jinxing, the First National University Students Mathematical Modeling Contest was held in 1992. The contest has gained widespread influence, prompting numerous regions and universities to launch relevant competitions and offer mathematical modeling courses. This test is designed to investigate the current level of freshmen's mathematical modeling ability, so as to provide a basis for the subsequent teaching of mathematical modeling courses for student teachers.

2.1 Research Methods

2.2.1 Research Subjects

The research subjects are freshmen from three majors of the School of Big Data, Tongren University, namely Mathematics and Applied Mathematics, Computer Science and Technology, and Data Science and Big Data Technology, with a total of 148 participants. Among them, there are 84 male students (43.2%) and 64 female students (56.7%). To explore the impact of native place on mathematical modeling competence, students from Guizhou Province are grouped by prefecture-level cities, while students from other provinces are classified into one group. Detailed information is shown in Table 1. A total of 148 questionnaires were distributed and all recovered, with an effective recovery rate of 100%.

Table 1 Distribution of Participants by Hometown Origin

Region	A	B	C	D	E	F	G	H	I	K
Number of People	4	10	80	5	3	11	2	15	2	16
Percentage	2.7%	6.7%	54.0%	3.3%	2.0%	7.4%	1.3%	10.1%	1.3%	10.8%

Notes: A: Guiyang City; B: Zunyi City; C: Tongren City; D: Anshun City; E: Qiannan Buyei and Miao Autonomous Prefecture; F: Qiandongnan Miao and Dong Autonomous Prefecture; G: Qianxinan Buyi and Miao Autonomous Prefecture; H: Bijie City; I: Liupanshui City; K: Other Provinces

2.1.2 Research Instrument

A self-compiled mathematical modeling competence test paper was adopted, consisting of four short-answer questions: *Authenticity of News*, *Chalk Design*, *Fuel Refueling Problem* and *Window Design*. All participants were newly enrolled freshmen who had not received systematic university-level mathematical modeling training, so the test questions were designed to match the knowledge difficulty of senior high school.

A news report claimed that a robber stole 10 million RMB in cash from a bank in City A without any means of transportation. The cash was all bundled 100-yuan banknotes. Please judge whether the news is true or false and elaborate your judgment from a mathematical perspective.

This question is excerpted from Ji Yingxue's mathematical modeling proficiency test for students [2]. It examines students' ability to extract mathematical problems from real-life scenarios and conduct analysis based on volume or mass. Unlike conventional exercises, no known data is provided, so students need to set variables independently. Making reasonable assumptions about the length, width and mass of a single 100-yuan banknote or a bundle of banknotes is the key to completing the modeling.

Chalk is a common and essential teaching supply on campus. Traditional chalks are round, while hexagonal chalks are more widely used at present. According to manufacturers' specifications, the diameter of hexagonal chalk is slightly larger than that of round chalk. Why do manufacturers choose to produce hexagonal chalk? Please demonstrate your viewpoint from a mathematical perspective (using mathematical formulas, symbols, graphs or other forms as much as possible).

This question is also selected from Ji Yingxue's research [2]. Based on a familiar life scene, it assesses students' ability to convert real-life situations into mathematical problems and establish models to compare the two types of chalk to support their arguments.

Mr. Wang drives a Honda 180TURBO. There is Gas Station A near his home, and Gas Station B is 10 kilometers away. The price of No.95 gasoline at both stations is 7.60 yuan per liter this week. Mr. Wang holds a free membership of Gas Station B and enjoys a discount of 0.4 yuan per liter. Please solve the following problem: Analyze how Mr. Wang should choose a gas station to refuel to get the best deal.

Revised from a PISA test question, this type of practical problem is widely used as modeling exercises and teaching materials abroad. It evaluates students' ability to connect mathematics with

daily life, define variables, distinguish primary and secondary variables, and build corresponding mathematical models.

A factory needs to cut a window in a wall, with a semicircular upper part and a rectangular lower part, as shown in the omitted figure. Given that the perimeter of the window frame is fixed, it is required to maximize the amount of light passing through the window. How should the window be designed?

This question is adapted from Niu Weiqiang's Senior High School Students' Mathematical Modeling Competence Test Paper (Version B) [3]. It examines whether students can abstract practical problems: maximizing light transmission is equivalent to maximizing the window area. Once the practical problem is transformed into a mathematical one, the modeling task can be solved smoothly.

2.1.3 Evaluation Criteria

Mathematical modeling is a complete procedural system, and a short test cannot fully present the entire modeling process. The above questions mainly evaluate the sub-competencies involved in different stages of mathematical modeling. Referring to existing studies, scholars divide the mathematical modeling process into multiple sub-stages and corresponding sub-competencies, and construct a hierarchical evaluation framework. Following the five sub-competencies of the modeling process proposed by Blum and Kaiser, Lu Xiaoli and other researchers classified students' mathematical modeling ability into six levels[4]:

- **Level 0:** Fail to identify any quantitative relationships from practical scenarios, or deliver irrelevant and meaningless answers.
- **Level 1:** Try to sort out practical scenarios and raise questions, but fail to establish mathematical models.
- **Level 2:** Put forward reasonable assumptions and build practical models, yet the models are mathematically flawed.
- **Level 3:** Convert practical scenarios into valid mathematical models, but obtain wrong results or make calculation errors.
- **Level 4:** Establish correct mathematical models and work out accurate solutions, but fail to interpret and verify results in combination with real situations.
- **Level 5:** Complete model construction and accurate calculation, interpret and verify results against real scenarios, and evaluate the rationality of the established models.

The six levels clearly describe students' specific performance in mathematical modeling and conform to the principle of process-oriented evaluation. This study adopts the above grading standards for paper scoring. It is assumed that students reaching a higher level have fully mastered all competencies required for lower levels.

2.1.4 Test Implementation and Data Processing

Anonymous test papers were distributed and collected by class within 90 minutes. All papers were graded, and the scoring data were imported into Excel. SPSS 19.0 was used to conduct independent-samples t-test and analysis of variance.

2.2 Results and Analysis

2.2.1 Overall Level of Freshmen's Mathematical Modeling Competence

As shown in Table 2, the average scores of the four questions are 2.20 (*Authenticity of News*), 1.70 (*Chalk Design*), 2.32 (*Fuel Refueling Problem*) and 1.81 (*Window Design*) respectively. The overall average score of all test papers is 2.02, indicating that freshmen's mathematical modeling competence is generally at Level 2. Most students can understand practical scenarios, put forward basic assumptions and build practical models, but cannot convert them into standard mathematical problems.

Table 2 Overall Results of Freshmen's Mathematical Modeling Competence Test

Item	Authenticity of News	Chalk Design	Fuel Refueling Problem	Window Design	Overall Result
Average Level	2.20	1.70	2.32	1.81	2.02
Standard Deviation	1.34	1.05	1.14	1.52	0.73

The main problems of freshmen include difficulties in converting real scenarios into mathematical problems and a weak awareness of variable definition. Transforming practical models into mathematical ones is the core link of mathematical modeling, which requires students to identify variables and complete logical conversion. Influenced by traditional mathematics teaching from primary to secondary school, students are accustomed to calculating quantitative relations in overly idealized application problems divorced from real life. When faced with practical problems without given data, they struggle to extract mathematical questions effectively.

2.2.2 Analysis on Regional and Gender Differences

In empirical research, difference analysis is generally indispensable. As shown in Table 3, $F = 1.549$ and $Sig = 0.137$, indicating no significant difference in the mathematical modeling ability of freshmen from different places of origin. A possible reason is that mathematical modeling activities were not offered in senior high schools for these students, resulting in a general lack of awareness and understanding of mathematical modeling, so no obvious disparity based on student origin was observed.

Furthermore, Li Mingzhen's research verified that senior high school students' mathematics performance is significantly correlated with their mathematical modeling proficiency [5]. Since freshmen admitted to the same college and department have relatively similar scores in the college entrance examination mathematics, their performance in mathematical modeling is not affected by regional differences in student origin.

As presented in Table 4, $F = 0.396$ and $Sig = 0.530$, which suggests that there is no gender difference in the mathematical modeling ability of the participants.

Table 3 Analysis of Differences in Freshmen's Mathematical Modeling Ability by Place of Origin

Levene's Test for Equality of Variances ^a			
Dependent Variable: Average Level			
F	df1	df2	Sig.
1.549	9	138	0.137

Table 4 Analysis of Gender Differences in Freshmen's Mathematical Modeling Ability

Levene's Test for Equality of Variances	
F	Sig.
0.396	0.530

2.2.3 Analysis of Individual Questions

For the question *Authenticity of News*: 29.7% of participants reached Level 2. They tried to calculate the volume or mass of 10 million yuan and built models, but their assumptions deviated greatly from reality (for example, assuming a bundle of 10,000-yuan banknotes weighs 500 grams). 10.8% of students were at Level 0, giving no answers or only a simple true/false judgment, showing a complete lack of understanding of mathematical modeling. 20.2% were at Level 1, merely presenting subjective descriptions such as "too heavy" or "too bulky". Only 6.7% reached Level 5: they made reasonable assumptions (e.g., a bundle of 10,000-yuan banknotes weighs 100 to 105 grams), calculated the total mass or volume accurately, verified the results with real situations and drew valid conclusions. Some students used vivid analogies, reflecting flexible thinking free from rigid mindsets.

For the question *Fuel Refueling Problem*: 9.4% failed to understand the question and gave irrelevant answers. 27.7% built basic models but ignored the extra fuel consumption caused by the longer trip to Gas Station B. 43.9% took the extra fuel consumption into account, yet set an unrealistic refueling volume exceeding the vehicle's tank capacity. Only 3.3% considered both round-trip fuel consumption and the reasonable range of refueling volume, and completed modeling and problem-solving correctly.

In general, excluding *Fuel Refueling Problem*, more than 60% of students scored at Level 2 or below in the other three questions. The difficulty of transforming real scenarios into mathematical problems has become a major bottleneck restricting students' mathematical modeling ability.

3. Implications

The test results reveal that university freshmen generally have low mathematical modeling

competence, which is consistent with Wei Chengdong's research conclusion that college students in ethnic minority areas of Guangxi have superficial understanding and poor ability in mathematical modeling [6]. This fully reflects the insufficient cultivation of mathematical modeling in senior high school education. According to follow-up interviews, all 148 participants had never received mathematical modeling training or participated in related activities during their senior high school years.

Therefore, universities should objectively assess students' current modeling level before offering mathematical modeling courses. Overestimating students' ability will lead to mismatched teaching content, making it difficult for students to keep up with lessons and resulting in loss of learning interest.

At present, many universities attach great importance to mathematical modeling competitions. While this is a positive trend, some problems have emerged: in quite a number of universities, mathematical modeling courses are only offered to competition participants rather than all students. Even for courses open to all students, their core objective still serves competitions.

As Professor Li Daqian pointed out, the cultivation of mathematical modeling competence is not simply knowledge instillation or case accumulation. It requires in-depth experience, practice, assimilation and flexible application. Teachers can select typical practical problems and guide students to explore the whole modeling process step by step from simple to complex cases. The priority is to let students personally perceive the charm, ideas and methods of mathematical modeling, and understand that models can be continuously optimized rather than being absolutely perfect. In this process, students can acquire abilities that cannot be cultivated through textbooks and conventional classroom teaching.

4. Conclusion

Furthermore, university teachers must fully recognize the significance of modeling training for pre-service mathematics teacher. Under the exam-oriented education system, senior high school students focus on textbook knowledge and examination skills, with little experience in applying mathematics to real life. Professor Li Daqian stated that mathematical modeling, which constructs mathematical descriptions for the real world, is the fundamental starting point of mathematical research. Training in mathematical modeling is an indispensable part of education, not an optional extra [7]. Pre-service mathematics teachers are the future educators. A qualified mathematics teacher must be capable of solving practical problems with mathematical knowledge, ideas and methods. Hence, the cultivation of mathematical modeling competence among pre-service mathematics teachers must be valued and fully implemented.

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