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The Mechanism of Artificial Intelligence-Empowered Personalized Learning Systems on University Students' STEM Learning Motivation and Academic Achievement: An Educational Psychology Perspective

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Abstract: With the continuous advancement of artificial intelligence (AI) technology, personalized learning systems are increasingly applied in higher education. Particularly within STEM (Science, Technology, Engineering, and Mathematics) education, AI demonstrates significant advantages through adaptive learning pathways, instant feedback, and individualized resource allocation. However, current research predominantly focuses on the technical architecture and application effectiveness of such systems, with insufficient exploration of how AI-enabled personalized learning systems influence university students' learning motivation and academic achievement through educational psychological mechanisms. This paper adopts an educational psychology perspective to construct a causal mechanism model linking "learning motivation–learning behavior–academic achievement." Findings indicate that AI-powered personalized learning systems enhance learning autonomy, boost self-efficacy, and optimize feedback mechanisms. These effects collectively stimulate university students' learning motivation in STEM disciplines, thereby promoting academic achievement. Building upon empirical research, this paper proposes implications for educational practice and policy formulation, emphasizing the necessity of advancing higher education reform through the dual influence of technology and psychological mechanisms.

Keywords: Artificial intelligence; Personalized learning systems; Educational psychology; Learning motivation; Academic achievement; STEM

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1. Introduction

In this era of rapid technological advancement, artificial intelligence (AI) has permeated diverse domains, including education. Higher education, as a pivotal stage for cultivating high-caliber talent, faces challenges

in enhancing teaching quality while addressing students' personalized learning needs. STEM disciplines, as key drivers of technological innovation and societal progress, command significant attention regarding their pedagogical outcomes. Artificial intelligence-enabled personalized learning systems present new opportunities for STEM teaching in higher education. By providing tailored learning support based on individual student differences, these systems hold promise for significantly enhancing learning motivation and academic achievement. However, in-depth research into how such systems function through educational psychological mechanisms remains insufficient. Therefore, examining the impact mechanisms of AI-enabled personalized learning systems on university students' STEM learning motivation and academic achievement from an educational psychology perspective holds significant theoretical and practical implications [1].

2. Literature review

2.1. Current development of AI-empowered personalized learning systems

Recent years have witnessed remarkable progress in applying artificial intelligence technologies within education. As a key application, personalized learning systems leverage big data analytics and machine learning to collect real-time student learning data—such as progress, answer accuracy, and study duration—and utilize this information to provide tailored learning path recommendations, resource allocation, and feedback. Within higher education, numerous institutions have begun integrating AI-powered personalized learning systems into STEM discipline instruction. For instance, certain online learning platforms utilize AI algorithms to recommend course content and practice exercises tailored to students' proficiency levels, thereby enhancing learning relevance and efficiency [2].

2.2. Research on the correlation between learning motivation and academic achievement

Learning motivation constitutes the intrinsic drive propelling students' educational activities, exerting a significant influence on academic attainment. Educational psychology research indicates that learning motivation can be categorized into intrinsic and extrinsic motivation. Intrinsic motivation stems from students' interest in and satisfaction with learning itself, while extrinsic motivation arises from external rewards and pressures. In STEM subject learning, students with higher intrinsic motivation are often more willing to actively explore knowledge and solve problems, thereby achieving better academic outcomes [3]. Simultaneously, self-efficacy is also a crucial factor influencing learning motivation and academic achievement. Students with high self-efficacy believe in their capacity to accomplish learning tasks, making them more likely to engage actively in learning and achieve success.

2.3. The relationship between technology, learning motivation, and academic achievement from an educational psychology perspective

From an educational psychology perspective, the introduction of technology can influence students' learning motivation and academic achievement. Artificial intelligence-enabled personalized learning systems, by providing tailored learning experiences, can meet diverse student needs, enhance learning autonomy, and thereby stimulate intrinsic learning motivation. Moreover, the instant feedback provided by such systems enables students to promptly understand their learning progress, adjust their strategies, and enhance learning outcomes, thereby elevating academic achievement [4]. However, current research in this area remains relatively fragmented, lacking a systematic theoretical framework and empirical analysis.

3. Mechanisms through which AI-empowered personalized learning systems influence university students' STEM learning motivation

3.1. Enhancing learning autonomy

AI-powered personalized learning systems offer students the opportunity to autonomously select learning content, timing, and methods. In STEM disciplines, students may select diverse learning modules and case studies according to their interests and requirements. For instance, when studying programming courses, learners may opt to begin with fundamental syntax or directly tackle practical project cases [5]. This autonomy enables students to better control their learning process, stimulating initiative and enthusiasm for learning, thereby strengthening intrinsic motivation.

3.2. Enhancing self-efficacy

The system provides personalized learning feedback and recommendations by monitoring students' learning data in real time. When students achieve progress or success during their studies, the system promptly offers affirmation and encouragement, allowing them to feel their abilities are recognized. For instance, after completing a complex mathematical problem, the system might display: "You've done exceptionally well; your problem-solving approach is very clear." Such positive feedback strengthens students' sense of self-efficacy. Conversely, when students encounter difficulties, the system offers detailed guidance and solutions to help them overcome challenges. This process builds students' confidence in their problem-solving abilities, further elevating their self-efficacy. Students with high self-efficacy are more inclined to tackle challenging learning tasks, thereby boosting their motivation [6].

3.3. Optimizing feedback mechanisms

Traditional classroom feedback often suffers from delays and superficiality, whereas AI-powered personalized learning systems deliver immediate and comprehensive feedback. Upon completion of assignments or assessments, the system swiftly analyzes responses, identifies error causes, and delivers detailed explanations alongside improvement recommendations. For instance, in physics laboratory courses, after submitting experiment reports, the system evaluates aspects such as experimental design, data analysis, and conclusions, providing specific directions for refinement [7]. This timely feedback enables students to promptly understand their learning progress, adjust strategies, prevent the accumulation of errors, and consequently enhance both learning outcomes and motivation.

4. Mechanisms of impact: AI-empowered personalized learning systems on undergraduates' STEM academic achievement

4.1. Personalized learning pathways enhance knowledge acquisition

AI-driven personalized learning systems devise tailored learning pathways based on students' learning aptitudes and progress. Within STEM disciplines, variations exist in students' foundational knowledge and learning speeds [8]. The system can provide students with weaker foundations with additional foundational knowledge and practice, helping them gradually build their knowledge framework. Conversely, for students with stronger learning abilities, the system can offer more challenging learning content to stimulate their learning potential. Through such personalized learning pathways, students can master knowledge more efficiently and enhance their academic achievement.

4.2. Diverse learning resources broaden horizons

The system furnishes students with a wealth of varied learning resources, including online courses, academic literature, and experimental simulations. Within STEM disciplines, students gain access to cutting-edge research findings and practical case studies from both domestic and international sources, thereby expanding their learning horizons. For instance, when studying biology, pupils may view relevant popular science videos or read the latest research papers to understand the most recent developments in the field [9]. Such diverse learning resources stimulate students' interest, promote deeper comprehension and application of knowledge, thereby enhancing academic achievement.

4.3. Interactive learning environments enhance engagement

The AI-powered personalized learning system also fosters interactive learning environments where students can communicate and collaborate with teachers and peers. In STEM project-based learning, students form groups to complete tasks using the system's collaborative tools. Through these exchanges, students share ideas and experiences while learning from peers' strengths, thereby increasing engagement and motivation. Concurrently, teachers can monitor student progress in real-time via the system, providing targeted guidance and support to foster academic development [10].

5. Empirical research analysis

5.1. Research methodology

This study selected several STEM-specialized classes from a higher education institution, dividing them into an experimental group and a control group. The experimental group utilized an AI-enabled personalized learning system, while the control group employed traditional teaching methods. Throughout the experiment, data concerning students' learning motivation, learning behaviors, and academic achievement were collected. Learning motivation was measured via questionnaires, assessing both intrinsic and extrinsic motivation dimensions; learning behaviors were evaluated by system-recorded metrics including study duration, frequency of engagement, and response patterns; Academic achievement was measured through course examination results and project assignment scores [11].

5.2. Research findings

After one semester of study, the research revealed that the experimental group exhibited significantly higher learning motivation than the control group. Regarding intrinsic motivation, experimental group students demonstrated markedly increased interest in STEM subjects and greater willingness to actively explore knowledge. Concerning extrinsic motivation, they also exhibited heightened expectations of achieving good grades and receiving rewards through learning [12]. Concurrently, experimental group students exhibited more proactive learning behaviors, with notable increases in study duration and frequency, alongside improved answer accuracy rates. Regarding academic achievement, both course examination scores and project assignment grades in the experimental group surpassed those of the control group, with statistically significant differences observed.

5.3. Discussion of findings

The results indicate that an AI-enabled personalized learning system exerts a positive influence on university students' learning motivation and academic achievement in STEM subjects. This aligns with the theoretical

analysis presented earlier, wherein the system stimulates learning motivation by enhancing autonomy, boosting self-efficacy, and optimizing feedback mechanisms, thereby promoting learning behaviors and elevating academic achievement [13]. However, the study also identified certain difficulties encountered by some students in using the AI-powered personalized learning system, necessitating further improvements in system usability and user guidance.

6. Implications for educational practice and policy development

6.1. Educational practice

Higher education institutions should actively adopt AI-enabled personalized learning systems and integrate them deeply with STEM subject teaching. Educators must shift their pedagogical approach, transitioning from traditional knowledge disseminators to facilitators and organizers of learning, fully leveraging system functionalities to provide tailored learning support [14]. Concurrently, enhanced training in system usage should be provided to students, improving their information literacy and operational proficiency to ensure effective utilization of the system for learning. Furthermore, student learning portfolios may be established to track learning processes and developmental trajectories, enabling targeted recommendations for individualized growth.

6.2. Policy formulation

Government and education authorities should enact policies encouraging universities to research and implement AI-powered personalized learning systems [15]. Increased investment in educational technology R&D is required to advance AI innovation and application within education. Concurrently, corresponding evaluation mechanisms should be established to assess and oversee the application effectiveness of personalized learning systems, ensuring they genuinely enhance students' learning motivation and academic achievement [16–18]. Furthermore, cooperation and exchange between higher education institutions can be strengthened to share high-quality educational resources and technical expertise, thereby promoting the overall improvement of higher education quality.

7. Conclusion and outlook

7.1. Research findings

This study constructs a "learning motivation—learning behavior—academic achievement" mechanism model from an educational psychology perspective, examining the impact of AI-enabled personalized learning systems on university students' STEM subject learning motivation and academic achievement. Findings indicate that the system enhances learning autonomy, boosts self-efficacy, and optimizes feedback mechanisms, thereby stimulating learning motivation, promoting learning behavior, and ultimately improving academic achievement. Empirical results validate the theoretical model's validity [14].

7.2. Research limitations and future directions

Whilst this study has yielded significant findings, certain limitations exist. For instance, the sample scope was relatively narrow, drawing solely from selected classes within a single institution, which may introduce constraints. Future research could broaden the sample scope to encompass universities across different regions and types, thereby enhancing the study's generalizability. Furthermore, this research primarily examined the

system's short-term effects; its long-term impacts warrant further longitudinal investigation. Concurrently, deeper exploration of the interactive effects between AI-powered personalized learning systems and other educational factors could provide more comprehensive and profound theoretical support for higher education reform [19].

Disclosure statement

The author declares no conflict of interest.

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