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Enhancement of Innovation Competence of College Students Majoring in Mathematics Education through Curriculum Optimization

Chengqiang Wang*, Qiuxia Wu, Xiangqing Zhao, Zhiwei Lv

School of Mathematics and Physics, Suqian University, Suqian 223800, Jiangsu Province, China

Corresponding author: Chengqiang Wang, chengqiangwang2022@foxmail.com

Abstract: The innovation competence of K-12 education teachers undoubtedly plays a crucial role in fostering the innovation abilities of their students. K-12 mathematics education equips students with the critical thinking and problem-solving skills essential for their future studies in colleges and universities, helping them grasp complex techniques to address challenges in everyday life and their careers. Therefore, it is of great significance to study strategies for improving the innovation competence of college students majoring in Mathematics Education, as they will likely become K-12 education mathematics teachers directly after graduating from colleges or universities. In this paper, we study strategies for enhancing the innovation competence of college students majoring in Mathematics Education through curriculum optimization. We analyze and explain in detail the importance of innovation competence for college students majoring in Mathematics Education and the difficulties encountered in enhancing college students' innovation competence. With the help of the analysis of the importance and challenges of enhancing college students' innovation competence, we propose several strategies to improve the innovation competence of college students majoring in Mathematics Education based on curriculum optimization. The findings presented in this paper can be applied to develop strategies for college students majoring in Physics and Chemistry Education.

Keywords: K-12 education; Innovation competence; College students; Mathematics Education; Curriculum optimization

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1. Introduction

In today's fast-changing world, K-12 education is offering a whole new range of experiences and striving to achieve new objectives. One of these significant objectives is that the schools or education workers would strive to improve K-12 students' innovation abilities. It is well known that K-12 education teachers play key roles in cultivating K-12 students' innovation abilities. It is widely accepted that mathematics equips students with the critical thinking and problem-solving skills to be engaged citizens and to attain high-paying, in-

demand jobs. Therefore, we can conclude that K-12 mathematics teachers' innovation competence plays a key role in cultivating K-12 students' innovation abilities. In China, most of the K-12 mathematics teachers graduated as college students majoring in Mathematics Education [1]. Therefore, it is of great significance to devise, via intensive studies, strategies to promote the innovation competence of college students majoring in Mathematics Education. In this paper, we are devoted to the study of strategies to optimize the curriculum to enhance the innovation competence of college students majoring in Mathematics Education.

2. The importance of innovation competence for college students majoring in Mathematics Education

2.1. Possessing intrinsic motivation to improve K-12 students' innovation abilities in their future educational careers

College students with high innovation competence achieved much success by perceiving and utilizing mathematics creatively, solving mathematical problems in innovative ways, and reflecting on their mathematical problem-solving experiences through creative views. Mathematical innovation competence has greatly contributed to their personal growth and fulfillment [2]. Therefore, in their future educational careers, college students majoring in Mathematics Education with high innovation competence are more inclined to improve K-12 students' mathematical innovation abilities.

Generally, college students with strong mathematical innovation skills are highly motivated and passionate about making a positive impact on mathematics education. By focusing on K-12 mathematics education, they can play a role in shaping the future workforce and helping students become more creative thinkers. This aligns with their values of contributing to the advancement of mathematics education and fostering a more innovative mindset in their students.

Based on the theoretical analysis above, our teaching team's empirical experience reveals that college students majoring in mathematics education, who possess high innovation competence, are intrinsically motivated to enhance K-12 students' mathematical innovation abilities in their future educational careers.

2.2. Understanding the K-12 instructional materials in creative ways during their future educational careers

Instructional materials, such as textbooks, include widely accepted knowledge concepts and ideas and play important roles in the mathematical instruction of K-12 students. To effectively teach K-12 students mathematics, it is crucial for teachers to possess a thorough understanding of instructional materials. College students with high mathematical innovation competence would understand K-12 teaching materials, such as textbooks, in creative ways during their future educational careers.

2.3. Teaching K-12 mathematics creatively in their future educational careers

College students with high innovation competence have extensive experience in mathematical innovations and know how to teach K-12 students to perceive mathematics creatively, solve mathematical problems innovatively, and reflect on their problem-solving experiences through a creative lens. As revealed by our teaching team's extensive practical experiments, these distinguished experiences indicate that college students with high innovation competence will teach K-12 mathematics in creative ways during their future educational careers.

3. Striking difficulties encountered in enhancing college students' innovation competence

3.1. College students' lack of awareness of the need to improve their innovation competence

Many college students usually progress through their studies without encountering significant challenges. Due to being preoccupied with their regular academic workloads, they lack diverse experiences and critical engagement with complex issues. This focus on conventional paths ultimately results in a diminished awareness of the necessity to enhance their innovation competence. As suggested by the theories of Maslow's Hierarchy of Needs, intrinsic motivation is seemingly essential for personal development and self-actualization. As a consequence, one of the key factors preventing college students from improving their innovation competence is their lack of awareness of the need to do so.

3.2. Challenges in finding effective methods to improve college students' innovation competence

For college students majoring in Mathematics Education, the process of improving their innovation competence involves fostering critical thinking, creativity, and practical experience, which require consistent practice, feedback, and exposure to challenging mathematical problems. Therefore, it would take a long time to achieve the goal of enhancing college students' innovation competence. This leads to two drawbacks: First, it is rare for students to consistently dedicate themselves to improving their innovation competence over such a long period. Second, due to the curriculum, college students often have a heavy study burden, leaving them insufficient time to enhance their innovation competence.

Different college students possess diverse academic backgrounds and experiences, which significantly impact how they approach learning and innovation. Consequently, there is no universal method to effectively enhance all students' innovation competence simultaneously. For instance, students' previous exposure to innovative practices varies widely. Some may have engaged in challenging mathematical problems, while others may lack such experiences, necessitating different levels of support and resources. Tailored approaches, therefore, become essential. However, due to the constraints of the curriculum, there is often inadequate time to implement strategies specifically designed to enhance each student's innovation competence.

College students' innovation competence is implicit and difficult to assess. In addition to numerical data, many evaluation results are presented in text, graphs, and tables, making it challenging to collect comprehensive educational big data. Evaluating the effectiveness of efforts to improve college students' innovation competence is complicated, which in turn makes it difficult to provide constructive feedback for understanding which strategies are most effective. As a result, there is little clarity on how to enhance these strategies to better support the development of students' innovation competence.

4. Strategies for curriculum improvement

In the previous two sections, we found that the curriculum plays a key role in improving the innovation competence of college students majoring in Mathematics Education. Broadly speaking, the curriculum, which is directly linked to the talent cultivation programs for college students, guides the design of subsequent courses and their syllabi. Based on our detailed analysis, we propose several objectives for optimizing the curriculum for the Mathematics Education major.

4.1. To supply college students majoring in Mathematics Education with more challenging mathematical problems

Just as simple mathematical problems, challenging problems can help convey concepts to students. In contrast to straightforward problems, these challenging ones can provoke new ideas and innovations. To enhance the innovation competence of college students majoring in Mathematics Education, it is essential to allocate sufficient time for them to engage with challenging mathematical problems. For instance, an example from the 14th National College Student Mathematics Competition of China is incorporated into Mathematical Analysis courses.

Example 1: Assume that the function $z = f(x,y)$ is differentiable in the region D where $D = \{(x,y) \in R^2 | 0 \leq x \leq 1, 0 \leq y \leq 1\}$, that $f(0,0) = 0$, and that $dz|_{(x,y)=(0,0)} = 3dx + 2dy$. Please calculate the limit

$$\lim_{x\to 0^+} \frac{\int_0^{x^2} dt \int_x^{\sqrt{t}} f(t,u)du}{1-\sqrt[4]{1-x^4}}.$$

Diverse elements of calculus, such as the differentiability of functions and their applications, equivalent infinitesimals and their applications, the theory of multiple integrals, the limit theory of functions, and so on, are encompassed in Example 1. By solving problems like Example 1, college students majoring in Mathematics Education can build a stronger foundation in mathematics, become more mathematically sophisticated, and gain valuable experience in perceiving and solving challenging mathematical problems creatively. Therefore, Example 1 serves as an excellent resource for fostering the innovation competence of college students majoring in Mathematics Education, as it provides them with opportunities to tackle complex problems, think critically, and develop creative solutions that enhance their overall mathematical skills. Based on our experience, in actual classrooms of the Mathematical Analysis courses, some college students are able to find the following solution after receiving instruction from our teaching team

$$\lim_{x\to 0^+} \frac{\int_0^{x^2} dt\int_x^{\sqrt{t}} f(t,u)du}{1-\sqrt[4]{1-x^4}} = -4\lim_{x\to 0^+} \frac{\int_0^x \int_0^{u^2} f(t,u)dtdu}{x^4} = -\lim_{x\to 0^+} \frac{\int_0^{x^2} f(t,x)dt}{x^3} = -2,$$

where the last '=' is obtained directly by analyzing the differentiation assumption of the function f. It is worth pointing out that the previously mentioned '=' follows also through an intuitive analysis of **Figure 1**.

As evidenced by our teaching team, challenging mathematical problems significantly contribute to improving college students majoring in Mathematics Education. Therefore, through theoretical analysis and practical empirical evidence, it is an excellent strategy to optimize the curriculum by providing these students with more challenging mathematical problems.

4.2. To offer college students majoring in Mathematics Education more opportunities to bridge K-12 mathematics with college-level mathematics

Since college students majoring in Mathematics Education are extremely likely to become K-12 education workers, it is essential and beneficial to provide them with more opportunities to connect K-12 mathematics with college-level mathematics. To bridge secondary school and college-level mathematics, Example 2: Question 21 from the 2019 Zhejiang Province Mathematics test of the National College Entrance Examination (NCEE) in China, is included within the Analytical Geometry course [3].

Example 2: Assume that $F(1,0)$ is the focus of the parabola $y^2 = 2px$ ($p > 0$), and that a straight line passing through F intersects the parabola at points A and B. Let G be the centroid (barycenter) of ΔABC, which lies on the x axis, where C is another point on the parabola. Furthermore, the line AC intersects the

x axis at point Q, which is located to the right of F (**Figure 2**). (i) Determine the equation of the concerned parabola; (ii) Determine the minimum of the expression $S_{\Delta AFG}$ divided by $S_{\Delta CQG}$, where $S_{\Delta AFG}$ and $S_{\Delta CQG}$ denote the areas of the triangles ΔAFG and ΔCQG, respectively.

By some routine calculations, we can get $p = 2$ and $y^2 = 4x$. Following the methods collected by Wang [3], we can obtain the minimum $(\frac{S_{\triangle AFG}}{S_{\triangle CQG}})_{\min} = 1 + \frac{\sqrt{3}}{2}$ and the (unique) minimizer, by introducing several geometric variables, some of which are closely related to college-level mathematics. As evidenced by Wang [3], during the Analytic Geometry actual classrooms, introducing Example 2 helps college students majoring in Mathematics Education connect secondary school mathematics with college-level mathematics. They use their knowledge of secondary school mathematics to assimilate college-level concepts and, in turn, reflect on secondary school mathematics from the perspective of more advanced college-level understanding. This approach allows them to develop a deeper, faster, and more systematic comprehension of mathematics.

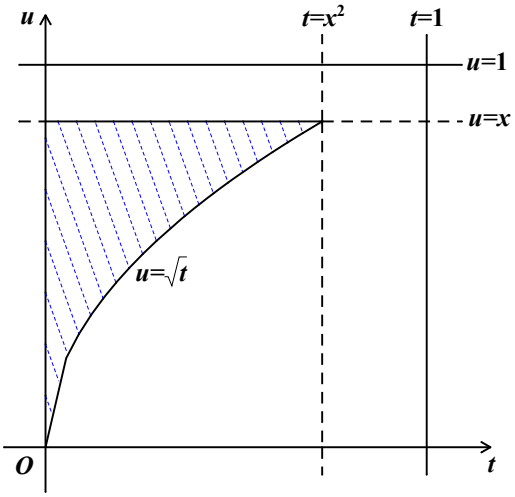

Figure 1. The integration domain of the double integral in Example 1

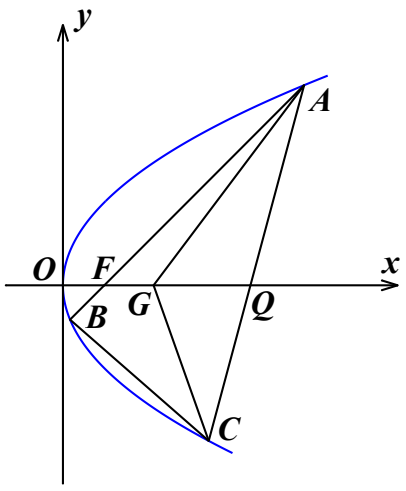

Figure 2. Parabola in Example 2 [3]

4.3. To allow college students majoring in Mathematics Education more time to develop innovative solutions to common or typical mathematical problems

To fully leverage textbook exercises to improve the innovation competence of college students majoring in Mathematics Education, several methods for solving the following question were obtained from a Mathematical Analysis textbook [4].

Example 3: Let b > a > 0 and β > α > 0. Calculate the area m_G of the quadrilateral region G formed by the straight lines $x + y = a$, $x + y = b$, $y = \alpha x$, and $y = \beta x$ (**Figure 3**).

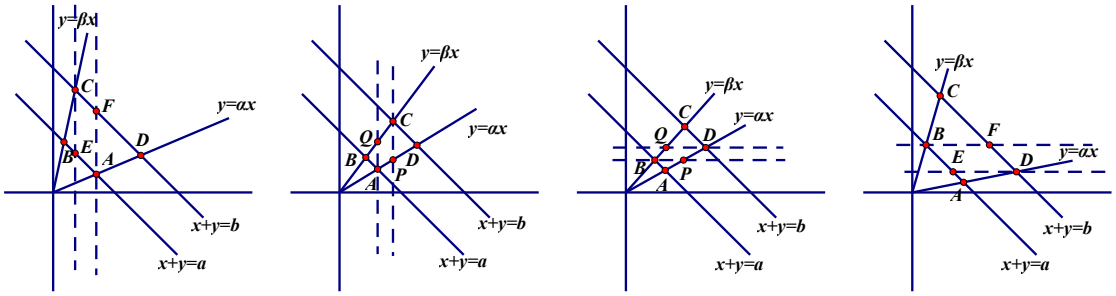

Figure 3. The shape of the region G in different situations [4]

By the very definition, G is a trapezoid. The equation $m_G = \dfrac{(b^2 - a^2)(\beta - \alpha)}{2(1+\alpha)(1+\beta)}$ is obtained via applying several different approaches developed by Wang [4]. Similar to Example 3, our teaching team attempted in recent years to guide college students majoring in Mathematics Education towards innovative solutions, such as multiple approaches to common or typical mathematical problems in Mathematical Analysis, Analytic Geometry, and Advanced Algebra. These practical experiments reveal that guiding college students majoring in Mathematics Education to develop innovative solutions, including multiple approaches to common mathematical problems, is an effective way to enhance their innovation competence.

5. Conclusion

In this paper, we studied strategies for enhancing the innovation competence of college students majoring in Mathematics Education. We delved into the impact of innovation competence on the future career development of college students majoring in Mathematics Education. We found that these students with high innovation competence are intrinsically motivated to enhance K-12 students' innovation abilities in their future educational careers. Additionally, they are likely to interpret K-12 instructional materials, such as textbooks, in creative ways and will teach K-12 mathematics using innovative approaches. Combining our theoretical analysis with our teaching team's empirical experience, we concluded that there are two main challenges in helping college students majoring in Mathematics Education improve their innovation competence. First, many students lack awareness of the need to enhance their innovation skills. Second, it is extremely difficult to identify effective common strategies for improving college students' innovation competence. Based on our analysis of the significance and challenges of improving the innovation competence of college students majoring in Mathematics Education, we proposed three strategies to enhance this competence: To optimize the curriculum to provide college students majoring in Mathematics Education with more challenging mathematical problems, to enhance the curriculum to offer students more opportunities to connect K-12 mathematics with college-level mathematics, and to adjust the curriculum

to allow college students majoring in Mathematics Education more time to develop innovative solutions, including multiple approaches, to common or typical mathematical problems. The findings presented in this paper can serve as both theoretical and practical references for promoting the innovation competence of college students majoring in Mathematics Education. Besides, these findings can be adapted to develop strategies for college students majoring in Physics and Chemistry Education.

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Disclosure statement

The authors declare no conflict of interest.

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