Advances in Educational Technology and Psychology (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/aetp.2025.090218
ISSN 2371-9400 Vol. 9 Num. 2

Research on the Coupling Relationship between Advanced Mathematical Thinking Cultivation and Technological Innovation Capability from the Perspective of New Engineering Education

Xiaojing Wang[1,a,*], Bo An[2,b], Wumei Hu[3,c]

[1]Basic Department, Xi'an Siyuan University, Xi'an, Shaanxi, China
[2]Institute of Technology, Xi'an Siyuan University, Xi'an, Shaanxi, China
[3]College of Arts and Business, Xi'an Siyuan University, Xi'an, Shaanxi, China
[a]1017411047@qq.com, [b]2226576815@qq.com, [c]735808775@qq.com
**Corresponding author*

Keywords: New Engineering Education; advanced mathematical thinking; technological innovation capability; coupling relationship

Abstract: Under the backdrop of New Engineering Education, cultivating students' advanced mathematical thinking and technological innovation capabilities has become crucial for enhancing talent competitiveness. This paper deeply analyzes the coupling relationship between advanced mathematical thinking (including logical thinking, abstract thinking, innovative thinking, etc.) and technological innovation capabilities. It explores how to promote their synergistic development through reforms in advanced mathematics teaching, providing theoretical support and practical guidance for New Engineering talent cultivation. Research indicates that strengthening advanced mathematical thinking training can effectively enhance students' technological innovation capabilities, with the two mutually reinforcing and complementing each other.

1. Introduction

With the rapid development of technology and profound industrial transformation, New Engineering Education has become a critical direction for higher engineering education reform in China. New Engineering Education emphasizes interdisciplinary integration[1-3], practical innovation, and support for emerging industries. In this context, equipping students with solid mathematical foundations and robust mathematical thinking skills is essential for enhancing their technological innovation capabilities and adapting to future complex engineering demands. As a foundational course for engineering disciplines, advanced mathematics not only provides mathematical tools for subsequent specialized courses but also serves as a vital source for cultivating students' innovative and problem-solving abilities. In-depth research into the coupling relationship between advanced mathematical thinking cultivation and technological innovation capabilities holds significant practical value for advancing New Engineering talent cultivation models and improving talent quality.

2. Constituent Elements of Technological Innovation Capabilities under the New Engineering Perspective

2.1. Problem Identification and Analysis Capability

In the context of New Engineering, technological innovation[4] often stems from acute insight into and in-depth analysis of practical engineering challenges. Students must develop the ability to identify problems by recognizing potential technical issues within complex engineering systems and conducting comprehensive, thorough analyses using their acquired knowledge. For instance, in the development of intelligent transportation systems, students should be able to detect issues such as traffic congestion and frequent accidents, then analyze factors like traffic flow data and road conditions to pinpoint root causes. This capability to identify and analyze problems marks the starting point of technological innovation, as only by accurately defining challenges can targeted innovation activities be effectively pursued.

2.2. Knowledge Application and Integration Capability

Technological innovation requires students to organically integrate and apply multidisciplinary knowledge—spanning mathematics, physics, engineering, and technology—to solve real-world problems. In New Engineering fields, many innovation projects involve cross-disciplinary convergence, necessitating students' proficiency in applying and synthesizing knowledge across domains. For example, in biomedical engineering, developing novel medical devices demands the integration of biology, medicine, electronic technology, computer science, and other disciplines. Students must master the ability to synthesize knowledge from diverse fields to formulate effective solutions. This capacity for knowledge application and integration is pivotal to achieving technological innovation, enabling students to transcend disciplinary boundaries and explore novel creative pathways.

2.3. Innovative Design and Practical Implementation Capability

Innovative design and practical implementation capabilities form the core of technological innovation. During the design process, students must fully leverage their imagination and creativity, employing diverse design methodologies and tools to devise innovative and practical products or technologies. For instance, in designing new energy vehicles, students need to innovatively develop critical components such as battery management systems and power transmission systems to enhance vehicle performance and range. Simultaneously, students must possess practical skills to translate design concepts into reality, validating and optimizing solutions through experimentation, testing, and other means. This ability to innovate in design and implement solutions represents the culmination of technological innovation, as only through practice can innovative ideas be translated into tangible productivity.

3. Analysis of the Coupling Relationship Between Higher Mathematical Thinking and Technological Innovation Capabilities

3.1. The Facilitative Role of Higher Mathematical Thinking in Technological Innovation

3.1.1. Logical Thinking as a Rational Foundation for Technological Innovation

Logical thinking empowers students to systematically analyze and reason through challenges during technological innovation, ensuring the rationality and feasibility of innovative ideas. For

example, when developing a new software system, students must apply logical thinking to meticulously analyze and design aspects such as functional requirements, data flow, and user interfaces, ensuring the system's architecture is rational and operates stably. In the implementation phase of innovation projects, logical thinking further aids students in analyzing experimental data, identifying issues, and making timely adjustments. Thus, logical thinking serves as an indispensable rational foundation for technological innovation, enhancing the efficiency and success rate of innovative endeavors.

3.1.2. Abstract Thinking Facilitates Model Construction in Technological Innovation

Abstract thinking enables students to extract mathematical models from complex engineering problems, transforming real-world challenges into solvable mathematical formulations. Establishing appropriate mathematical models is a critical step in addressing issues during technological innovation. For instance, when studying the aerodynamic performance of aircraft, students can employ abstract thinking to disregard minor structural details and factors, constructing a mathematical model of aerodynamics. By solving and analyzing this model, they can optimize the aircraft's design to enhance its flight performance. Additionally, abstract thinking empowers students to extend and refine existing mathematical models to meet emerging engineering demands.

3.1.3. Innovative Thinking Sparks Inspiration and Breakthroughs in Technological Innovation

Innovative thinking serves as the soul of technological innovation, igniting students' inspiration and creativity during the innovation process and propelling them to transcend conventional thought patterns to propose novel technical solutions and approaches. Many problems and methodologies in higher mathematics possess an open-ended and exploratory nature, fostering students' capacity for innovative thinking. For example, in mathematical modeling competitions, students confront real-world problems, applying mathematical knowledge and methods to devise creative solutions. Participation in such activities hones their innovative thinking, which subsequently transfers to future technological innovation endeavors. This capability equips them to tackle technical challenges by approaching problems from diverse perspectives, seeking unconventional solutions, and achieving breakthroughs in technological innovation.

3.2. The Reciprocal Influence of Technological Innovation Capabilities on the Cultivation of Higher Mathematical Thinking

3.2.1. Technological Innovation Practices Enrich the Application Scenarios of Higher Mathematical Thinking

Technological innovation practices provide rich real-world contexts for applying higher mathematical thinking, enabling students to deepen their understanding and utilization of such thinking through problem-solving. When engaging in technological innovation projects, students must apply logical, abstract, and innovative thinking—core components of higher mathematics—to address specific engineering challenges. Through hands-on experience and practical application, they gain a more profound grasp of these cognitive skills. For example, in projects involving data analysis and processing, students employ logical thinking to organize and interpret data, abstract thinking to construct data models, and innovative thinking to develop novel algorithms. Such practices not only enhance their technological innovation capabilities but also elevate their proficiency in higher mathematical thinking.

3.2.2. Technological Innovation Demands Drive the Deepening and Expansion of Higher Mathematical Thinking

As technological innovation evolves, emerging engineering challenges and technical requirements impose higher demands on higher mathematical thinking, propelling its refinement and broadening. For instance, innovations in artificial intelligence rely heavily on advanced mathematical knowledge such as probability theory, linear algebra, and numerical analysis. To innovate in this field, students must delve deeply into these areas, cultivating corresponding mathematical thinking skills. Simultaneously, novel problems encountered during innovation processes prompt students to critically reflect on and improve existing methodologies in higher mathematical thinking. This iterative interaction fosters the continuous development and enhancement of higher mathematical thinking, ensuring its relevance and adaptability to cutting-edge technological advancements.

4. Talent Development Strategies for New Engineering Based on Coupling Relationships

4.1. Optimizing the Higher Mathematics Curriculum System by Integrating Innovative Practical Elements

4.1.1. Adjusting Course Content to Strengthen Mathematical Thinking Training

In designing the higher mathematics[5] curriculum, emphasis should be placed on cultivating mathematical thinking by incorporating content related to logical reasoning, abstract generalization, and innovative exploration. For example, when introducing mathematical concepts, instructors can elaborate on the background and evolution of these concepts to help students understand how they are abstracted from real-world problems, thereby fostering abstract thinking. During theorem-proof instruction, guiding students to analyze proof methodologies can enhance their logical reasoning skills. Additionally, open-ended mathematical problems should be integrated to encourage independent exploration of solutions, nurturing innovative thinking. Furthermore, aligning with the characteristics of New Engineering disciplines, relevant professional case studies can be embedded into mathematics courses. This approach allows students to recognize the application value of mathematics in their fields, boosting their motivation and engagement in learning.

4.1.2. Enhancing Practical Teaching Components to Cultivate Innovation Capabilities

To strengthen the coupling between higher mathematical thinking and technological innovation capabilities, practical teaching elements should be expanded within the higher mathematics curriculum. Activities such as mathematical experiments and modeling competitions can be organized to enable students to apply mathematical knowledge and thinking methods to solve real-world problems, thereby fostering innovation and practical skills. For instance, involving students in mathematical modeling competitions challenges them to address actual engineering issues by constructing mathematical models, programming solutions, and analyzing results. Throughout this process, students synthesize logical, abstract, and innovative thinking to translate practical problems into mathematical frameworks and resolve them through hands-on practice. Such experiences significantly enhance their technological innovation capabilities while reinforcing their mastery of higher mathematical thinking.

4.2. Strengthening Faculty Development to Enhance Teaching and Innovation Capabilities

4.2.1. Conducting Teacher Training to Improve Pedagogical Competence in Mathematical Thinking

Teachers play a pivotal role in cultivating students' higher mathematical thinking and technological innovation capabilities. To enhance instructors' teaching proficiency, universities should regularly organize training sessions for faculty, inviting mathematics education experts and distinguished educators to deliver specialized lectures and teaching demonstrations. These sessions should introduce advanced pedagogical methods and practical experiences in fostering mathematical thinking. Additionally, teachers should be encouraged to engage in pedagogical research, exploring innovative higher mathematics teaching models and approaches tailored to the needs of New Engineering talent development, thereby continuously refining their instructional skills. Furthermore, organizing faculty participation in activities such as mathematical modeling competitions and research projects can help teachers improve their mathematical application and innovation abilities through practical experience, enabling them to better guide students in innovative practices.

4.2.2. Recruiting Industry Professionals to Diversify Faculty Composition

To better align higher mathematics education with engineering practices, universities should recruit technical professionals with industry experience to enrich the faculty structure. These professionals bring extensive hands-on engineering expertise and technological innovation skills, allowing them to incorporate real-world engineering cases and innovation experiences into classroom instruction, thereby making teaching content more relevant to practical engineering contexts. They can also mentor students in practical learning activities, helping them understand industry demands and processes for technological innovation, which enhances students' innovation capabilities. Moreover, universities should establish partnerships with enterprises, arranging for faculty to undertake temporary assignments or internships within companies. This exposure enables teachers to gain in-depth insights into industrial operations, production management, and technological innovation, enriching their practical engineering experience and elevating both their teaching quality and innovative capacities.

4.3. Establishing a Diversified Evaluation System to Promote Students' Holistic Development

4.3.1. Emphasizing Process-Oriented Evaluation to Focus on Students' Mathematical Thinking Development

In the evaluation of higher mathematics courses, a diversified evaluation system should be established, with an emphasis on process-oriented evaluation to monitor the development of students' mathematical thinking during their learning journey. Process-oriented evaluation may encompass classroom performance, assignment completion, participation in group discussions, mathematics experiment reports, and other dimensions. Through a comprehensive assessment of students' learning processes, instructors can gain timely insights into their academic progress and the evolution of their mathematical thinking, identify existing challenges and shortcomings, and offer prompt guidance and feedback. For example, in evaluating classroom performance, instructors may observe students' cognitive engagement, logical reasoning skills, and problem-solving abilities. In assessing assignments, attention should be paid to evaluating students' problem-solving approaches and methods, encouraging them to apply diverse thinking strategies. By implementing

process-oriented evaluation, students' learning motivation and initiative can be stimulated, effectively fostering the advancement of their mathematical thinking.

4.3.2. Strengthening Innovative Evaluation to Encourage Students' Engagement in Technological Innovation Activities

To cultivate students' technological innovation capabilities, innovative evaluation should be emphasized within the assessment system. This can be achieved by establishing evaluation criteria such as innovation projects and scientific/technological competitions to encourage active student participation in technological innovation activities. Students who achieve outstanding results in innovation projects or competitions should be rewarded with corresponding incentives and academic credit recognition. Simultaneously, when evaluating students' innovative outcomes, emphasis should be placed on assessing their innovative thinking, methodologies, and practical implementation skills, encouraging them to break through conventional approaches and propose novel solutions. For instance, in evaluating mathematical modeling competitions, attention should not only be paid to students' modeling results but also to their modeling approaches, methodological innovations, and their ability to analyze and solve real-world problems. By strengthening innovative evaluation, a conducive atmosphere for innovation can be fostered, students' enthusiasm for innovation can be ignited, and their technological innovation capabilities can be effectively enhanced.

5. Conclusions

Under the perspective of New Engineering, there exists a close coupling relationship between the cultivation of higher mathematical thinking and technological innovation capabilities. The logical thinking, abstract thinking, and innovative thinking inherent in higher mathematical thinking provide robust support for enhancing technological innovation capabilities, while the development of technological innovation capabilities, in turn, promotes the deepening and expansion of higher mathematical thinking. By optimizing the higher mathematics curriculum system, integrating elements of innovative practice, strengthening the development of teaching faculty, enhancing instructors' pedagogical and innovative competencies, establishing a diversified evaluation system, and fostering students' holistic development, it is possible to effectively advance the synergistic growth of higher mathematical thinking and technological innovation capabilities. These strategies provide a solid foundation for cultivating talents in New Engineering disciplines. Moving forward, with the continuous advancement of New Engineering initiatives, further exploration of innovative models and methods for talent development should be pursued to nurture more high-quality engineering and technical professionals with innovative spirit and practical abilities for the nation.

References

[1] Rui H U, Xin-Zhong C, Shan X. Higher Schools to Promote Interdisciplinary Fusion Strategy—Taking Massachusetts Institute of Technology as an Example[J].Journal of Huazhong Agricultural University(Social Sciences Edition), 2012.

[2] Micoli L L, Barsanti S G, Guidi G. Interdisciplinary Data Fusion For Diachronic 3d Reconstruction Of Historic Sites[J]. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2017, XLII-2/W3:489-494.

[3] Tian X , Tirakoat S .The Creative Watercolor Flow in the Digital Epoch: A Novel Approach to Cross-Disciplinary Aesthetics Integration[J].TEM Journal, 2024, 13(4).DOI:10.18421/TEM134-19.

[4] Office U S G A .Higher Education: Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends[J].Us Government Accountability Office, 2005, 22(3):656-659.

[5] Engineering M P I .Retracted: Quality Assessment Method of Information Model Reform of Higher Mathematics Education Based on Big Data[J].Mathematical Problems in Engineering, 2023.DOI:10.1155/2023/9805925.