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Research on the Innovation of Teaching Mode in Mechanical Engineering Major Driven by Big Data and Artificial Intelligence

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Abstract: With the rapid development of big data (BD) and artificial intelligence (AI) technologies, the teaching of mechanical engineering major is facing new opportunities and challenges. This article deeply explores the application status, problems, and challenges of BD and AI in the teaching of mechanical engineering major. Through a review of relevant domestic and foreign research and an analysis of practical application cases, it proposes an innovative strategy for the teaching mode of mechanical engineering major driven by BD and AI, including innovations in teaching methods, learning methods, practical teaching, curriculum design, teaching objectives and concepts, teaching content and methods, practical teaching links, and teaching evaluation systems. At the same time, it analyzes the challenges faced in the innovation process and proposes corresponding countermeasures. Finally, it summarizes the research and provides theoretical and practical references for the innovation of the teaching mode of mechanical engineering major.

1. Introduction

In the current information age, big data (BD) and artificial intelligence (AI) technologies are transforming various fields at an astonishing pace. Mechanical engineering, as a traditional engineering discipline, is also inevitably deeply influenced by BD and AI. BD technology can offer vast amounts of data resources for mechanical engineering teaching, enabling teachers to better understand students' learning situations and needs, and optimize teaching content and methods [1, 2]. AI technology can achieve intelligent teaching assistance, such as personalized learning recommendations and intelligent question answering, enhancing teaching efficiency and quality [3, 4]. Therefore, exploring the innovation of the teaching mode of mechanical engineering major driven by BD and AI holds significant practical importance.

The development of BD and AI technologies has brought numerous possibilities for reforming in the teaching of mechanical engineering major [5]. On the one hand, BD technology can collect and analyze various interaction data of students during the learning process, such as access to course materials, homework submission time, and grades. These data assist teachers in understanding students' learning habits, knowledge mastery, and learning difficulties, thereby providing personalized guidance and timely intervention. On the other hand, AI technology can customize personalized learning paths based on each student's learning progress and knowledge level. Students can obtain interactive learning materials, practice questions, and feedback that are tailored to their specific needs, thus optimizing learning efficiency. Additionally, in the teaching of mechanical engineering major, BD and AI technologies can also be applied to practical teaching. For instance, the combination of AI and virtual reality technologies can provide students with immersive and interactive practical learning experiences. Students can simulate complex mechanical systems in a virtual environment, conduct virtual experiments, and receive real-time feedback based on their performance. Simultaneously, BD technology can support project-based learning, providing students with real-world data and problems, allowing them to apply the knowledge they have learned to solve actual engineering challenges. Students can collaboratively analyze data, develop models, and design solutions, strengthening their critical thinking and problem-solving abilities. However, there are still some issues in the current application of BD and AI in the teaching of mechanical engineering major.

Firstly, the curriculum system is unreasonably configured. Most courses in the mechanical engineering major primarily focus on the teaching of theoretical knowledge, and the related practical teaching is relatively insufficient. The curriculum system does not place sufficient emphasis on students' practical learning, fails to provide students with ample practical teaching opportunities, restricts students' practical abilities, and cannot effectively enhance students' employment competitiveness.

Secondly, the teaching method is monotonous. Teachers still adopt traditional teaching methods, teaching theoretical knowledge in the classroom, and students passively participate in classroom learning, with low learning initiative and failing to fully exert the main role of students in learning. In daily teaching, teachers' teaching methods are relatively dull, mainly presenting knowledge points through slides. Classroom teaching is rather lifeless, with limited interaction between teachers and students. Teachers cannot promptly grasp students' learning situations and adjust teaching methods, resulting in a rigid learning atmosphere, low student learning interest, and poor learning outcomes.

Furthermore, the teaching difficulty is considerable. In the current context of intelligent manufacturing development, the teaching of mechanical engineering major in colleges and universities needs to effectively integrate automation, informatization, and networking. Students in this major generally have a relatively weak learning foundation and low learning initiative. Teachers face significant teaching difficulties, and due to the limitations of teaching itself and the constraint of classroom teaching time, the classroom teaching effect is restricted, which to a large extent will also lead to students' aversion to learning and is not conducive to students' mastery of relevant knowledge.

Finally, the cultivation of innovation and entrepreneurship abilities is lacking. The current teaching of mechanical engineering major in colleges and universities emphasizes pertinence, practicality, and advanced nature. In the era of BD, society is developing and updating rapidly, and more attention is paid to the cultivation of talents with innovative spirit and innovation ability. In actual teaching, the mechanical engineering major in colleges and universities has not set up relevant innovation courses, and the curriculum system is not perfect. Students' learning is relatively passive and cannot effectively promote the all-round development of students' current learning abilities.

To sum up, in the context of the era of BD and AI, the innovation of the teaching mode of mechanical engineering major is extremely urgent. This research aims to provide theoretical support and practical guidance for the teaching reform of mechanical engineering major. Through the research on the application of BD and AI in the teaching of mechanical engineering major, new teaching modes and methods are explored. At the same time, through the innovation of the teaching mode, students' practical abilities, innovative spirit and comprehensive qualities are cultivated, the training quality of mechanical engineering professionals is improved, and talent support is provided for the development of the mechanical engineering field in China.

2. Research Status and Application Cases

The teaching of mechanical engineering major is facing new opportunities and challenges in the current era. With the rise of BD and AI technologies, colleges and universities at home and abroad have launched exploration and practice one after another.

2.1. Comparison of Domestic and Foreign Status

In foreign countries, the teaching of mechanical engineering major in developed countries has begun to actively introduce BD and AI technologies and has achieved remarkable results. For example, some universities in the United States apply BD analysis technology to the analysis of students' learning behaviours and the evaluation of teaching quality, providing teachers with personalized teaching suggestions and improvement measures. Some universities in Germany apply AI technology to the fields of mechanical design and manufacturing, developing intelligent design software and intelligent manufacturing systems, improving production efficiency and product quality.

In China, with the development of BD and AI technologies, the teaching of mechanical engineering major is also actively exploring and innovating. Some universities have begun to try to apply BD analysis technology to the optimization of teaching resources and the evaluation of teaching quality and have achieved certain results. At the same time, some universities are also actively carrying out research on the application of AI technology in the field of mechanical engineering, such as research on intelligent robots and intelligent detection. However, overall, the application of BD and AI technologies in the teaching of mechanical engineering major in China is still in the initial stage, and there is still a certain gap compared with developed foreign countries.

2.2. Analysis of Relevant Application Cases

Following the comparison of the domestic and foreign status, after understanding the overall development situation, let's specifically look at the relevant application cases. These cases further demonstrate the actual application effects and innovation potentials of BD and AI technologies in the teaching of mechanical engineering major.

2.2.1. Knowledge Graph Construction

In order to actively implement the national education digitalization strategic action, deepen the practical application of digital transformation, and comprehensively promote the high-quality development and reform of the mechanical engineering major, many Chinese universities have, on the basis of the existing major construction, combined with the requirements of the "101 Plan" core curriculum construction and the needs of AI technology to empower education and teaching, completed the construction of the mechanical engineering major knowledge graph [6].

The construction of the mechanical engineering major knowledge graph covers many professional core courses, such as "Engineering Graphics", "Engineering Training", "Engineering Materials", etc. Based on the structured and systematic logical relationship of knowledge points, a digital knowledge graph is established to display a complete visual graph of the knowledge architecture of each course. With knowledge points as the granularity, rich and systematic learning resources are attached, integrating digital teaching resources, teaching content, teaching process, and teaching evaluation. The completed course knowledge graph can realize the search of knowledge point content, and the system can recommend related knowledge points, knowledge point learning paths, knowledge point portraits, detailed information of knowledge points, and learning resources. Combined with the AI intelligent teaching assistant, it provides students with personalized intelligent question answering and resource search, which not only stimulates students' learning interests and internal driving forces but also meets students personalized and accurate learning needs.

The complete professional knowledge graph system emphasizes knowledge intersection and forms a professional curriculum layout system characterized by intersection and integration, helping students explore knowledge connections, establish a complete professional core knowledge system, and enhance the cultivation of students' heuristic thinking and active learning ability. Through AI intelligent analysis, the correlation and similarity of interdisciplinary knowledge points in the major are analysed, the teaching effect is quantitatively analysed, and a resource construction guide is formed to guide major construction, providing data support for managers to optimize curriculum settings and resource allocation; providing teaching support for teachers to promote the digital transformation and intelligent upgrade of education, reconstruct teaching methods, improve teaching models, and optimize teaching evaluation; meeting students' personalized learning needs, promoting students' autonomous learning, continuously improving teaching quality and students' learning efficiency, and implementing and promoting the new paradigm of educational informatization and digital teaching through deepening the integration and innovation of information technology and education and teaching.

2.2.2. Innovation in Teaching Methods

In the context of AI, there are new innovation points in the teaching of mechanical engineering major in colleges and universities.

On the one hand, AI innovates teaching methods. In the traditional teaching mode, teachers adopt "cramming" teaching, suppressing students' learning initiative and making it difficult to improve students' professional abilities. By integrating AI into mechanical major teaching, it can enrich teachers' teaching means, innovate teaching design, and build a complete knowledge system targeting students' knowledge weaknesses. Teachers can use AI to count students' preview key points and difficulties, and teach with a clear purpose in classroom teaching. They can also transform abstract knowledge into concrete forms to help students understand. For example, teachers can make videos or animations with good visual effects for relevant knowledge points and skill difficulties, and students can use AR software to scan and realize the three-dimensional display of resources, getting close to abstract knowledge and thus helping understanding. At the same time, teachers can also realize the precise search of mechanical major courses through the man-machine dialogue mode, so that students can get quick answers when encountering problems, and realize real-time communication through the community discussion function.

On the other hand, AI innovates learning methods. In the past, students obtained knowledge through books and textbooks, which was a dull way and it was difficult for them to directly ask teachers when encountering problems. In the context of AI, students' learning methods and knowledge acquisition methods have changed. Teachers fragment the teaching resources in many aspects such as course content, task objectives, and knowledge and skills, and build a complete digital teaching classroom system. When students encounter problems, they can query and communicate through the network, truly realizing the improvement of learning efficiency. Teachers can also monitor students' learning situations through various learning softwares, including course learning duration, course task completion degree, and the focus knowledge points of the issued questions, etc., helping teachers conduct timely teaching analysis, adjust teaching plans, and achieve the purpose of teaching students in accordance with their aptitude.

The above cases reflect the actual application of BD and AI in the teaching of mechanical engineering major from different aspects, providing a practical basis for the subsequent proposal of teaching mode innovation strategies.

3. Innovation Strategies for the Teaching Mode of Mechanical Engineering Major

In the context of the era of BD and AI, the teaching methods of the mechanical engineering major have ushered in many innovation points, as shown in Figure 1.

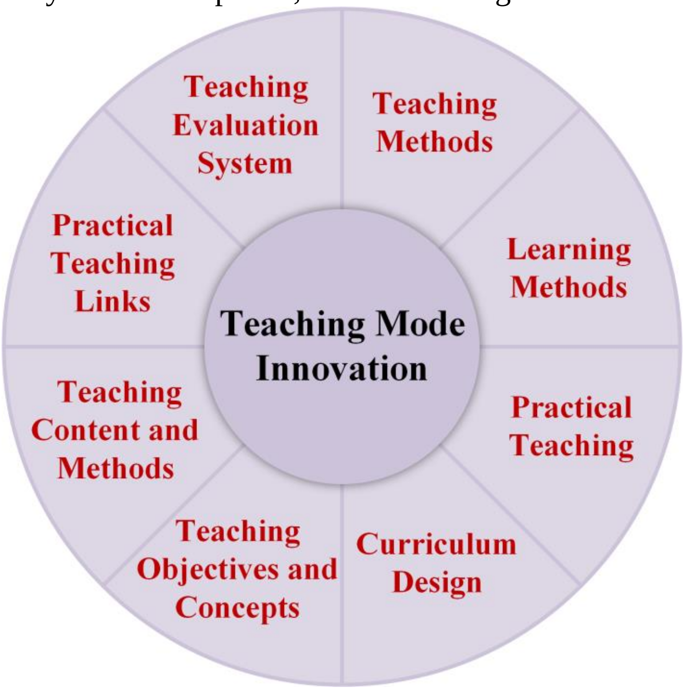

Figure 1: Eight aspects of teaching mode innovation.

3.1. Innovation in Teaching Methods

Enriching Teaching Means: Educators can leverage AI technology to help teachers innovate teaching design. By gauging students' preview challenges, they can understand learning needs and confusions for targeted design. Meanwhile, enabling man-machine dialogue for course content search aids students in accessing resources. Additionally, community discussions enhance teacher-student and student-student interaction, boosting students' learning interest and engagement.

Knowledge Visualization: Leveraging AI technology, teachers can convert abstract mechanical engineering knowledge into visual formats like videos and animations. This enables students to comprehend and master knowledge more intuitively. Simultaneously, AR software showcases real-world application scenarios, enhancing learning interest and practical skills. Moreover, VR and AR technologies offer immersive practical learning experiences, letting students perform mechanical design, manufacturing, and testing in virtual settings, thus boosting their innovation and practical capabilities.

3.2. Innovation in Learning Methods

Digital Teaching Classroom System: Teachers should establish a digital teaching classroom system, segment teaching resources, and enable students to learn and communicate effortlessly anytime, anywhere. Students can access learning materials, share experiences, and submit assignments online, overcoming traditional teaching's time-and-space constraints. For instance, in the "Engineering Graphics" course, they can utilize digital resources for self-study and seek help via community discussions to enhance learning outcomes.

Learning Situation Monitoring: Teachers can leverage learning software to monitor students' learning metrics, such as study duration, task completion rate, and exam scores. Accordingly, they can promptly adjust teaching strategies and offer personalized learning guidance. For example, for "Mechanical Principles" learners facing difficulties, teachers can customize plans, provide targeted resources and tutoring to help them surmount obstacles.

3.3. Innovation in Practical Teaching

Introduction of AR and Man-Machine Dialogue System: In practical teaching, the integration of AR and man-machine dialogue systems can be introduced. Teachers can develop visual practical teaching materials, enabling students to access the content on mobile devices via QR-code scanning, thus enhancing their learning interest and engagement. Meanwhile, the man-machine dialogue system can conduct precise course-content searches and provide practical operation guidance, facilitating students' self-directed learning and hands-on operations. For instance, in the engineering drawing practical teaching, students can utilize AR to present mechanical parts' 3D models, facilitating intuitive understanding and mastery of relevant knowledge and skills.

Virtual Practical Learning Experience: Integrating AI and virtual reality technologies offers students virtual practical learning experiences. They can simulate mechanical system operations, perform fault diagnosis and maintenance in virtual settings, enhancing practical and innovative capabilities. Meanwhile, BD technology supports project-based learning, enabling students to conduct mechanical design and manufacturing projects, boosting comprehensive skills and employability.

3.4. Innovation in Curriculum Design

BD Analysis of Student Needs: By leveraging BD technology, teachers can precisely analyze students' learning needs and pain points, optimizing curriculum content and teaching methods. For instance, analyzing data like homework completion time and exam scores reveals knowledge-point difficulties, enabling timely curriculum and material adjustments for enhanced teaching effectiveness.

Project-Based Learning: BD technology can underpin project-based learning. Teachers, in line with market demands and real-world problems, assign project-based learning tasks to students. Through group cooperation, students carry out project practices, enhancing their comprehensive and innovative capabilities. For example, in the mechanical design course, based on market needs, teachers offer mechanical product design tasks, and students, via activities like consulting materials, devising schemes, and making models, improve their mechanical design and innovative skills.

3.5. Innovation in Teaching Objectives and Concepts

Clear Teaching Objectives: Teachers must clearly define the teaching objective of cultivating mechanical engineering professionals equipped with BD and AI literacy, innovation, and practical skills. During teaching, they focus on developing students' capabilities for fault prediction and optimized design using these technologies in the mechanical engineering field, enhancing students' employment competitiveness and career prospects.

Advanced Teaching Concepts: Educators should adopt a student-centric teaching philosophy, stressing personalized learning and interdisciplinary collaboration. They leverage BD to analyse students' learning behaviours and needs, offering tailored learning guidance and services. Simultaneously, they inspire students to engage in interdisciplinary cooperation, fostering comprehensive skills and innovation. For instance, in mechanical engineering curriculum design, students can be urged to collaborate with those majoring in computer science or electronic engineering for the intelligent design and development of mechanical products.

3.6. Innovation in Teaching Content and Methods

Optimization of Teaching Content: Educators need to incorporate BD and AI knowledge, updating the mechanical engineering major’s curriculum content. They introduce advanced data collection methods and analysis tools like sensor technology and data-mining algorithms, enabling students to master BD and AI application techniques in mechanical engineering. Meanwhile, they highlight knowledge intersection and integration, constructing a knowledge graph for students to build a comprehensive knowledge system.

Innovation in Teaching Methods: Teachers should implement innovative teaching approaches, including interactive learning and personalized instruction. By integrating AI and virtual reality technologies, they offer students hands-on learning experiences, enhancing students’ learning interest and engagement. Teachers also advocate project-based learning, enabling students to apply acquired knowledge in real-world projects, thus improving their comprehensive and innovative capabilities. For instance, in the Mechanical Manufacturing Technology course, project-based learning can be employed, where students design and manufacture a mechanical part, mastering relevant knowledge and skills through practical operations.

3.7. Innovation in Practical Teaching Links

Establishment of School-Enterprise Cooperative Practice Bases: Universities must enhance school-enterprise collaboration, establishing on-campus training bases and off-campus practical teaching bases featuring work-study integration. The on-campus base can replicate enterprise production environments, enabling students to perform practical operations therein, thus boosting their practical skills and professional qualities. The off-campus base offers internship and job-hunting opportunities, helping students grasp enterprise needs and industry trends, and enhancing their employment competitiveness. Moreover, base construction in school-enterprise integration promotes industry-academia-research cooperation, improving teachers’ research and teaching levels.

Encouragement of Scientific Research Projects and Innovation Competitions: Universities ought to arrange for students to engage in diverse scientific research projects and innovation contests, like the “Challenge Cup” and “Mechanical Innovation Design Competition”. Through such participation, students can enhance their innovation and practical capabilities, while also bringing honours to schools and enterprises. Additionally, universities can stimulate student involvement via professor salons and college-led initiatives, fostering their research interest and innovation awareness.

3.8. Innovation in Teaching Evaluation System

Establishment of Diversified Evaluation Indicators: Teachers need to formulate a diversified teaching evaluation indicator system, encompassing aspects like learning achievements, practical capabilities, and innovation skills. Learning achievements may consist of indicators like exam scores, homework completion, and classroom performance. Practical abilities can be appraised according to students' practical operation performance and internship reports. Innovation abilities can be judged by referring to scientific research project accomplishments and innovation competition awards. This system enables a comprehensive and objective assessment of students' learning outcomes and overall qualities.

BD and AI-Assisted Evaluation: BD and AI technologies can be harnessed to support teaching effect evaluation and student learning behaviour analysis. BD tracks students' learning achievements and behaviour data, offering a basis for teachers to assess teaching effectiveness. AI analyses students' learning habits and difficulties, providing personalized teaching suggestions. For instance, analysing online learning time and progress data helps understand students' habits and efficiencies, enabling teachers to give personalized guidance.

4. Challenges and Countermeasures

4.1. Challenges

Although there are many strategies for innovation in the teaching mode of mechanical engineering major under the drive of BD and AI, challenges still remain in the implementation process.

Technical Application Difficulty: Applying BD and AI technologies in mechanical engineering teaching demands that teachers and students have specific technical literacy and operational skills. Yet, for some, mastering these is challenging, necessitating specialized training. Moreover, tech updates add ongoing learning pressure.

Data Security and Privacy: Collecting and using BD implicates students' personal info and learning data, entailing data security and privacy leakage risks. Ensuring data security and privacy is a key challenge for BD- and AI-driven teaching mode innovation in mechanical engineering.

Teaching Resource Construction: BD- and AI-driven mechanical engineering major teaching demands substantial teaching resource support, like teaching videos, courseware, and practice questions. Crafting these resources demands much time and effort, and teachers need certain development capabilities. Moreover, resource quality and update speed directly impact teaching effectiveness.

4.2. Countermeasures

In response to the above challenges, corresponding countermeasures need to be taken to ensure the smooth progress of teaching mode innovation.

Strengthening Teacher Training: Universities can arrange for teachers to attend training courses and seminars on BD and AI technologies. This enhances teachers' technical proficiency and teaching capabilities. During training, inviting enterprise experts and technicians to lecture and guide helps teachers grasp the latest industry trends and application cases. Additionally, schools can motivate teachers to engage in research projects and innovation competitions, thus improving their technology-application and innovation skills.

Improving the Data Security Management Mechanism: Universities should establish and refine a data security management system to safeguard students' personal and learning data. By leveraging encryption and access control, data storage and transmission are secured. Also, universities enhance data security and privacy education for teachers and students to boost their awareness and self-protection.

Integrating Teaching Resources: Universities should enhance school-enterprise cooperation, integrating teaching resources from both sides to jointly develop high-quality ones. They should encourage teachers and students to partake in resource development and sharing, and establish a platform for easy access and utilization.

5. Conclusions

This research centres on the BD- and AI-propelled innovation of the mechanical engineering major's teaching mode. In the information-age backdrop, while these technologies present numerous opportunities for mechanical engineering education reform, like offering data-based support for teaching optimization and enabling intelligent teaching aids, the current application in mechanical engineering teaching still has flaws. These include problems in the curriculum system, teaching approaches, teaching difficulty levels, and the nurturing of innovation and entrepreneurship capabilities. By comparing domestic and international situations and analysing relevant application cases, it's clear that foreign countries have achieved notable success. In contrast, China, despite active exploration, is still in the nascent stage with a distinct gap. Cases such as knowledge graph construction and teaching method innovation have shown practical application results and innovation potential, laying a practical foundation for subsequent teaching-mode innovation strategies. Consequently, a series of such strategies are put forward, covering teaching and learning methods, practical instruction, curriculum design, teaching goals and concepts, teaching content, and evaluation systems. However, during implementation, challenges like technical application hardships, data security and privacy concerns, and teaching resource building issues arise. Thus, countermeasures such as enhancing teacher training, perfecting data-security management mechanisms, and integrating teaching resources should be adopted.

In essence, this teaching-mode innovation is a complex systematic undertaking that demands the collaborative efforts of schools, teachers, students, and enterprises. With the ongoing development and application of BD and AI, the mechanical engineering teaching mode will keep evolving, better serving the cultivation of high-calibre mechanical engineering professionals.

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References

[1] Li Huaqing, Xia Dawen, Wang Lin, et al. (2020) Systematic Practice of Cultivating Innovative Ability of Postgraduates in Era of Big Data. Journal of Southwest China Normal University (Natural Science Edition), 45(11), 171-175.
[2] Xia Dawen, Zhang Zili. (2016) On Training Mode of Big-Data Talents in the Age of Data Technology. Journal of Southwest China Normal University (Natural Science Edition), 41(9), 191-196.
[3] Chen Jingyuan, Hu Liya, Wu Fei. (2023) Investigation into the Transformation of Knowledge-Centered Pedagogy with ChatGPT/Generative AI. Journal of East China Normal University (Education Sciences), 7, 177-186.
[4] Xu Tao, Yan Li, Yin Junfeng, Zhou Bin. (2018) Development Models and Approaches of AI+ "New Engineering" from the Perspective of Innovation and Entrepreneurship Education. Journal of Distance Education, 1, 80-88.
[5] X. Liu, G. Wang, J. Wu. (2021) The Research Status, Progress, and Future Trends of New Engineering Education. Journal of Northwestern Polytechnical University (Social Sciences), 4, 63-70.
[6] Ding Guofu, Wang Shuying, Ma Shuwen, Zhang Jian. (2024) Exploration of Construction Model for Industry-Education Integration Curriculum System Based on Knowledge Graph. Research in Higher Education of Engineering, 2, 79-83&90.