Academic Education Publishing House

Higher Education and Practice Vol. 1 No. 11, 2024

Leveraging Generative Artificial Intelligence to Enhance Mathematical Innovation and Practical Abilities of University Students

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Abstract: With the rapid development of artificial intelligence technology, generative artificial intelligence (GenAI) has been increasingly applied in the field of education. By analyzing the current application status, advantages, challenges, and implementation strategies of GenAI in mathematics education, this paper aims to explore how to leverage GenAI to enhance the mathematical innovation and practical abilities of university students and seeks to provide valuable references and insights for educators. Specifically, GenAI can be used to create personalized learning materials and provide real-time feedback, which can significantly improve students' understanding and application of mathematical concepts. The integration of GenAI in teaching can facilitate innovative teaching methods, such as inquiry-based learning and collaborative problem-solving, which are crucial for developing students' mathematical innovation abilities. However, challenges such as ensuring the accuracy of AI-generated content and addressing ethical concerns must be carefully managed. This paper will also discuss practical strategies to overcome these challenges and maximize the benefits of GenAI in mathematics education.

Keywords: Generative Artificial Intelligence; Higher Education; Mathematical Innovation; Practical Abilities; Personalized Learning.

1. Introduction

Since the launch of ChatGPT 3.5 by OpenAI in November 2022, artificial intelligence (AI) has rapidly iterated and evolved, seamlessly integrating into our work and lives over the past two years. As a cutting-edge AI chatbot program, its powerful natural language processing capabilities and highly intelligent interactive experience have quickly captured the attention of global users, marking an important milestone in the development of AI technology [1,2]. Meanwhile, major internet companies have accelerated their layouts in the AI field, following in OpenAI's footsteps and successively launching AI programs with unique features. The rapid development and widespread application of AI technology have also brought new opportunities and challenges to talent cultivation in universities. On the one hand, many university teachers and students actively embrace this technological transformation, utilizing AI tools for teaching, research, and learning activities, which not only improves work efficiency but also expands learning methods and research horizons. On the other hand, this technology requires students to not only master solid professional knowledge but also possess interdisciplinary comprehensive literacy and innovation abilities to adapt to the rapid development of AI in the future. At the same time, teachers also need to constantly update their educational concepts and teaching methods, efficiently integrating AI technology into the curriculum system and teaching practice to cultivate more talents with AI literacy and innovation abilities.

Generative artificial intelligence (GenAI) refers to the artificial intelligence technology that can automatically generate new and creative content based on given input data or conditions [3]. Its core lies in training models to understand and imitate data distributions, thereby generating new data like the input data or possessing specific attributes. GenAI demonstrates broad application prospects in

various fields such as text generation, image creation, music composition, program code generation, as well as design and innovation.

In the field of education, the applications of GenAI are mainly manifested in the following aspects [4,5]: Firstly, personalized learning, which involves analyzing students' learning behaviors and achievement data to provide customized learning plans and resources for them; secondly, intelligent tutoring, which utilizes natural language processing and machine learning technologies to achieve instant answers and personalized guidance for students' questions; and thirdly, innovative practice, which stimulates students' innovative thinking and practical abilities through generative design tools, programming assistance, and other means.

Mathematics, as a fundamental discipline of natural sciences, places great demands on students' logical thinking, innovative abilities, and practical skills. It is a broad and diverse field encompassing the study of numbers, quantities, structures, patterns, and logical deduction. It forms the bedrock for comprehending and elucidating the fundamental principles that govern our universe. Its applications extend into numerous domains, including engineering, physics, finance, and computer science, making it an essential discipline for individuals to master. However, traditional mathematics teaching models often only focus on the imparting of theoretical knowledge but neglecting the cultivation of students' innovative and practical abilities. GenAI has great potential in enhancing university students' innovative and practical abilities in mathematics. It can inject new vitality into mathematics teaching by automatic content generation, intelligent recommendations, and assisted learning etc. Recent studies [6] highlight the potential of GenAI models such as large language models (e.g., ChatGPT) and symbolic computation systems to revolutionize traditional pedagogical approaches. These tools enable personalized learning experiences, allowing students to engage with mathematical concepts at their own pace and according to their individual learning styles. In paper [7], authors investigated undergraduate students' engagement in using GenAI to prove mathematical propositions and proposed a new framework called "Students' Interactive Proving Experience with AI" (SIPE-AI), which explains how students use GenAI in their proving processes and the factors that influence these processes. The research indicates that students need guidance to critically use GenAI tools rather than passively accepting their outputs. The paper [8] describes the gradual influences of Natural language processing, ChatGPT and Intelligent Tutoring Systems in mathematical education. Fu offers a comprehensive overview of the amalgamation of mathematics and AI, introducing the implementations and applications of the Sofia and ITS methodologies. These approaches hold substantial potential within the fields of mathematics and AI [9].

2. Analysis of the Current Situation of College Students' Mathematical Innovation and Practical Ability

Nowadays, university mathematics education faces significant challenges in cultivating students' mathematical innovation and practical abilities. For a long time, traditional mathematics teaching models have emphasized the imparting of theoretical knowledge and the refinement of tips for solving mathematical problems while neglecting the nurturing of students' innovative thinking and independent thinking abilities to some extent. This tendency has led students to remain focused on memorizing textbook knowledge and mastering exam-taking techniques, but lacking opportunities to integrate abstract mathematical concepts with real-life problems, which hinder the full unleashing and enhancement of their innovative potential.

Besides, even though mathematical knowledge is widely applied in daily life and various industries, many university students often feel they aren't good enough at applying it in real situations. This is mainly because there weren't enough hands-on opportunities and platforms available to us while we were in university. Moreover, some students don't have the right analysis and solving skills when they come across certain problems. This makes it tough for them to turn the math they've learned into practical problem-solving abilities. The gap between theory and practice impacts students' overall development of mathematical skills. At the same time, it restricts their ability to compete in the job market in the future.

Therefore, how to effectively integrate theory and practice in mathematics education, both stimulating students' innovative thinking and strengthening their practical abilities has become an important issue that educators urgently need to explore and address. This requires innovations in teaching models such as the introduction of project-based learning and inquiry-based learning and necessitates collaboration among schools, businesses, and society to jointly provide students with more practical opportunities and resources to promote the comprehensive enhancement of their mathematical literacy.

3. The Application of GenAI in Mathematics Teaching

3.1 Personalized Learning Plans

GenAI can create math learning plans just for each student, depending on how they're doing. By gathering information like how much homework students finish, their test results, and how long they study, AI can look at where students struggle and what they like. Then, it suggests good study materials and practice questions for them. For instance, if a student is having trouble with tough math problems, AI can offer more like those to practice on and show clear answers, helping them solve the issues one step at a time. This personal help can make students learn faster and boost their confidence and drive to study.

3.2 Instant Tutoring and Problem-Solving Guidance

When students encounter difficulties in mathematics learning, they can simply ask GenAI for help, and AI can immediately give them the steps to solve the problem and explain it clearly. This instant tutoring function helps students solve problems and deepens their understanding of knowledge points by demonstrating the problem-solving process. What's more, based on student feedback and progress, AI can dynamically adjust tutoring content and difficulty ensuring to help students remain in an optimal learning state.

3.3 Design of Innovative Tasks and Challenges

GenAI can design engaging mathematics games and challenging tasks to inspire students' interest and creativity in learning mathematics. These activities not only allow students to learn mathematics in a relaxed atmosphere but also cultivate their innovative thinking and abilities to solve problems. For instance, AI can design open-ended questions or projects that encourage students to explore and experiment. Alternatively, it can provide challenging mathematical problems that prompt students to find suitable solutions through collaboration and sufficient discussion. This design of innovative tasks and challenges could enhance students' interest in learning and participation and fosters their teamwork and communication skills.

3.4 Visualization of Abstract Concepts

Mathematics contains many abstract concepts, such as geometric shapes and algebraic formulas, which may be difficult for some students to understand. However, GenAI can make these abstract concepts concrete and intuitive through various means such as graphics and animations. For example, AI can dynamically demonstrate the properties of lines and provide step-by-step demonstrations to aid in understanding the solution to algebraic equations. This visual teaching method could increase students' learning interest and lower the learning difficulty, contributing to the enhancement of mathematical literacy.

3.5 Interdisciplinary Integration and Application

As a fundamental discipline, math goes hand in hand with other subjects. GenAI can integrate this interdisciplinary knowledge to give students all-around learning help. For example, it can provide mathematical support in physical calculations or methodological guidance for statistical analysis in economics. This interdisciplinary integration not only broadens students' knowledge horizons but also improves their ability to solve practical problems.

4. Strategies to Enhance College Students' Mathematical Innovation and Practical Abilities Utilizing GenAI

4.1 Strengthen Teacher Training and Technical Support

To fully leverage GenAI in enhancing college students' mathematical innovation and

practical abilities, it is first necessary to strengthen teacher training and technical support. Universities should organize relevant training courses and workshops to help teachers understand the technical characteristics and application advantages of GenAI and master its usage methods and techniques in teaching. Simultaneously, universities should provide necessary technical support, and resource guarantees to ensure that teachers can smoothly carry out teaching activities based on GenAI.

4.2 Construct Personalized Learning Environments

GenAI can provide personalized learning support based on students' individual differences and learning needs. Therefore, universities should construct personalized learning environments to provide students with learning resources and tutoring that are more aligned with their learning characteristics and needs. This can be achieved through the establishment of student profiles and analysis of learning data. At the same time, universities should encourage students to actively participate in personalized learning activities and select suitable learning paths and challenging tasks based on their interests and strengths.

4.3 Promote Project-Based Learning Models

The project-based learning model is an effective teaching method that helps students apply their knowledge to practical problems, thereby cultivating their mathematical practice and innovation abilities. Universities should promote this learning model and encourage teachers to use GenAI to design challenging and innovative project tasks. These project tasks may involve cross-disciplinary areas between mathematics and other disciplines or focus on social hotspots and practical problems. By participating in these project tasks, students can not only deepen their understanding of mathematical knowledge but also cultivate team collaboration, problem-solving, and innovation abilities.

4.4 Establish a Diversified Evaluation System

The traditional evaluation system for mathematics teaching often focuses on the mastery of theoretical knowledge and the training of skills to solve mathematical problems, neglecting the evaluation of students' mathematical innovation and practical abilities. To make good use of GenAI to improve college students' abilities, universities should establish a diversified evaluation system. This may include checking if students have finished their project tasks, judging their creative ideas and how well they can do things, and testing how well they work together and communicate in a team. Through a diversified evaluation system, a more comprehensive understanding of students' learning situations and ability development can be obtained, providing targeted guidance and support for subsequent teaching activities.

4.5 Strengthen Interdisciplinary Cooperation and Exchange

Mathematics has strong ties and overlaps with other disciplines. To fully leverage GenAI in enhancing college students' mathematical innovation and practical skills, universities need to increase cooperation and communication between different disciplines. This can be achieved through organizing interdisciplinary seminars, establishing interdisciplinary research teams, and other means. By working together and talking with each other, we can share knowledge and combine resources from different fields. This helps give students more complete and deeper learning experiences, along with hands-on chances to apply what they've learned. And it can help boost students' skills in tackling problems across different subjects.

5. Challenges of GenAI in Higher Education

In the preceding discussion, we talked about how GenAI helps both teachers and students with math learning in college. However, the application of these technologies also comes with a range of challenges [10-14]. In the following section, we will focus on analyzing the major challenges that the use of GenAI poses to higher education and propose corresponding strategies to address them.

5.1 Reliability and Accuracy of Technology

The content generated by GenAI, while offering immense convenience and speed, needs to be checked carefully due to potential errors or biases inherent in the algorithms. In math learning and real-life use, being exact is

super important. Incorrect information or solutions can not only mislead students but also reinforce incorrect understanding, which can be detrimental to their academic growth and practical skills. So, it's important for teachers and schools to have a good check and make sure the content created by AI is right. This means checking information against well-known textbooks, reviewing journals by other experts, and getting opinions from professionals to make sure everything is as accurate as possible. Also, we need to keep watching and updating the AI systems regularly. This way, we can fix any biases or mistakes as soon as we find them.

5.2 Balancing AI Assistance and Student Autonomy

Although GenAI can help a lot with math practice and new ideas, students might rely on it too much. This could make it hard for them to think for themselves and solve problems on their own. To reduce this risk, we need to set some rules for using AI tools in the classroom. These rules should tell students to see AI as a helper, not the main way to solve problems. We can do this by including AI in their learning in a way that makes them take part actively and think critically. Also, the courses need to be set up so that AI tools work together with old-fashioned teaching methods. For instance, AI can be used to create practice problems or give students tips. But students still must solve the problems by themselves.

5.3 Ethics and Privacy Concerns

Using GenAI in schools brings up lots of ethical and privacy worries. For instance, there's the issue of keeping data safe and the risk that the content might be biased. Also, we must think about whether it's right to use AI-made materials. To solve these problems, we need to set up and follow simple, clear rules about ethics in education when using AI. These rules should protect data privacy, make sure the content is accurate, and make sure AI-made materials are used in the right way. Also, we need to put plans in place to find and reduce biases in AI content. This means using a mix of different training data and checking AI models often to make sure they are fair and inclusive.

5.4 Effectively Measuring and Evaluating the Impact of GenAI

Assessing the effectiveness of GenAI in enhancing mathematical practice and innovation capabilities is crucial. However, developing suitable indicators and assessment methods to quantify this impact can be quite challenging. To solve this problem, we can adopt the following strategies: Firstly, develop outcome-based assessment methods that focus on measuring improvements in students' mathematical practice and innovation capabilities, encompassing both quantitative indicators such as test scores and problem-solving efficiency and qualitative assessments such as student feedback and project-based evaluations. Secondly, implement continuous monitoring and feedback mechanisms to track the effectiveness of AI interventions, allowing for improvements step by step to make sure the AI tools help us reach our educational goals.

By dealing with these issues fully, universities can use GenAI to their advantages and reduce its possible problems. This will help create a good environment for serious academic work and ethical tech development.

6. Conclusion

Putting GenAI into math education brings both big chances and some tough challenges. On the one hand, it has a lot of potential to help students understand math concepts better, encourage creative thinking, and get better at solving real-life problems. On the flip side, to make the most of this potential, we need to think carefully about ethical problems, technical help, and training teachers. This will guarantee that GenAI is put into use in an effective and responsible way. Future studies should keep looking into its effects and find the best ways to smoothly include them in the curriculum. We need to keep researching how it affects students and teachers and figure out the best methods to make sure it fits well with what's already being taught.

Acknowledgments

This paper is supported by the Research Project on Education and Teaching of China Association for Construction Education (No. 2023178).

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