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Research on the Adaptation Mechanism of Mathematics Teaching in Vocational Undergraduate Education from a Multi-Dimensional Stratification Perspective

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Abstract: Against the macro background of the typified and standardized development of vocational undergraduate education, the student source structure presents the coexistence of diverse groups, including senior high school graduates, secondary vocational school graduates, and top-skilled talents. Students show significant heterogeneity in mathematics knowledge reserve, logical thinking ability, learning habits and strategies, as well as future career development orientation, which puts forward an urgent practical demand for precise and adaptive teaching of mathematics courses. At present, the practice of stratified mathematics teaching in vocational undergraduate education is mostly based on academic performance as the single criterion for stratification, which is difficult to systematically respond to the complexity of student differences, the diversity of professional needs and the hierarchy of ability development, resulting in obvious limitations in the effect of teaching adaptation. Accordingly, from the perspective of multi-dimensional stratification, this study conducts an integrated analysis of the internal structure and external manifestations of mathematics learning differences among vocational undergraduate students, and constructs a multi-dimensional stratification model consisting of four core elements: knowledge foundation, ability development, learning characteristics and professional needs. On this basis, an integrated teaching adaptation mechanism is proposed, which integrates teaching objectives, teaching content, teaching process and teaching evaluation. Meanwhile, the mechanism is systematically explained and theoretically deepened from three aspects: operation logic, implementation path and guarantee conditions. The study shows that multi-dimensional stratification can break through the inherent defects of traditional single-dimensional stratification, significantly improve the pertinence, flexibility and professional compatibility of mathematics teaching, and provide a theoretical framework with explanatory power and operability for the curriculum reform and high-quality development of mathematics in vocational undergraduate education.

1. Introduction

With the continuous advancement of the construction of China's modern vocational education system, vocational undergraduate education, as an important carrier for cultivating high-level technical and skilled talents, has an increasingly clear talent training orientation of being application-oriented, competence-based and integrating posts, courses, competitions and certificates. As a public basic course in vocational undergraduate education, mathematics not only undertakes the basic supporting function of consolidating students' scientific and cultural literacy and cultivating their logical thinking and rational spirit, but also plays an irreplaceable instrumental service role in professional course learning, engineering practice, technological innovation and post performance, and is a key link connecting basic theory and professional application[1-4].

However, in actual teaching scenarios, the student group of vocational undergraduate education presents highly heterogeneous characteristics: there are not only fault differences in their mathematics knowledge reserve, but also hierarchical differentiation in their learning abilities such as abstract thinking, computing ability and application awareness, as well as obvious differences in their cognitive styles, learning motivations, learning strategies and future development goals. In this context, the traditional teaching mode, which is typically characterized by a unified teaching progress, homogeneous teaching content and standardized teaching requirements, is difficult to take into account the development needs of students with different foundations, abilities and orientations, leading to prominent structural imbalance problems such as students with weak foundations being unable to keep up, students with medium levels failing to improve, and students with strong abilities not being fully challenged, and there is a certain gap between the teaching effect and the talent training goal[5-7].

To solve the teaching dilemma caused by student heterogeneity, stratified teaching has gradually become the mainstream practical path for the reform of mathematics teaching in vocational undergraduate education. However, most of the existing research and teaching practices carry out stratification based on a single indicator such as final exam scores and entrance test scores, which is essentially a static and linear stratification model. Although such a model has alleviated the problem of 'one-size-fits-all' teaching to a certain extent, it still has prominent limitations such as a one-sided stratification basis, lagging teaching response, rigid stratification structure and lack of professional adaptability. Especially under the core requirements of vocational undergraduate education that emphasize professional connection, post adaptation and ability progression, single-dimensional stratification cannot cover all dimensions of learning differences, and it is difficult to meet the practical needs of refined, personalized and professional development of teaching, which restricts the full play of the educational and service functions of mathematics courses.

Based on this, this study starts from the perspective of multi-dimensional stratification, places students' learning differences in a comprehensive analysis framework of knowledge, ability, characteristics and profession, systematically constructs an integrated adaptation mechanism for mathematics teaching in vocational undergraduate education, and carries out theoretical explanation from the aspects of structural model, operation logic and implementation path, aiming to provide a more explanatory, targeted and operable theoretical support for the teaching reform of mathematics courses in vocational undergraduate education, and promote the transformation of mathematics teaching from extensive stratification to precise adaptation.

2. Construction of the Multi-Dimensional Stratification Model

2.1. Composition of Stratification Dimensions

The differences in mathematics learning among vocational undergraduate students are not determined by a single factor, but by the interactive coupling of multiple factors such as knowledge reserve, ability level, learning habits and professional requirements. To comprehensively depict the characteristics of student differences and break through the one-sidedness of traditional stratification, this study constructs a multi-dimensional stratification framework composed of four core dimensions: knowledge foundation, ability development, learning characteristics and professional needs, so as to realize the panoramic identification of students' learning status.

Among them, the knowledge foundation dimension focuses on the students' mastery of pre-requisite mathematics knowledge, the level of conceptual understanding, and the proficiency of computing skills, which is the core premise determining the starting point and acceptance efficiency of mathematics learning, and directly affects the progress of subsequent teaching content. The ability development dimension focuses on the students' key abilities such as abstract logical thinking, mathematical reasoning, mathematical modeling, data processing and problem-solving, reflecting the students' learning potential, knowledge transfer ability and professional application potential, and is the core orientation of mathematics ability training in vocational undergraduate education.

The learning characteristics dimension focuses on non-intellectual factors such as the students' learning styles, learning strategies, learning motivation, classroom participation and self-regulation ability. This dimension directly acts on the efficiency, stability and sustainability of the learning process, and is an important internal variable affecting learning outcomes. The professional needs dimension is based on the type characteristics of vocational undergraduate education, closely linked to the talent training programs and post ability standards of different majors, reflecting the differentiated requirements of different professional fields such as engineering technology, economic management and information technology on the structure of mathematical knowledge, application scenarios and ability levels, and is a key bridge to realize the in-depth connection between mathematics teaching and professional training.

The four dimensions are interrelated and interact with each other, jointly forming a complete structural system of mathematics learning differences among vocational undergraduate students, and providing a comprehensive basis for precise stratification.

2.2. Organizational Form of Stratification

Under the multi-dimensional stratification framework, students are no longer simply divided into three fixed levels: high, medium and low, but present complex characteristics of multi-dimensional intersection and dynamic combination, which completely breaks the limitations of traditional single-axis linear stratification. In practical teaching, students' development in various dimensions is often unbalanced: some students have a relatively weak knowledge foundation but strong awareness of mathematical application and practical ability; some students have a solid theoretical foundation and proficient computing skills, but are insufficient in comprehensive application, cooperative inquiry or independent learning strategies; others have strong learning motivation and good learning habits, but their ability improvement is slow due to the fault of pre-requisite knowledge.

This non-linear, diversified and personalized structural characteristic makes it impossible for the traditional single-dimensional stratification centered on scores to accurately depict students' real learning status, which is likely to cause problems such as stratified labeling and insufficient adaptation accuracy. Through multi-dimensional cross-analysis and combined classification, a more refined and practical learner profile can be generated, which can clearly identify the advantages and shortcomings of each student in the four dimensions of knowledge, ability, characteristics and profession. Furthermore, it provides an accurate basis for stratified teaching design, promotes the transformation of mathematics teaching in vocational undergraduate education from extensive stratification to refined, personalized and combined regulation, and truly realizes teaching students in accordance with their aptitude.

2.3. Dynamic Stratification Mechanism

Multi-dimensional stratification is not a one-time static division, but a dynamic regulation process relying on the continuous collection, analysis and feedback of learning process data, with the core characteristics of phased update and periodic adjustment. With the orderly advancement of teaching activities, students will undergo continuous changes in knowledge mastery, ability improvement, and learning habit optimization. If the stratification results are solidified for a long time, it will lead to the lag of teaching adaptation behind students' development and lose the core value of stratified teaching.

Therefore, it is necessary to establish a normalized dynamic stratification mechanism. Based on multi-source information such as phased diagnostic evaluation, classroom performance data, homework completion quality, project practice results, and learning behavior records, the students' stratification results are periodically revised and optimized to ensure that the stratification results truly reflect the students' current learning status and development level. The dynamic stratification mechanism realizes the transformation from 'initial one-time classification' to 'whole-process dynamic regulation', which can timely adjust the stratification attribution according to students' progress range, ability shortcomings and development needs, provide adaptive teaching support for students at different development stages, maximize the stimulation of students' learning potential, and ensure that each student can achieve effective improvement on their original basis.

2.4. Professional Needs Dimension

The professional needs dimension is a symbolic feature that distinguishes multi-dimensional stratification from the stratification models of general undergraduate and higher vocational colleges. Its core value lies in breaking the phenomenon of 'two separate skins' between mathematics teaching and professional training, and establishing an internal logical connection between mathematics teaching, professional goals and post needs. There are significant differences in talent training orientation, curriculum system and post ability requirements among different majors in vocational undergraduate education, and the demand for mathematics presents obvious professional and scenario-based characteristics: engineering majors focus on engineering application abilities such as mathematical modeling, numerical calculation and geometric operation; management majors focus on management tool abilities such as data analysis, statistical inference and decision optimization; information technology majors focus on technical support abilities such as logical operation, algorithm foundation and data processing; cultural and creative majors focus on the cultivation of basic mathematical literacy and logical thinking.

These professional differences directly determine the content selection, focus setting, difficulty gradient and practice direction of mathematics courses. Therefore, in the process of implementing multi-dimensional stratification, it is necessary to systematically interpret the talent training programs, curriculum standards and core post ability requirements of each major, clarify the positioning of the basic supporting function and instrumental service function of mathematics courses in different majors, adjust the teaching content, task design and evaluation standards in combination with professional scenarios, so as to make mathematics learning closer to professional needs and post reality, and enhance the pertinence, practicality and professional adaptability of mathematics teaching.

3. Construction of the Teaching Adaptation Mechanism

3.1. Hierarchical Adaptation of Teaching Objectives

Based on the results of multi-dimensional stratification, the mathematics teaching objectives of vocational undergraduate education should break through the unified requirements, and construct a hierarchical, gradient and progressive objective system to realize the organic unity of ensuring the minimum common foundation and improving the quality of differentiated development. The design of teaching objectives needs to integrate the four dimensions of knowledge mastery, ability development, literacy improvement and professional application, forming a progressive structure according to the basic layer, progressive layer and innovative layer.

For students in the basic layer with weak knowledge foundation and insufficient learning ability, the teaching objectives focus on the understanding of core concepts, the mastery of basic formulas and the training of basic computing skills, ensuring that they meet the minimum common requirements of mathematics courses and lay a solid foundation for subsequent learning. For students in the progressive layer with relatively solid knowledge reserve and certain learning ability, the teaching objectives focus on the cultivation of abilities such as the deepening of mathematical methods, the solution of comprehensive problems and the simple application of professional knowledge, strengthening the ability of knowledge transfer and application awareness. For students in the innovative layer with solid knowledge, outstanding ability and strong learning initiative, the teaching objectives focus on high-level abilities such as comprehensive project practice, cross-professional application and mathematical modeling innovation, guiding students to carry out inquiry-based, open and innovative learning, and cultivating the thinking of technological and skilled innovation.

The hierarchical teaching objectives not only ensure that all students meet the basic mathematical literacy requirements for talent training in vocational undergraduate education, but also provide adaptive development space for students at different levels, fully implementing the concept of differentiated teaching.

3.2. Structural Adaptation of Teaching Content

To match the multi-dimensional hierarchical teaching objectives, it is necessary to reconstruct the traditional mathematics teaching content in a modular way, break the linear chapter arrangement mode, and form a three-layer structured content system of basic module, improvement module and application module to meet the learning needs of students at different levels and different majors.

The basic module is a compulsory content for all students, covering core mathematical concepts, basic theorems, common formulas and basic computing methods, focusing on knowledge popularization and skill standardization, ensuring that students have the most basic mathematical literacy and learning foundation. The improvement module is oriented to students in the progressive layer, focusing on the expansion of mathematical methods, the analysis of comprehensive questions and the integration of knowledge, strengthening the ability of logical reasoning and problem-solving, and realizing the transition from knowledge mastery to ability improvement. The application module is closely linked to professional needs and post reality, designing professional scenario-based practical content for students in the progressive layer and innovative layer, deeply integrating mathematical knowledge with professional scenarios such as engineering practice, management decision-making and technical application, and highlighting the practicality and professionalism of knowledge.

The modular content structure endows students with flexible learning choices and development paths. Within the unified curriculum framework, students can choose adaptive modules according to their own stratification attribution and professional needs, form personalized learning paths, improve learning autonomy and pertinence, and promote the transformation of mathematics teaching from knowledge transmission to ability cultivation.

3.3. Strategic Adaptation of Teaching Processes

The teaching implementation process is the core link for the landing of the teaching adaptation mechanism. It is necessary to construct a teaching organization strategy with multi-path parallel, diversified support and personalized guidance to fully adapt to the learning characteristics and development needs of students at different levels.

In classroom organization, the form of combining hierarchical grouping, task-driven and cooperative inquiry is adopted. Heterogeneous groups and homogeneous groups are set up according to the results of student stratification, and complementary advantages and mutual progress are achieved through group cooperation. In task design, hierarchical task-driven is implemented, and learning tasks with progressive difficulty and different objectives are designed for students in the basic layer, progressive layer and innovative layer, ensuring that each student can complete the learning objectives within the zone of proximal development. In the guidance method, the combination of common explanation and personalized tutoring is implemented, focusing on solving common problems in class, and carrying out precise tutoring for the shortcomings of students at different levels after class, timely answering questions and making up for gaps. In rhythm control, teachers dynamically adjust the teaching progress and methods based on classroom feedback, homework situation and learning data, taking into account the acceptance speed of students in the basic layer and the improvement needs of students in the innovative layer.

The diversified teaching strategies can effectively improve the adaptability and inclusiveness of classroom teaching, enable students at different levels to obtain appropriate learning support, and enhance the efficiency of classroom teaching and learning experience.

3.4. Multivariate Adaptation of Evaluation Methods

A diversified evaluation system matching multi-dimensional hierarchical teaching is constructed to promote the transformation of evaluation from a single result-oriented to a comprehensive orientation of ‘process + result, knowledge + ability, commonness + individuality’, giving full play to the diagnostic, incentive and improvement functions of evaluation.

In terms of evaluation content, breaking through the limitation of traditional knowledge-based testing, it takes into account multiple dimensions such as knowledge mastery, ability development, learning process, professional application and literacy improvement, comprehensively measuring students' learning effects. In terms of evaluation methods, it integrates various forms such as classroom participation, homework quality, phased testing, project practice, group cooperation and self-reflection, forming a multi-evaluation model combining process evaluation and summative evaluation, and supplementing quantitative evaluation with qualitative evaluation. In terms of evaluation standards, hierarchical evaluation is implemented, and differentiated evaluation indicators are formulated for students at different levels: the basic layer focuses on progress range and basic compliance, the progressive layer focuses on ability improvement and method mastery, and the innovative layer focuses on innovative application and comprehensive literacy, avoiding ‘measuring with one ruler’. In terms of evaluation function, the role of feedback and improvement is strengthened, and the evaluation results are timely fed back to students and teachers. Students clarify the direction of improvement based on this, and teachers optimize teaching design and stratification strategies based on this, forming a virtuous cycle of ‘evaluation - feedback - adjustment - improvement’ to ensure the continuous optimization of the teaching adaptation mechanism.

4. Operation Logic and Implementation Path of the Teaching Adaptation Mechanism

4.1. Operational Logic

The multi-dimensional hierarchical teaching adaptation mechanism for mathematics in vocational undergraduate education is essentially a closed-loop cycle system of ‘stratification identification - teaching matching - process regulation - feedback optimization’, in which each link is connected, cooperates and iterates continuously.

Stratification identification is the basic premise of the mechanism operation. Through multi-dimensional data collection, diagnostic evaluation and cross-analysis, the differential characteristics of students in the four dimensions of knowledge, ability, characteristics and profession are accurately identified, forming scientific and reasonable initial stratification results. Teaching matching is the core link of the mechanism operation. Based on the stratification results, comprehensive adaptive design of teaching objectives, teaching content, teaching strategies and teaching evaluation is carried out to ensure that the teaching supply is highly consistent with students’ needs. Process regulation is the key guarantee for the mechanism operation. Relying on the dynamic stratification mechanism and real-time learning data, the stratification attribution, teaching progress and teaching strategies are dynamically adjusted to solve the problem of lagging teaching adaptation. Feedback optimization is the driving force for the improvement of the mechanism operation. The teaching effect information is obtained through multi-evaluation, which reversely drives the optimization of stratification standards, the improvement of teaching design and the improvement of teaching resources, promoting the continuous iteration and upgrading of the entire mechanism.

4.2. Implementation Path

The implementation of the multi-dimensional hierarchical teaching adaptation mechanism for mathematics in vocational undergraduate education follows a progressive path of ‘identification - design - implementation - adjustment - optimization’, with clear operation procedures and implementation steps.

The first step is multi-dimensional accurate identification. Through entrance diagnostic testing, pre-learning situation investigation, learning behavior analysis, professional demand interpretation and other methods, the identification of students’ differences in the four dimensions is completed, and initial stratification results are formed. The second step is hierarchical teaching design. Based on the stratification results, hierarchical teaching objectives are formulated, modular teaching content is reconstructed, diversified teaching strategies are designed, and a hierarchical evaluation system is constructed to realize the adaptation of all teaching elements. The third step is teaching organization and implementation. According to the adaptation plan, teaching activities such as classroom teaching, group inquiry, task-driven and personalized tutoring are carried out to implement the requirements of hierarchical teaching. The fourth step is dynamic process adjustment. Teaching process data is to be continuously collected, learning situation diagnosis is to be regularly carried out, and the stratification results and teaching plans are to be dynamically revised. The fifth step is evaluation, feedback and optimization. The teaching effect should be summarized through multi-evaluation. Problems and deficiencies should be sorted out. Optimization of the stratification standards, teaching content and implementation strategies should be carried out. The improvement basis for the next teaching cycle should be provided.

4.3. Guarantee Conditions

The effective operation of the multi-dimensional hierarchical teaching adaptation mechanism requires the coordinated support of various conditions such as teachers, resources, systems and technology, forming a comprehensive guarantee system.

First, teacher ability guarantee. Teachers need to have solid mathematical professional literacy, hierarchical teaching design ability, learning situation data analysis ability, personalized guidance ability and professional integration awareness, and be able to accurately grasp students' differences and professional needs, which is the core foundation for the mechanism implementation. Second, curriculum resource guarantee. It is necessary to strengthen the construction of modular teaching resources, develop teaching resources such as textbooks, courseware, exercises, practical projects and micro-course videos that are suitable for different levels and different majors, to meet the needs of differentiated teaching. Third, teaching system guarantee. Schools should improve the supporting teaching management system, endow teachers with flexible rights of teaching organization, hierarchical evaluation and progress adjustment, and establish an assessment, evaluation and incentive mechanism suitable for hierarchical teaching to stimulate teachers' enthusiasm for reform. Fourth, information technology guarantee. Relying on intelligent teaching platforms, learning situation analysis systems and online learning tools, automatic collection of learning data, accurate analysis of learning situation, hierarchical intelligent recommendation and precise push of resources are realized, providing technical support for dynamic stratification and personalized teaching.

5. Conclusions

Based on the realistic needs of the typified development of vocational undergraduate education and the reform of mathematics teaching, this study carries out systematic theoretical construction and in-depth research on the mathematics teaching adaptation mechanism in vocational undergraduate education from the core perspective of multi-dimensional stratification. The study shows that integrating and analyzing students' learning differences under the multi-dimensional framework of knowledge foundation, ability development, learning characteristics and professional needs can effectively break through the limitations of one-sidedness, staticity and non-professionalism of traditional single-dimensional stratification, and significantly improve the pertinence, flexibility and professional compatibility of mathematics teaching. Constructing an integrated teaching adaptation mechanism integrating teaching objectives, teaching content, teaching process and teaching evaluation can better respond to the talent training requirements of 'application-oriented and competence-based' in vocational undergraduate education, and promote the transformation of mathematics teaching from homogenization to differentiation, from extensiveness to precision, and from subjectivity to professionalism.

This study mainly focuses on theoretical analysis, focusing on the framework construction of the multi-dimensional stratification model and the teaching adaptation mechanism. It has not carried out empirical testing and effect verification combined with specific teaching practice, and there is still room for further improvement in practical operability and effect quantitative analysis.

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