Education Reform and Development, 2025, Volume 7, Issue 9
https://ojs.bbwpublisher.com/index.php/ERD
Online ISSN: 2652-5372
Print ISSN: 2652-5364

New Era of Smart Classrooms-Innovation and Autonomous Learning Enhancement in Linear Algebra Courses Driven by Artificial Intelligence

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Abstract: Artificial Intelligence (AI) offers innovative solutions to address the teaching challenges of linear algebra courses caused by their high level of abstraction, such as students' difficulties in comprehension, lack of interest, and weak self-directed learning abilities. This study proposes empowering educators to reconstruct teaching models through three key strategies: building intelligent teaching platforms (enabling personalized resource recommendations, learning path planning, and real-time feedback), leveraging data-driven instructional decisions (to dynamically optimize teaching content), and deploying intelligent tutoring systems (with virtual assistants to explain abstract concepts). Meanwhile, to tackle challenges such as data privacy, teachers' adaptability to technology, and integration of educational resources, it is necessary to enhance data security mechanisms, strengthen teacher training, and promote inter-institutional collaboration. Future development will move toward multimodal interaction (e.g., VR/AR to enhance visual intuition) and interdisciplinary integration, advancing AI from a supporting tool to a core driving force of educational innovation, ultimately serving the goal of cultivating high-quality, versatile talents.

Keywords: Artificial intelligence; Self-directed learning; Linear algebra; Teaching reform

Online publication: September 30, 2025

1. Introduction

With the rapid advancement of information technology, Artificial Intelligence (AI), as the core driving force of a new round of technological revolution and industrial transformation, is permeating all sectors of society and the economy with unprecedented depth and breadth, and the field of education is no exception [1–4]. As the main front for cultivating high-level talents, higher education now faces an urgent need and a cutting-edge research focus: how to effectively leverage AI to drive deep reforms in curriculum systems, teaching models, and evaluation methods, thereby improving the quality and efficiency of instruction [5].

Linear algebra, a fundamental theoretical course essential to disciplines such as mathematics, computer science, physics, engineering, and economics, is characterized by highly abstract and logically rigorous core

concepts, including matrices, vector spaces, linear transformations, eigenvalues, and eigenvectors [6,7]. These features commonly lead to student difficulties in comprehension, weak intuitive connections, and low learning motivation. The traditional one-way "teacher lectures, students listen" model often fails to address these challenges effectively, resulting in suboptimal learning outcomes. Consequently, exploring how to harness the power of AI to reshape the teaching process, stimulate intrinsic student motivation, and cultivate higher-order thinking skills and independent inquiry habits has become a critical problem urgently needing resolution by university educators, particularly those teaching foundational courses.

This paper focuses on the linear algebra course and aims to systematically explore feasible pathways, practical models, potential challenges, and corresponding strategies for AI-empowered curriculum reform and innovation in higher education. By combining theoretical analysis with practical case studies, it seeks to provide front-line university teachers with actionable ideas and methods to promote deep integration of AI with teaching and learning, ultimately serving the goal of cultivating high-quality, innovative talents.

2. Current status and existing problems in linear algebra course teaching

2.1. Strong abstraction of course content

The core appeal of linear algebra lies in its abstraction and universality, but these very qualities also present the main challenges in teaching. Concepts such as "n-dimensional vector space," "linear independence," and "rank" rely heavily on mathematical notation and formal definitions, with relatively weak intuitive connections to the real world. Students often find themselves lost in a maze of symbolic manipulation, struggling to grasp the geometric interpretations and physical meanings behind these ideas [8]. This high level of abstraction significantly increases cognitive load, particularly when tackling complex problems, such as solving large systems of linear equations or understanding the applications of singular value decomposition, leading to frustration and anxiety, which in turn hinders the deep understanding and internalization of key concepts.

2.2. Limitations of traditional teaching models

Currently, linear algebra courses still primarily adopt a traditional teacher-centered instructional model, where classroom teaching is dominated by lectures and students passively receive knowledge. This one-way transmission lacks sufficient interactive elements and real-time feedback mechanisms, making it difficult to stimulate students' interest in learning. As a result, the classroom atmosphere becomes monotonous, and student engagement remains low. In such a learning environment, students have limited opportunities for in-depth thinking and discussion, leading to a lack of knowledge internalization and difficulty in truly understanding and mastering course content.

At the same time, constrained by the limitations of traditional teaching methods, students often lack systematic learning strategies and effective tools for self-directed learning. They struggle to personalize their study plans according to their cognitive characteristics and learning pace. When they fail to grasp the content during class, they find it difficult to make up for the gap on their own, which leads to the accumulation of knowledge deficiencies. The lack of autonomous learning ability not only affects their current academic performance but also hinders their progress in subsequent courses, limiting the development of their innovative thinking and ability to apply knowledge in an integrated manner.

Therefore, it is imperative to introduce modern educational technologies such as artificial intelligence to transform traditional teaching models. This will help build a learning environment that is highly interactive,

provides timely feedback, and promotes learner autonomy, thereby enhancing students' proactive learning awareness and capabilities, and ultimately improving the overall teaching quality of linear algebra courses [9,10].

3. Theoretical foundation of AI empowerment in teacher-led course development

3.1. Theoretical exploration of AI and education integration

In recent years, the application of artificial intelligence technology in the education sector has gradually matured. Based on technologies such as big data, machine learning, and natural language processing, AI can enable intelligent recommendation of teaching resources, personalized learning path planning, and real-time monitoring of online learning processes. The theory of educational informatization posits that by breaking the time and space constraints of traditional teaching through technological means, personalized instruction ("teaching according to students' aptitude") can be achieved, thereby meeting the individual needs of different students and improving teaching quality and efficiency [11].

3.2. Application of autonomous learning theory in teaching

Autonomous learning theory emphasizes that students should actively construct their knowledge systems, continuously improving their learning abilities through self-exploration and practice [12]. AI systems can provide students with personalized learning plans, monitor learning progress in real time, and provide feedback, which helps to stimulate students' enthusiasm for learning and cultivate their autonomous learning abilities [13–15].

4. Practical application of artificial intelligence in curriculum development reform

4.1. Construction of intelligent teaching platforms

Using artificial intelligence technology to build intelligent teaching platforms is an important means of achieving curriculum development reform. Taking Linear Algebra as an example, the platform can integrate the following functions:

(1) Intelligent Recommendation of Learning Resources: Based on students' learning records and knowledge mastery, the platform can recommend targeted resources such as textbooks, videos, exercises, etc., to help students form a knowledge framework.

(2) Personalized Learning Path Planning: Through data analysis, the system can create personalized learning plans for students with different learning progress, ensuring that each student can gradually deepen their understanding of knowledge points at their own pace.

(3) Real-time Learning Monitoring and Feedback: Using machine learning algorithms, the platform can monitor students' learning progress in real time and provide feedback through online tests and practice exercises, helping teachers understand students' grasp of the material and offer targeted guidance.

4.2. Data-driven teaching decisions

Artificial intelligence technology can not only provide personalized learning support for students but also offer data support for teachers. Teachers can use data analysis tools to understand students' grasp of different knowledge points, common mistakes, and learning trends, allowing them to adjust teaching strategies and optimize classroom design. For example, if data analysis shows that most students struggle with matrix operations in Linear Algebra, teachers can add targeted explanations and exercises in subsequent lessons.

4.3. Intelligent tutoring systems and virtual teaching assistants

Intelligent tutoring systems and virtual teaching assistants are key components of AI applications in curriculum development. These systems can use natural language processing technology to answer students' questions during the learning process, while virtual teaching assistants can simulate the teacher's role, providing online Q&A and guidance. For complex concepts in Linear Algebra, virtual teaching assistants can provide detailed step-by-step explanations and example demonstrations, making abstract concepts more tangible and helping students better understand and apply the knowledge.

5. Challenges and countermeasures in AI empowered teaching reform

5.1. Data privacy and security issues

In the process of applying artificial intelligence for teaching reform, the collection and analysis of large amounts of data inevitably raise concerns about student privacy and data security. To address this, schools and platforms must strictly adhere to relevant laws and regulations, establish robust data encryption and access control mechanisms, and ensure the security and confidentiality of data during use.

5.2. Technological adaptability and teacher capacity building

Although AI technology provides strong support for teaching reform, some teachers have limitations in applying technology effectively. To address this, universities should organize regular training and seminars to enhance teachers' technical skills, enabling them to fully utilize AI tools for teaching design and classroom management. Additionally, a collaborative mechanism between teachers and technical experts should be established to jointly solve the practical problems encountered in the application.

5.3. System improvement and resource integration

Building intelligent teaching platforms requires a wealth of high-quality educational resources, yet some schools still face challenges in integrating teaching resources and constructing platforms. There should be increased cooperation between universities, departments, and industry to jointly develop and share quality educational resources, promoting continuous improvement and upgrading of platform functions. Moreover, for foundational courses like Linear Algebra, it is important to develop practical cases and experimental projects that align with industry needs, enhancing the practical value of the course.

6. Future outlook

The AI-driven reform and innovation in teacher-led course development is a continuously evolving process. In the future, as technology advances and teaching concepts evolve, intelligent teaching platforms will become more refined and widespread. For foundational courses such as Linear Algebra, the future development trends include the following aspects: First, deep integration and personalized learning. Future intelligent teaching platforms will focus more on personalized learning experiences, using more precise data analysis and intelligent algorithms to provide customized learning plans for students, further enhancing their autonomous learning abilities. Second, multimodal interaction and virtual reality. With the development of technologies such as virtual reality (VR) and augmented reality (AR), AI-based multimodal interactive teaching models will gradually be realized, offering more intuitive and engaging teaching displays for abstract courses like Linear Algebra. Finally, interdisciplinary

collaboration and innovative applications. Future teaching reforms will break down disciplinary barriers and promote interdisciplinary collaborative innovation. Mathematical theories based on Linear Algebra will deeply integrate with fields such as computer science and engineering technology, cultivating interdisciplinary talents with cross-boundary thinking and practical abilities.

7. Conclusion

In the current era of global digital transformation, Artificial Intelligence (AI) has become a pivotal force reshaping the landscape of higher education. For university educators, AI is far more than just an auxiliary teaching tool; it is the golden key to unlocking educational innovation. It empowers curriculum development in an all-encompassing and profound manner, triggering transformative changes in teaching models, propelling education from tradition to modernity, from uniformity to diversity, and from isolation to openness. AI continuously injects powerful momentum into the high-quality development of higher education.

In the challenging yet opportunity-filled domain of linear algebra education, the introduction of AI is like a timely rainfall. With intelligent teaching platforms as its foundation, AI delivers personalized learning resources to students, akin to lighting beacons that guide learners through the maze of knowledge. Personalized learning path planning crafts tailor-made journeys for each student, allowing them to progress steadily at their own pace without being constrained by standardized teaching schedules—thus realizing the ideal of differentiated instruction. Real-time learning monitoring and feedback systems act as the teacher's eyes and ears, continuously tracking students' learning status, promptly identifying issues, and offering targeted guidance, making teaching more focused and effective.

Data-driven instructional decisions give educators a powerful lens to observe students' learning conditions. By mining vast amounts of data, teachers can discern students' mastery of specific concepts, uncover areas of confusion, and identify learning trends. This enables precise adjustment of teaching strategies, allowing content to be delivered like timely rain to the driest areas of students' knowledge structures—significantly enhancing the scientific grounding and effectiveness of instruction. Meanwhile, intelligent tutoring systems and virtual teaching assistants serve as ever-present companions to students, ready to answer questions and simplify abstract, complex concepts through vivid examples and detailed explanations. With such support, learning becomes a guided journey of exploration, no longer a solitary and daunting struggle.

However, the path of AI-empowered educational reform is not without its hurdles. Data privacy and security issues loom like the sword of Damocles, where a single misstep can lead to serious consequences. Schools and platforms must remain vigilant at all times, safeguarding student data with the strictest standards and most rigorous measures to ensure that technology usage always stays within the bounds of legality and compliance. Teachers, as the implementers of educational reform, also face adaptation challenges when it comes to new technologies. Institutions should actively build broad platforms for training and communication, helping educators continuously improve their technical competencies so they can confidently and effectively use AI tools in instructional design and classroom management, turning technology into a powerful teaching asset rather than a burden.

At the same time, the construction and development of intelligent teaching platforms face challenges related to resource integration and system optimization. Schools should expand collaboration channels, strengthen cooperation across institutions, departments, and even with enterprises, bringing together high-quality educational resources from multiple sources. This will enrich the platform's content, refine its functional design,

and transform it into an ever-evolving treasure trove of education, providing teachers and students with abundant, efficient, and convenient support.

In summary, the journey of AI-empowered curriculum reform and innovation in higher education is well underway. It offers educators unprecedented opportunities to break free from traditional teaching limitations and achieve a transformative leap in instructional models. Looking ahead, as technology continues to advance and educational philosophies evolve, AI is poised to write even more brilliant chapters in the realm of higher education—cultivating generations of high-quality talents with innovative minds and practical abilities, and propelling society toward a more prosperous and promising future.

Funding

Higher Education Research Project of Beijing Information Science and Technology University (Project No.: 2024GJYB13); 2025 Artificial Intelligence Special Project of Beijing Information Science and Technology University (Project No.: 2025JGAI28); Young Backbone Teacher Support Plan of Beijing Information Science & Technology University (Project No.: YBT 202446)

Disclosure statement

The author declares no conflict of interest.

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