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A TPACK-Based Study on the Precise Embedding of Ideological and Political Education in Advanced Mathematics Courses

Xiufang Lin[a], Qi Wang[b,*], Senyue Luo[c], Tinghan Xie[d]

Department of General Education, Guangdong Polytechnic Institute, Guangzhou, China
[a]xflin@gdrtvu.edu.cn, [b]qwang@gdrtvu.edu.cn, [c]syluo@gdrtvu.edu.cn, [d]thxie@gdrtvu.edu.cn
**Corresponding author*

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Abstract: In the "3+2" segmented higher vocational education system, Advanced Mathematics not only undertakes the task of knowledge transmission, but also serves as an essential carrier of ideological and political education. Drawing on the TPACK framework and constructivist learning theory, this paper proposes a graph-based precision push mechanism that aligns ideological and political elements with key knowledge points in Advanced Mathematics and enables personalized resource recommendation. Pilot results show that this mechanism effectively enhances students' classroom participation, learning interest, and value identification, providing a new pathway for the precise, digital development of ideological and political education in higher vocational curricula.

1. Introduction

As a fundamental course for science and engineering majors in higher vocational colleges, Advanced Mathematics not only focuses on the transmission of mathematical theories and skills but also serves as an effective vehicle for ideological and political education. In recent years, colleges and universities have vigorously promoted curriculum-based ideological and political education[1], clearly requiring that "every course must guard a section of the canal and cultivate its own field of responsibility," to ensure that all courses move in the same direction as ideological and political theory courses and jointly foster a new generation who love the country and pursue moral excellence. The integration of ideological and political education into Advanced Mathematics can combine rigorous, abstract mathematical knowledge with value guidance, thereby enhancing the effectiveness of moral education in the classroom. For students in the "3+2" segmented higher vocational education system, their group characteristics are often manifested as weak mathematical foundations, unbalanced cognitive structures, vague professional identities, and unstable learning motivation, which make them more prone to fear of difficulty and value confusion in the study of Advanced Mathematics. They are in urgent need of targeted teaching strategies from teachers. In traditional teaching, many higher vocational students do not appreciate the significance of learning Advanced Mathematics, and their classroom participation and interest are low. Organically integrating ideological and political elements into the Advanced Mathematics classroom is expected to stimulate students' intrinsic cognitive motivation, enhance classroom enthusiasm, and help them develop a correct outlook on the world, life, and values.

In this context, this paper focuses on a precise embedding mechanism for ideological and political education in Advanced Mathematics. It explores practical pathways suited to the characteristics of students in the "3+2" segmented higher vocational education system. Based on the TPACK[2] framework and constructivist learning theory, we propose design principles for ideological and political education in Advanced Mathematics, and analyze a graph-based precision push mechanism that uses knowledge graphs to provide students with customized learning resources and ideological and political cases. This paper will elaborate in detail on the theoretical construction, resource design, implementation procedures, and technical support of this mechanism and, in combination with teaching cases, analyze its effectiveness in improving students' classroom participation, learning interest, and value identification.

2. Theoretical Foundations and Design Principles for Ideological and Political Education in Advanced Mathematics Courses

TPACK[3] (Technological Pedagogical Content Knowledge) emphasizes that teachers should integrate technology, pedagogy, and content knowledge in an organic way to optimize instructional design and effectiveness. In the ideological and political development of Advanced Mathematics courses, teachers need the ability to integrate information technology with disciplinary mathematics knowledge and to embed ideological and political elements skillfully into the teaching content. This requires teachers not only to have a solid command of Advanced Mathematics but also to be adept at using appropriate pedagogical approaches, such as case-based discussion and inquiry-based learning, to convey values and to make full use of digital platforms such as online courses, knowledge-graph tools, and feedback systems to enhance the interactivity and specificity of teaching. From the TPACK perspective, the design of ideological and political education in Advanced Mathematics should ensure alignment among technological means, instructional objectives, and value-education goals, so that technology serves as a booster for students' knowledge construction and value internalization rather than a mere ornamental embellishment.

Constructivist learning theory[4] holds that knowledge is not passively received, but actively constructed by learners based on their existing cognitive structures. Given that students in the "3+2" segmented higher vocational education system differ in their prior knowledge and possess uneven cognitive structures, they are in greater need of effective learning through situational creation and active inquiry. Based on constructivism, ideological and political education in Advanced Mathematics should be student-centered and provide contextualized cases closely related to students' life experiences and professional backgrounds, to promote their connection of new knowledge with prior cognition and reflection on the value implications through interaction. For example, when teaching the applications of definite integrals, teachers can introduce engineering or everyday examples familiar to students and further explore the scientific spirit or sense of social responsibility embodied in these examples, enabling students to experience the ideological and political connotations as they solve practical problems. Such a design allows ideological and political education to permeate the entire teaching process "silently yet effectively," aligns with students' cognitive patterns, and helps to internalize these elements into stable value orientations.

Based on the above theories, this paper distills five design principles for ideological and political education in Advanced Mathematics in higher vocational colleges. First, the principle of organic integration requires combining knowledge transmission and value guidance, ensuring that ideological and political elements are closely aligned with mathematical content and integrated as a whole rather than mechanically inserted. Teachers should deeply excavate the philosophical thinking, scientific spirit, and cultural stories embedded in mathematical concepts, theorems, and applications, so that ideological and political content naturally permeates all stages of teaching. Second, the principle of student subjectivity emphasizes students' central role in the teaching process and encourages them to engage in autonomous inquiry and discussion. In curriculum design, problem-based and project-based learning can be introduced, enabling students to participate in case analysis and debate, and thereby grasp the rationale and values behind the knowledge. Attention should be paid to differentiated instruction, with ideological and political activities designed around students' interests and confusions to enhance their sense of participation and identification. Third, the principle of technology empowerment calls for full use of information technology to enrich teaching forms and resources. Online course platforms and data-analysis tools can enable real-time monitoring and feedback on the teaching process. In contrast, innovative teaching platforms can present the associations between knowledge points and ideological and political elements and support personalized learning. Fourth, the principle of precise targeting emphasizes the precision of ideological and political education and the implementation of targeted interventions based on students' weaknesses and developmental needs. By analyzing real-time teaching feedback data, teachers can identify individual differences in knowledge mastery and value orientation, and then provide customized guidance and resource recommendations, thus achieving "one policy for each student." Such precision in education reflects the requirements of "all-round education throughout the whole process" in the "three-wide education" framework[5], ensuring that students with different foundations all benefit. Fifth, the principle of multidimensional evaluation advocates the development of a comprehensive evaluation system that covers knowledge, ability, attitude, and values, to examine students' growth in an all-round way. Evaluation should not only focus on students' performance in mathematics but also on process indicators, such as changes in learning attitudes and the development of a value orientation, with an emphasis on timely, visualized feedback to guide students' self-reflection and continuous improvement.

These principles provide design guidelines for ideological and political teaching in Advanced Mathematics. On this basis, the following sections will elaborate on the construction and application of a graph-based precision push mechanism.

3. Graph-based Precision Push Mechanism

The graph-based precision push mechanism leverages knowledge graph technologies[6, 7] to construct a networked graph connecting the knowledge points of the Advanced Mathematics course with ideological and political elements, and, through intelligent analysis, provides different students with precisely matched learning resources and ideological and political cases. The basis for constructing the knowledge graph is shown in Figure 1. Breaking with the linear structure of traditional Advanced Mathematics chapters, it organically links scattered knowledge points and related content. In the context of curriculum-based ideological and political education, the knowledge graph is expanded to form a "dual graph" comprising a subgraph of knowledge points and a subgraph of ideological and political elements. That is, on the one hand, mathematical concepts, theorems, and their preceding and subsequent relationships are sorted out; on the other hand, ideological and political materials such as stories of historical figures, application cases, and current affairs issues, together with the values they embody, are organized. An association links the two. Such a graph-based architecture can address the previous problems of curriculum-based ideological and political content being fragmented and unsystematic, and, through intelligent push, precisely meet students' individualized needs. When knowledge or understanding gaps arise during learning, the system can identify weak nodes in the graph and proactively push the corresponding learning content from the associated resource pool, helping students promptly address deficiencies.

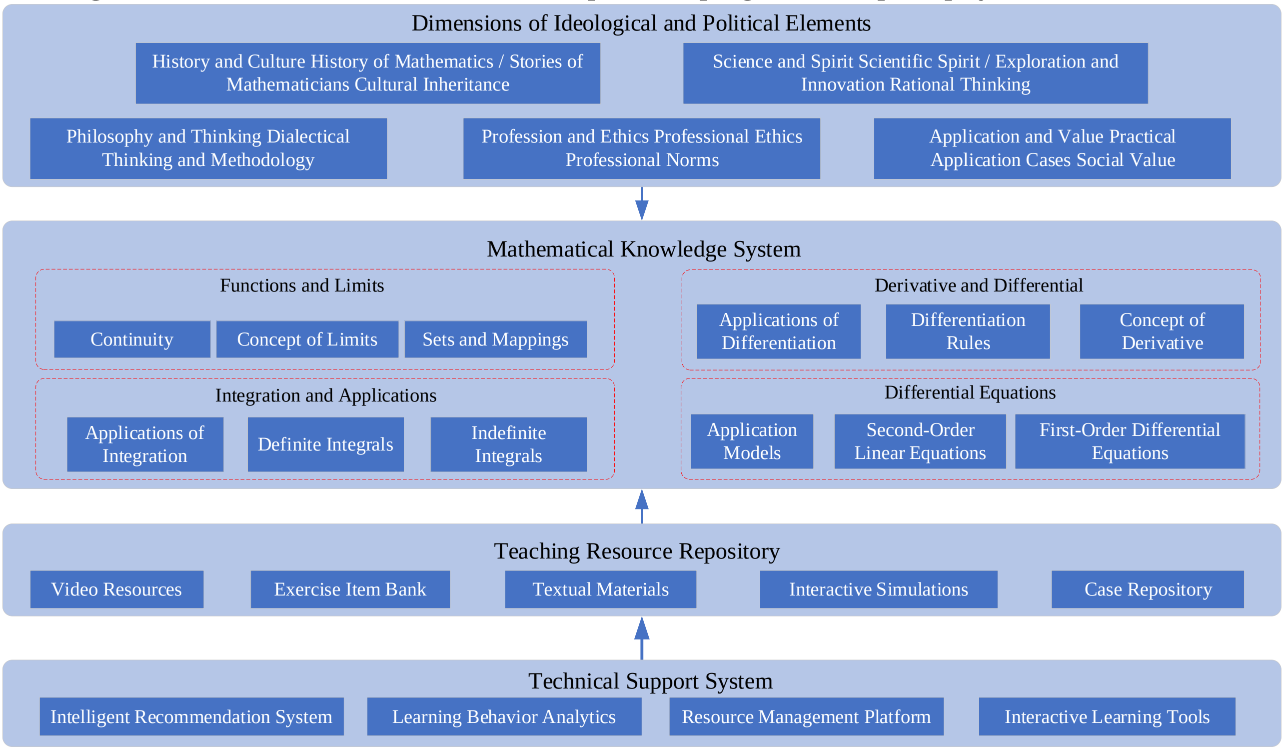

Figure 1. Network of Course Content Based on a Knowledge Graph

The implementation of graph-based precision push relies on constructing a high-quality course knowledge graph and supporting resource repository. First, the teaching team should, in accordance with the Advanced Mathematics syllabus, sort out all knowledge points and clarify the hierarchical structure and dependency relationships among them, for example, by subdividing concrete concepts and formula-theorem items under core modules such as functions, derivatives, and integrals, and then mapping them into a knowledge network. On this basis, the ideological and political elements or relevant cases contained in each knowledge point are mined. Resources can be matched along a temporal dimension, by drawing on the discovery of the knowledge in the history of mathematics and on the patriotic dedication of related figures; along a spatial dimension, by incorporating examples from national development and industrial applications. All these resources are associated with the corresponding nodes in the knowledge graph via tags, thereby forming a curriculum-based ideological and political resource graph. This graph intuitively displays the intrinsic links between mathematical knowledge and ideological and political elements, and realizes the transformation from "point-like ideological and political education" to "systematic ideological and political education". In terms of resource types, it can include a wide variety, such as written stories, images and videos, interactive exercises, and web links, to meet different students' learning preferences.

To ensure the effectiveness of precision push, resource design also needs to account for stratified difficulty and diversity. For higher vocational students with a weak mathematical foundation, easy-to-understand cases should be provided; for those with stronger capabilities, more challenging reading materials can be recommended. In addition, the resources under each knowledge point should be sufficient in quantity and reliable in quality, so that the system has enough content to push in repeated learning or for different students. In practice, this study has built a graph database containing 48 core knowledge nodes and 69 links to ideological and political materials, with some of the associations shown in Table 1. The database includes videos on national scientific and technological achievements, stories of craftspeople in their professions, and enterprise case analyses, initially forming a structurally complete and richly diversified system of curriculum-based ideological and political resources.

Table 1. Association Table for the Ideological and Political Knowledge Graph in the Advanced Mathematics Course

Mathematical knowledge point	Dimension of ideological and political elements	Specific ideological and political elements	Example of an associated case
Functions and limits	History and culture	History of mathematical development; cultural inheritance	Liu Hui’s method of circle cutting; Zu Chongzhi’s value of π
Functions and limits	Philosophy and thinking	Quantitative change to qualitative change; approaching infinity	Dialectical thinking is embodied in the concept of limit
Derivatives and differentials	Science and spirit	Scientific exploration; spirit of innovation	The history of Newton and Leibniz's founding of calculus
Derivatives and differentials	Application and value	Practical applications; social value	Application of derivatives in engineering optimization
Integrals and applications	Application and value	Practice orientation; problem solving	Application of integrals in medical image processing
Integrals and applications	Profession and ethics	Professional ethics: the pursuit of excellence	Requirements for integral calculations in precision manufacturing
Differential equations	Science and spirit	Model-based thinking; scientific methods	Construction and prediction of infectious disease models
Differential equations	Application and value	Social responsibility: serving the country through science and technology	Differential equations in orbital calculations for spaceflight

Based on the above graph and resource repository, the integration of precision push into course teaching primarily proceeds through the following five stages. The first is learning diagnosis: in their daily studies, students complete unit quizzes, in-class exercises, and assignment submissions via the online platform; the system analyzes their mastery of knowledge and marks the “weak nodes” in the graph. The second is profile modeling: students’ behavioral data on the platform, test scores, and learning preferences are integrated to form individualized learning profiles. The third is rule setting: teachers predefine push rules in the system for different types of weak nodes. For example, when a particular knowledge point fails to reach the standard in two consecutive tests, the system automatically pushes the corresponding introductory explanatory video and typical worked examples, together with one to two related ideological and political cases. The fourth is intelligent push: the system periodically or in real time recommends resources to students according to the rules, and students can receive prompts on the learning interface or mobile devices and access the learning content directly. The fifth is feedback and adjustment: the system records students’ viewing, completion, and evaluation of the recommended resources, and teachers optimize push rules and update the resource repository based on data analysis results. By comparing the learning paths of many students, the associative links in the knowledge graph are iteratively refined. In this way, a dynamically evolving intelligent teaching ecology is formed, which makes graph-based push increasingly precise and efficient.

4. Implementation

The key to implementation lies in obtaining timely information on each student’s learning situation, ensuring data transparency, and ensuring that the pushed content accurately addresses the problems and matches the required resources. In this study, we used the open course resources of the Smart Vocational Education platform to realize functions such as knowledge graphs, learning-behavior data collection, and an intelligent recommendation engine. In the project, we relied on the platform’s knowledge graph module to construct the course network and, at the same time, developed simple recommendation scripts to implement push rules and achieve precise pushing.

From 2023 to 2025, we piloted the graph-based precision push mechanism in several "3+2" classes across majors such as cost engineering, mechatronics, and automation at a higher vocational college. After the fifth week of teaching, we conducted a learning diagnosis for the "differential equations" unit. The results showed that about 30% of the students had a problem-solving accuracy below 60%, and most did not understand its significance in engineering applications. To address this, two push items were selected from the knowledge graph: the first was a set of consolidation exercises that provided step-by-step explanations for common error types; the second was a short case video that introduced the application of differential equations in epidemic propagation models and highlighted the value of mathematics in public health. These resources were then delivered to the relevant students via the SPOC classroom. Within the following two weeks, the resource click-through rate among these students exceeded 90%, and many left comments after watching the video, such as "I did not realize that mathematical models are so important to society; it is beneficial to learn mathematics well." After subsequent in-class Q&A and discussion, their mastery of and interest in differential equations improved markedly. In the final examination, the average score of the items on the corresponding knowledge points was 15 points higher than that of previous cohorts. In addition, we observed that several students in the class who had previously lacked learning motivation began, after receiving multiple rounds of personalized resource pushes, to take the initiative in asking teachers for more reference materials, and their attendance rate and assignment completion rate increased accordingly. This shows that the graph-based push mechanism not only remedies cognitive gaps but also gradually changes the learning attitudes of some students. Our practice confirms that the precision push mechanism enhances students' interest and self-confidence in learning mathematics and makes value shaping more subtle and profound.

To quantify the effect of the graph-based precision push mechanism, we designed a controlled experiment and questionnaire survey. At the end of the course, a comparison between the experimental class implementing the graph-based push and the control class adopting traditional teaching showed that the average chapter-test score of the experimental class was 8 points higher than that of the control class, and the classroom participation rate reached 88%, compared with 62% in the control class. The questionnaire results indicated that 92% of the students in the experimental class agreed that "the resources pushed by the system are helpful to my learning," and 83% reported that the mathematics course had "become more interesting and more meaningful." In contrast, only 58% of the control class expressed a high level of interest. In addition, on items related to "value identification", the average score of the experimental class was 0.7 points higher than that of the control class. These data show that graph-based precision push not only improves students' mastery of knowledge, but also stimulates their learning interest and intrinsic motivation, enhancing the implicit educational effectiveness of curriculum-based ideological and political education. It is worth noting that we also identified some problems during implementation, such as a significant increase in teachers' initial workload, requiring a considerable amount of time to construct the graph and screen resources, and a tendency among a few students to rely on system pushes, with their spirit of active exploration still needing to be fostered. These issues will be discussed in the subsequent improvement suggestions.

5. Recommendations for Institutionalized Promotion

The graph-based push mechanism discussed in this paper has achieved positive results in pilot teaching and has demonstrated strong applicability. To consolidate and extend these innovative practices on a larger scale and achieve the goal of improving the quality of curriculum-based ideological and political education in higher vocational colleges, the following five recommendations are proposed.

First, establish and improve supporting policies and incorporate them into routine teaching evaluation. The mechanism for the precise embedding of curriculum-based ideological and political education should be written into the school's teaching management regulations, with explicit requirements that teachers apply relevant approaches in course teaching and that such application be reflected in teaching-quality assessment and performance appraisal. For teams and individuals who achieve outstanding results in curriculum-based ideological and political practice, preferential treatment may be given in professional title evaluation and commendation to enhance teachers' enthusiasm for participating in reform. The system of teaching supervision and feedback should be improved, with regular checks on the embedding of ideological and political education in courses and students' feedback on courses taken as an essential basis for evaluation, thus promoting the solid implementation of the mechanism. In professional accreditation and teaching diagnosis and improvement, the weight of indicators such as the "degree of integration of curriculum-based ideological and political education" and "feedback on students' overall development" can be increased. Through institutional guarantees, scattered individual explorations by teachers can be elevated into school-wide action, thereby normalizing the mechanism of curriculum-based ideological and political education.

Second, build a shared resource platform to reduce teachers' implementation burden. In view of the heavy workload involved in constructing knowledge graphs and resource repositories, it is recommended that the academic affairs office take the lead in pooling the strength of various course teams to build a unified platform for curriculum-based ideological and political resources, where mature graphs and case resources are stored and labeled by category for repeated use. Open interfaces can be implemented on the platform so that teachers can easily retrieve resources that align with their course knowledge points and ideological and political elements, while supporting localized adaptation and personalized modification. At the same time, resource co-construction and sharing with peer institutions and industry enterprises can be strengthened, and cross-institution and school–enterprise alliances can be explored to facilitate the exchange of experience in graph construction and mutual complementation of strengths. Through co-construction and sharing of resources, teachers can focus more on flexibly applying the mechanism in their own classrooms, thereby improving implementation efficiency.

Third, strengthen teacher training and team cooperation to enhance information-based educational competence. The mechanism for the precise embedding of curriculum-based ideological and political education places higher demands on teachers' information literacy and cross-boundary collaboration. The school can regularly organize training sessions on the TPACK framework, knowledge graph construction, data analysis, and recommendation algorithms, inviting both information technology experts and frontline teachers to give lectures and conduct hands-on practice through workshops and teaching salons, thereby improving teachers' integrated application capabilities. At the same time, cross-disciplinary curriculum-based ideological and political project teams can be formed, in which subject teachers, ideological and political theory teachers, and technical personnel jointly design and implement schemes and develop experience that can be promoted in practice. The school can set up "teaching-innovation communities" to provide project funding, technical support, and policy backing for teachers who are willing to explore curriculum-based ideological and political education. Through continuous training and team-cooperation mechanisms, a "dual-qualified" teaching force that understands both the discipline and ideological and political education and is adept at using information technology can be built, laying a talent foundation for the long-term development of curriculum-based ideological and political education.

Fourth, conduct in-depth empirical research to optimize and iteratively refine the mechanism. Course instructors are advised to continuously track and evaluate the mechanism's actual effects in conjunction with classroom practice and to collect data for in-depth analysis. An evaluation index system can be constructed from multiple dimensions, such as learning achievement, classroom participation, learning engagement, and value identification. Methods such as pre–post comparison, an experimental–control group design, and the combination of interviews and questionnaires can be adopted to generate systematic research results. Teachers should be encouraged to elevate curriculum-based ideological and political practice into teaching-reform projects and to apply for related school-level and provincial-level programs to promote the deep integration of research and practice. On this basis, technologies such as learning analytics and artificial intelligence can be explored to optimize the structure of the knowledge graph and the push rules, and gradually realize more intelligent recommendations and interventions. For example, clustering analysis of learning trajectories can be used to identify typical learner profiles and provide differentiated push strategies for different types of students; sentiment analysis can be employed to mine emotional changes in students during the learning process and optimize the presentation of ideological and political cases. Ultimately, the system can move from a single "knowledge graph" towards an integrated "knowledge–ability–affect" graph and an affective graph, thereby enabling a holistic portrait of students' development. Through research-led, small-scale pilot work, the mechanism for embedding curriculum-based ideological and political education can be continuously refined and iterated, making it more intelligent, efficient, and aligned with students' needs.

Fifth, promote application in more courses and fields. The experience of curriculum-based ideological and political education in Advanced Mathematics can also serve as a reference for other professional foundational and technical courses. It is recommended that higher vocational colleges conduct activities to exchange and demonstrate curriculum-based ideological and political experience, and encourage teachers across disciplines to draw on the graph-based precision push model in Advanced Mathematics and adapt it locally to the characteristics of their own courses. For specialized courses, curriculum-based ideological and political graphs can be built around industry standards, professional norms, and authentic work tasks to highlight professional ethics, craftsmanship, and social responsibility; for general-education courses, more emphasis can be placed on dimensions such as humanistic literacy, civic awareness, and cultural confidence, and cross-disciplinary associations of ideological and political elements can be constructed. Education authorities can also guide various institutions at the policy level to carry out pilot reforms of graph-based curriculum-based ideological and political education, form typical cases and standard specifications that can be promoted, and advance the reform of curriculum-based ideological and political education from individual points to a broader scope and from individual subjects to the overall disciplinary system. For the "3+2" segmented training model in particular, curriculum-based ideological and political schemes should be holistically designed at the articulation stage between secondary and higher vocational education, with graph-based resources laid out in advance to integrate the five-year talent-training value chain into a coherent whole.

6. Conclusion

Research on the precise embedding mechanism of ideological and political education in Advanced Mathematics for "3+2" segmented higher vocational students shows that the use of innovative approaches, such as graph-based push, can effectively enhance students' classroom participation, learning interest, and sense of value identification, thus achieving synergistic enhancement between knowledge transmission and value guidance. The graph-based precision push mechanism leverages intelligent technologies to provide students with personalized learning support, making up for the shortcomings of traditional teaching in addressing individual differences, and building a closed-loop educational ecology for ideological and political education in Advanced Mathematics that meets the urgent need of higher vocational students for the integrated cultivation of moral character and intellectual competence.

It should be emphasized that the effective implementation of curriculum-based ideological and political education depends on teachers' sense of mission and professional competence. No matter how technology develops, teachers will always be the primary persons responsible for value guidance and must uphold the correct political orientation and their original aspiration for educating students. The precision embedding mechanism merely provides new tools and ideas; its genuine implementation still relies on teachers' careful instructional design and flexible application, as well as continuous improvement and refinement in practice. Through institutional guarantees, resource sharing, and team collaboration, more teachers can be drawn into curriculum-based ideological and political reform, thereby fostering a positive atmosphere in which "every course carries ideological and political elements, and everyone attaches importance to educating students."

As vocational education advances towards high-quality development, the integration of emerging technologies with education and teaching will become even closer. The mechanism for the precise embedding of curriculum-based ideological and political education will also be continuously upgraded: more intelligent evaluation and recommendation, richer cross-disciplinary ideological and political resources, and more personalized educational programmes tailored to students' characteristics will emerge. This mechanism not only serves the single course of Advanced Mathematics but also benefits clusters of related programmes, promoting the effective implementation of the "three-wide education" concept in higher vocational colleges. We are confident that, as long as we uphold integrity and pursue innovation, and implement moral cultivation in the details of teaching, higher vocational students will be able to elevate their ideological realm in the course of professional study and grow into a new generation of technical talents endowed with both solid skills and noble character.

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