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Analysis of the Alignment between Exercises in New Junior High School Mathematics Textbooks and Curriculum Standards from the Perspective of Core Competencies

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Abstract: *This study selects the exercises in the 2024 People's Education Edition of the seventh-grade mathematics textbook as the core analysis object. Taking the Compulsory Education Mathematics Curriculum Standards (2022 Edition) as the fundamental basis, this study constructs a "5 dimensions—7 competencies—3 levels" core competency evaluation model by integrating the SEC consistency analysis model with the core competency evaluation framework. The study conducts a systematic analysis of the alignment between textbook exercises and the curriculum standards across four dimensions: overall consistency, content themes, cognitive levels, and core competencies. The results indicate that, at the overall level, the textbook exercises and the curriculum standards exhibit statistically significant consistency, and the degree of alignment in the content themes dimension is relatively high. In the cognitive levels dimension, consistency regarding knowledge comprehension and knowledge innovation still needs to be strengthened. In the core competencies dimension, consistency for all core competencies except computational ability reached an acceptable level. Based on these findings, the study offers practical recommendations for the development of new textbooks and for teachers to better utilize textbook exercises.*

Keywords: *Junior High School Mathematics, Textbook Exercises, Curriculum Standards, Core Competencies, Alignment*

1. Research background

The Mathematics Curriculum Standards, as a guiding document in the field of mathematics education, have guiding significance for textbook development and classroom teaching. Mathematics textbooks are an important basis for teachers to carry out regular teaching activities. As a key component of textbooks, exercises are not only a source of material for teachers to design homework, but also an important carrier for students to deepen their knowledge understanding and strengthen their skill application. The degree of conformity between textbook exercises and curriculum standards is directly related to the effective achievement of teaching objectives, and has significant importance in optimizing and improving textbook writing. Since the use of the 2024 version of junior high school mathematics textbooks, there has been a lack of research on the consistency between the exercises in the new textbooks and the new curriculum standards. Kong Fanzhe[1], Xu Fan[2]have used different tools to analyze the consistency between academic evaluation, textbooks, and curriculum standards. Liu Jin[3] analyzed the consistency between the 2021-2023 National College Entrance Examination Paper I and the new curriculum standards based on the Achievement model. The relevant conclusions have great significance for guiding future reforms in test question design and curriculum standards. Therefore, this study is based on the core competency evaluation system, draws on the SEC model to construct evaluation tools, analyzes the fit between textbook exercises and curriculum standards, explores the value of exercise competency, and provides reference for teachers' teaching.

ISSN 2522-6398 Vol. 9, Issue 5: 160-167, DOI: 10.25236/FER.2026.090522

2. Research Design

2.1 Research Object

The research object of this article is mathematical textbook exercises and curriculum standards. Textbook exercises refer to the exercises, and review questions in the first and second volumes of the 2024 People's Education Press Mathematics textbook for Grade 7. The curriculum standards refer to the "Compulsory Education Mathematics Curriculum Standards (2022 Edition)" (hereinafter referred to as the "new curriculum standards"). This article uses the core competency evaluation framework proposed by Yu Ping[4] to better understand the curriculum content structure of the new curriculum standard. Innovation consciousness and application consciousness are distributed among various core competencies, so we mainly focus on seven core competencies: abstract ability, reasoning ability, computational ability, model concept, geometric intuition, spatial concept, and data concept[5].

2.2 Research Tools

Currently, the most widely used models in consistency research are the SEC model[6], Webb model [7], and Achieve model[8]. Among them, the two-dimensional matrix of the SEC analysis tool can unify the content themes and cognitive levels in the new curriculum standards into the analysis framework. There are five content themes involved in seventh grade: numbers and expressions, equations and inequalities, properties of graphics, graphics and coordinates, sampling and data analysis. Professor Yu Ping's core competency framework divides the three levels of "knowledge understanding, knowledge transfer, and knowledge innovation" that accurately match students' cognitive levels. Therefore, a consistency analysis matrix model of "5 dimensions-7 competencies -3 levels" is constructed based on the new curriculum standards.

2.3 Curriculum Standard Coding Principles and Results

The standard coding sequence of this research content is sorted by "content theme, core competency, and cognitive level". Part of the content in the new curriculum includes multiple action verbs at different levels. When encoding, detailed goals need to be separated according to the level of action verbs and encoded separately. For the same core competency, different cognitive levels should be encoded separately. Repetitive coding of the same core competency and cognitive level. Different core competencies are separated and encoded separately. For the convenience of data encoding and statistics, the English initials of each competency are used for encoding: "abstract ability" (A), "reasoning ability" (R), "computational ability" (C), "model concept" (M), "geometric intuition" (G), "spatial concept" (S), and "data concept" (D). Based on Yu Ping's interpretation[9] and referring to the classification of action verbs in the new curriculum standards, this study establishes a bidirectional detailed table (see Table 1).

Table 1: Bidirectional Detail Table

Cognitive level	Behavioral verbs
Level 1 (Knowledge understanding)	understanding, comprehension, knowledge, understanding, experience, feeling, appreciation, recognition, insight, recognition, etc.
Level 2 (Knowledge transfer)	ability, mastery, further understanding, etc.
Level 3 (Knowledge innovation)	application, exploration, proof, etc.

The new curriculum standard coding example is as follows:

"Being able to represent rational numbers with points on the number axis, and being able to compare the size of rational numbers." This content belongs to the learning topic 1.1.1" Rational Numbers "in the learning area 1.1" Numbers and Formulas "of learning module 1" Numbers and Algebra ". Being able to represent rational numbers with points on the number axis "is encoded as 1.1.1.3, which belongs to competency A" Abstract Ability ", and" Ability "cognitive level belongs to level 2" Knowledge Transfer ", encoded as A2." Being able to compare the size of rational numbers "is encoded as 1.1.1.4 Determine that the content belongs to competency C" computational ability ", and the cognitive level of" ability "belongs to level 2" knowledge transfer ", encoded as C2.

To ensure the reliability of the coding results, this study used SPSS 26.0 to perform Pearson correlation test on the new curriculum standard coding data independently completed by two coders. After testing, the correlation coefficient was 0.914 **, $P<0.001$. This indicates that the encoding results of the two individuals have a high level of reliability. The two coders discussed the differences in the encoded data and consulted with subject experts to establish the final encoded data. When processing the encoding results, due to the differences in specific requirements for core competencies among different

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analysis objects, it is not possible to directly compare the raw data. It is necessary to normalize the raw data to obtain the ratio table of the new curriculum standards(see Table 2).

Table 2: Coding Ratio Table for Curriculum Standards Content Standards

Table of Content Standard Coding Ratios for the 2022 Compulsory Mathematics Curriculum Standards											
	Abstract ability			Computational ability			Geometric intuition			Spatial concept	
Content theme	A1	A2	A3	C1	C2	C3	G1	G2	G3	S1	S2
Numbers and expressions	0.120	0.051	0.000	0.071	0.063	0.020	0.000	0.000	0.000	0.000	0.000
Equations and inequalities	0.017	0.009	0.000	0.009	0.034	0.000	0.000	0.017	0.000	0.000	0.000
properties of graphics	0.077	0.000	0.000	0.009	0.009	0.000	0.047	0.038	0.000	0.017	0.060
Graphics and coordinates	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.025
Sampling and data analysis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spatial concept	Reasoning ability			Model concept			Data concept			Total concept	
S3	R1	R2	R3	M1	M2	M3	D1	D2	D3		
0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	
0.000	0.000	0.000	0.017	0.000	0.026	0.000	0.000	0.000	0.000	0.128	
0.017	0.051	0.017	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.385	
0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.060	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.060	0.034	0.000	0.094	

2.4 Coding Principles and Results of Textbook Exercises

The textbook exercises are mainly distributed in three sections: practice, exercises, and review questions. The number of encoding times needs to be determined according to the type of question: when there are multiple questions in one question, each sub question is encoded separately. In fill in the blank questions, spaces are separated by semicolons or periods, and each space is encoded separately. Afterwards, this study determines the core competencies to be assessed and matches knowledge points with the curriculum coding table. If no corresponding knowledge points are available, this study makes a judgment by referring to the core competencies of similar knowledge items.

The example of coding exercises in textbooks is as follows:

"If a=-a, where is the point representing the number a on the number axis?"

This question is an exercise for the opposite numbers in Volume 1.2.3 of Grade 7, corresponding to the specific knowledge item "1.1.1.5 Understanding the meaning of opposite numbers and absolute values with the help of number axes" in the new curriculum standard. In terms of core competencies, this topic focuses on abstract abilities. From the perspective of cognitive level, it conforms to the definition of "knowledge understanding" level. Overall, the encoding result of this exercise is "A1".

To ensure the reliability of the encoding results, Pearson correlation test was also performed on the encoded data using SPSS 26.0, with a correlation coefficient of 0.801 **, P<0.001. The two coders discussed the differences in the encoded data and consulted with subject experts to establish the final encoded data. After normalization, they obtained the original data ratio table for the math textbook exercise content(see Table 3).

Table 3: Standard Encoding Ratio Table for Textbook Exercise Content

Standard coding ratio table for textbook exercise content											
	Abstract ability			Computational ability			Geometric intuition			Spatial concept	
Content theme	A1	A2	A3	C1	C2	C3	G1	G2	G3	S1	S2
Numbers and expressions	0.049	0.082	0.001	0.082	0.214	0.035	0.000	0.000	0.000	0.000	0.000
Equations and inequalities	0.019	0.015	0.005	0.009	0.086	0.000	0.000	0.000	0.000	0.000	0.000
Properties of graphics	0.016	0.000	0.000	0.005	0.014	0.000	0.023	0.035	0.000	0.018	0.016
Graphics and coordinates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.035
Sampling and data analysis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spatial concept	Reasoning ability			Model concept			Data concept			Total concept	
S3	R1	R2	R3	M1	M2	M3	D1	D2	D3		
0.000	0.006	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.474	

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0.000	0.000	0.009	0.012	0.000	0.086	0.001	0.000	0.000	0.000	0.242
0.005	0.009	0.037	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.179
0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.044
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.034	0.027	0.000	0.061

3. Results Analysis

3.1 Overall Consistency Analysis

Based on the statistical results of the coding ratio between the new curriculum standards and textbook exercises, the consistency indicator formula was adopted[10]. After converting the resulting data into ratios, the data were imported into a two-dimensional matrix table and calculated with Porter's formula to obtain the consistency coefficient P-value. The larger the value, the higher the degree of matching between the two in corresponding dimension. This study calculates the consistency coefficient P-value between exercises and curriculum standards across different dimensions. For the determination of the critical value, the distribution function of Porter's consistency index was simulated using MATLAB to obtain the critical interval at the 0.05 level. The specific process is as follows: the 117 specific requirements of the new curriculum standard are randomly assigned to a 5×21 matrix, and the 1550 exercises in the textbook are also assigned to a 5×21 matrix. After standardization, the consistency index is calculated, and this process is repeated 20000 times to obtain the critical interval. Using α=0.05 as the evaluation criterion at a 95% confidence level, the critical interval for the population dimension falls between [0.6166, 0.7199]. We analyzed the content topic and cognitive level dimensions using the above method. According to the significance test principle in the field of statistics, only when the P-value is higher than the lower threshold, that is, when it exceeds the critical value corresponding to the 0.025 percentile, can we determine the significant consistency between the two research subjects at the statistical level. The final results are shown in Table 4.

Table 4: Statistics of Consistency Coefficient

Dimension	Two-dimensional matrix	Target number and exercise number	P-value	Confidence interval (95%)
Overall dimension	5×21	117×1550	0.633	[0.6166,0.7199]
Content theme	5×7	117×1550	0.698	[0.5781,0.7588]
Cognitive level	5×3	117×1550	0.607	[0.5337,0.8072]

According to the data in Table 4, in the overall dimension, the consistency index between textbook exercises and curriculum standards is 0.633, which is higher than the critical lower limit of 0.6166, indicating good consistency between the two at the overall level. In both the dimensions of content theme and cognitive level, the corresponding P-values exceed the critical lower limit standard, indicating a statistically significant consistency between the two dimensions.

According to the requirements of the 2022 new curriculum standard and the 2024 mathematics textbook exercises, encode the original data ratio table and create the corresponding surface diagram.

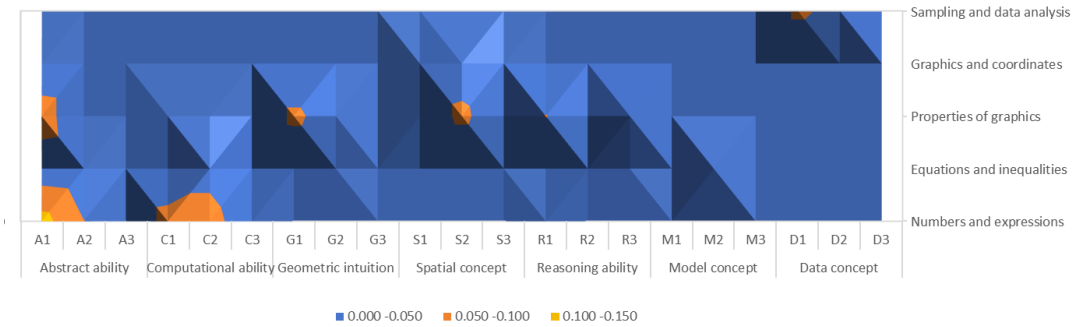

Figure 1: Surface Diagram of Core Competencies in Curriculum Standards

ISSN 2522-6398 Vol. 9, Issue 5: 160-167, DOI: 10.25236/FER.2026.090522

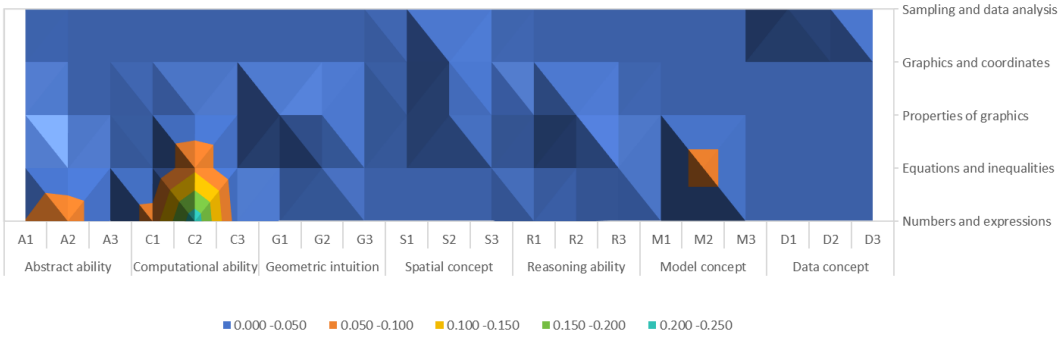

Figure 2: Surface Diagram of Core Competencies in Textbook Exercises

As shown in Figure 1 and Figure 2, there is a significant difference between the requirements for core competencies in textbook exercises and the new curriculum standards. In textbook exercises, the theme of Equations and inequalities focuses on the knowledge transfer of model concepts. The Properties of graphics, and Sampling and data analysis are more reflected in curriculum standard. The curriculum standards and textbook exercises focus on the transfer of abstract and computational skills in both mathematics and formula themes, with the least emphasis on knowledge innovation. This indicates that the distribution of exercises in textbooks and curriculum standard for testing core competencies is uneven. Therefore, exercise writing should be based on the new curriculum standards and reasonably distribute the content and level of core competencies.

3.2 Consistency Analysis of Content Themes

According to the data ratio table obtained from the encoding of exercises in the 2022 version of the new curriculum standards and the 2024 version of textbooks, the proportion of different themes varies.. Under the dimension of "Numbers and expressions", the proportion of computational ability in textbook exercises is higher than the requirements of the new curriculum standard, while the proportion of abstract ability is relatively low. Regarding theme 2 "Equations and inequality", the proportion of core competencies in abstract ability, computational ability, reasoning ability, and model concept in textbook exercises exceeds the corresponding requirements of the curriculum standard; In Theme 3 " Properties of graphics", the proportion of exercises in the textbook in terms of abstract ability, geometric intuition, spatial concept, and reasoning ability is lower than the standards set by the new curriculum standards. In Theme 4 "Graphics and coordinates", the curriculum emphasizes abstract ability and spatial concepts, while textbook exercises only focus on spatial concepts. In Theme 5 "Sampling and data analysis", the degree of consistency is relatively good.

3.3 Cognitive Consistency Analysis

According to the coding data ratio table of the new curriculum standards and textbook exercises, it can be seen that in the dimension of cognitive level, the cognitive level of the new curriculum standard presents a gradually decreasing distribution feature. The focus of textbook exercises is on "knowledge transfer", with the lowest proportion involving "knowledge innovation". Further analysis shows that the textbook exercises have a much higher assessment of "knowledge transfer" than the curriculum standard, while the assessment of "knowledge understanding" is significantly lower. The assessment of low-level and high-level cognition is insufficient, and has not met the expectations of the curriculum standard. It can be seen that the design of textbook exercises basically meets the requirements of the curriculum for basic knowledge, but there are obvious shortcomings in guiding deep learning and cultivating innovative thinking.

3.4 Consistency analysis of core competencies

Similarly, based on the coding data ratio table of the new curriculum standards and textbook exercises, they all focus on testing "abstract ability" and "computational ability". Abstract ability (0.282), computational ability (0.214), spatial concept (0.145), and reasoning ability (0.137) account for a relatively large proportion of the various qualities in the curriculum standards. When cultivating students' various qualities, textbook exercises account for a large proportion of "computational ability" (0.445)

ISSN 2522-6398 Vol. 9, Issue 5: 160-167, DOI: 10.25236/FER.2026.090522

and "abstract ability" (0.190). Comparison reveals a significant gap between the two in terms of "abstract ability" and "computational ability". The proportion of "abstract ability" in textbooks is lower than the curriculum standard by 0.092, while "computational ability" is higher by 0.231. The consistency between textbook exercises and the new curriculum standards in all core competencies except for "computational ability" has reached an acceptable level. The reason is that there is no examination of "computational ability" in the theme of graphics and coordinates, sampling and data analysis. However, the proportion of exercises in the first three topics is higher than the curriculum standard, with differences of 0.177, 0.052, and 0.002, respectively.

4. Conclusion

4.1 Consistency level of overall dimensions

This study adopts the SEC consistency analysis model to conduct a conformity analysis between the exercises in the 2024 edition of the People's Education Press seventh grade mathematics textbook and the 2022 edition of the new curriculum standards. The overall consistency coefficient between the two is 0.633, which is higher than the critical lower limit of 0.6166, indicating good consistency between textbook exercises and the new curriculum standards at the overall level. Through the surface diagram, it was further found that the distribution of exercises in textbooks and curriculum standard for testing core competencies is uneven. This shows that there is still room for optimization and improvement in the distribution of core competencies in textbook exercises.

4.2 Consistency level of content theme dimension

In the consistency analysis of the content theme dimension, the consistency coefficient is 0.698, exceeding the critical lower limit of 0.5781, indicating a statistically significant consistency between the two in this dimension. The exercise settings for the theme of "Sampling and data analysis" are in good agreement with the requirements of the new curriculum standard, but in the other four themes, there is a certain deviation between the textbook exercises and the requirements of the new curriculum standard in terms of the types and proportion of core competency tests. For example, in the theme of "Properties of graphics", the emphasis on geometric intuition, spatial concepts, and reasoning abilities is relatively insufficient, which fails to fully match the competency cultivation requirements corresponding to the new curriculum standards.

4.3 Consistency level of cognitive level dimension

In the consistency test of cognitive level dimension, the consistency coefficient between textbook exercises and the new curriculum standard is 0.667, which is higher than the critical lower limit of 0.5337, indicating good consistency. From the perspective of the distribution characteristics of cognitive levels, the new curriculum standard presents a gradually decreasing distribution pattern from low to high levels, while the cognitive examination focus of textbook exercises is on the "knowledge transfer" level, with insufficient attention paid to the low level "knowledge understanding" and high level "knowledge innovation" ability, resulting in an imbalance in the cognitive hierarchy structure.

4.4 Consistency level of core competency dimensions

In terms of core competencies, the consistency between textbook exercises and the new curriculum standards is good in core competencies other than "computational ability". Taking the theme of graphics and coordinates as an example, the proportion of testing "abstract ability" in the new curriculum standard is 0.009, but the exercises in the textbook do not test this competency. This makes the consistency index of the two in the dimension of "abstract ability" acceptable, but the emphasis on "abstract ability" in the competency testing structure of the new curriculum standard is not fully reflected, and there is a certain gap with the curriculum standard orientation.

5. Recommendations

5.1 Focus on theme deviation and adjust the proportion of exercises for content themes reasonably

Research shows that the consistency between textbook exercises and the new curriculum standards

ISSN 2522-6398 Vol. 9, Issue 5: 160-167, DOI: 10.25236/FER.2026.090522

in terms of content themes has reached an acceptable level, but the consistency index of the three themes of "numbers and expressions", "equations and inequalities", and "properties of graphics" is relatively low. Therefore, when revising exercises, textbook writers should moderately reduce the proportion of exercises on the topics of "numbers and expressions" and "equations and inequalities", reduce the repetition of exercises, strengthen the hierarchy of exercises and exercises with different knowledge correlations, and avoid a single competency structure due to overtraining. When teachers use textbooks, changing the types of questions or enriching the background can not only promote students' initiative in learning, but also enhance the hierarchical and diverse types of exercises in the textbooks[11]. Teachers can also conduct in-depth research on learning objectives that are not covered by post class exercises in the new curriculum standards, and supplement corresponding exercises based on these objectives to enhance the comprehensiveness of textbook exercises. By adjusting the deviation in the proportion of topics, the distribution of exercises in various content topics is more in line with the requirements of the new curriculum standard, ensuring that each topic can provide students with balanced opportunities for the development of core competencies.

5.2 Balance the distribution of core competency in various themes

The consistency index between textbook exercises and the new curriculum standards in core competencies such as "geometric intuition" and "data concepts" is relatively high. However, it cannot be ignored that the proportion of exercises in textbooks that test "computational ability" far exceeds the definition standard of the new curriculum standard, with a difference of 0.231 between the two. There are obvious deficiencies in the examination of "abstract ability", "spatial concept", and "model concept". To address this issue, optimization can be made from two aspects: introducing exercises that require abstract summarization and logical reasoning in computationally intensive topics such as numbers and equations, reducing the proportion of purely mechanical operation questions, and promoting the cultivation of "computational ability" and the coordinated development of "abstract ability" and "reasoning ability". For frontline teachers, they should carefully study the new curriculum standards, focus on core competencies in the teaching process, pay attention to the correlation between mathematical knowledge and competency performance, and reflect the advancement of students' core competencies while improving their knowledge and abilities[12]. They should use strategies such as multiple solutions to one question and variable training to break through the limitations of textbook exercises, carry out reasonable secondary development, and supplement the shortcomings of textbooks to help students achieve comprehensive and balanced development of core competencies at different cognitive levels.

5.3 Focus on cognitive advancement and optimize the exercise design of knowledge innovation

The current examination of exercises in textbooks overly focuses on "knowledge transfer" and seriously lacks examination of "knowledge understanding" and "knowledge innovation", leading to an imbalance in cognitive hierarchy. The Outline of the Plan for Building a Strong Education Country (2024-2035) clearly points out the need to improve the mechanism for discovering and cultivating top-notch innovative talents[13]. Among them, measures such as the fertile soil plan for cultivating the competency of primary and secondary school students and the outstanding plan for high school students with innovative potential have all confirmed that cultivating innovative consciousness has become one of the core directions of current education reform. The emphasis on innovation consciousness is gradually increasing from "dual basics" to "four basics" and then to "core competencies". Therefore, while emphasizing basic knowledge, textbook exercises should also increase the weight of testing high-level cognitive levels to ensure that the basic requirements set by the new curriculum standards are met. At the same time, textbook exercises should also take into account the cognitive needs of different levels, effectively balancing the cognitive goals of low, medium, and high levels to meet the needs of different students' potential development. Textbook writers need to enrich the background design of exercises, strengthen the correlation between exercises and students' real-life situations and other disciplines, and help students effectively develop their exploration awareness and abilities. This type of exercise can be designed as open-ended inquiry questions or interdisciplinary comprehensive questions, guiding students to actively diverge their thinking and solve problems, thereby making up for the shortcomings of advanced cognitive training, achieving the advancement from knowledge application to innovative thinking, and effectively implementing the requirements of the new curriculum standard for cultivating innovative talents.

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