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Exploration of Teaching Reform in Big Data and Data Mining Course under the Background of New Engineering Education Initiatives

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Abstract

This study explores teaching reform strategies for the Big Data and Data Mining course in response to the requirements of New Engineering Education Initiatives. The course currently faces challenges such as rigid teaching models, limited practical environments, and an underdeveloped assessment system. To address these issues, several reform strategies are proposed. First, a blended teaching approach that integrates online and offline instruction through Massive Open Online Courses (MOOC) and classroom teaching is implemented. Secondly, diverse teaching methods, including case-based instruction and innovative project-based learning, are adopted to enhance student engagement, foster active learning, and improve hands-on and problem-solving skills. Finally, the assessment system is restructured to incorporate both formative and summative evaluations, ensuring a more comprehensive assessment of students' theoretical knowledge and practical abilities. The results of the reform demonstrate significant improvements, effectively cultivating high-quality professionals with innovative thinking, practical competencies, and engineering literacy in the field of big data.

Keywords

New Engineering Education Initiatives, Big Data and Data Mining, Teaching Reform, Practical Teaching, MOOC

1. Introduction

Since February 2017, the Ministry of Education has actively promoted the development of New Engineering Education Initiatives. To align with the latest trends in the new wave of technological and industrial transformation, as well as to meet national strategic and regional development needs, the Ministry has accelerated the advancement of New Engineering Education with the goal of establishing an engineering education system that is both uniquely Chinese and globally competitive. The core philosophy of New Engineering Education is guided by the principle of "Foster Virtue and Cultivate Talents" with an emphasis on adaptation to change and shaping the future. Through approaches such as inheritance and innovation, interdisciplinary integration, coordination, and shared development, New Engineering Education aims to nurture future-oriented, multidisciplinary engineering talents with innovative abilities (Yao & Zhang, 2020; Jia, Guo, & Wang, 2024; Wang, 2018). University instructors, as frontline educators, play a crucial role in ensuring effective teaching methodologies and fostering appropriate learning strategies among students.

The Big Data and Data Mining course is a core subject in the Data Science and Big Data Technology major under the New Engineering Education framework. It is a critical component for equipping students with data processing and analytical skills, serving as a foundational course for advanced studies in data analytics, machine learning, and artificial intelligence.

At Inner Mongolia University, Big Data and Data Mining is a specialized course within the Electronic Information Engineering discipline. The primary objective of this course is to help students grasp fundamental concepts and foundational knowledge in big data and data mining, enabling them to clearly understand key data mining tasks and their functionalities. Students are expected to apply basic computational tasks, such as data preprocessing, association rule mining, classification, and clustering, using real-world datasets. Additionally, they should be able to analyze the results of association rules, classification, or clustering to extract valuable insights. The course also emphasizes proficiency in programming languages commonly used for data mining, such as Python and R. Furthermore, students are trained to independently consult academic literature, accurately implement classical data mining algorithms, and apply techniques for data preprocessing, classification, and clustering. Beyond technical knowledge, the course places significant emphasis on the development of students' comprehensive abilities. These include independent learning and problem-solving skills, the ability to continuously track advancements in the field, and enhanced analytical and critical thinking skills through classroom discussions, team projects, and hands-on experiments. Additionally, the course fosters strong communication and presentation skills. In summary, the course aims to develop students with a solid theoretical foundation, strong practical skills, and well-rounded competencies. This study thus explores innovative teaching approaches for this course.

2. Current Teaching Situation and Challenges

A comprehensive investigation into the practical teaching process of the course "Big Data and Data Mining" was undertaken. This investigation was complemented by an analysis of feedback provided by teaching staff and students. The analysis revealed that the current teaching mode employed by Inner Mongolia University is plagued by the following deficiencies.

2.1. Rigid Teaching Methods, Limited Teacher-Student Interaction, and Lack of Student Motivation

The Big Data and Data Mining course requires students to have strong mathematical and computational skills, as it covers a broad and interconnected set of knowledge points. However, the current teaching model primarily relies on multimedia presentations, supplemented by traditional blackboard instruction. Conventional teaching classrooms primarily rely on multimedia presentations with blackboard writing as supplementary support, often resulting in unidirectional "teacher-speaks-students-listen" dynamic, or even "teacher-speaks-students-disengage" scenarios. This approach suffers from insufficient interactive communication, creating a lackluster classroom atmosphere (Song, Li, & Zhang, 2024). Furthermore, this "one-size-fits-all" teaching approach fosters a passive learning environment where students are conditioned to receive information without actively engaging in knowledge acquisition. As a result, they struggle to fully grasp key concepts and fail to develop a comprehensive knowledge framework. This limitation hinders their deep understanding of course materials and their ability to apply knowledge effectively (Tang & Shi, 2019).

2.2. Limited Practical Learning Opportunities and Lack of Collaborative Awareness Among Students

Due to resource constraints, students primarily rely on in-class theoretical knowledge and supplementary online research for practical exercises. However, this approach often overlooks the importance of collaboration, discussion, trial-and-error, and innovation among peers. Additionally, laboratory experiments are predominantly designed to verify theoretical concepts rather than encourage creativity. Many students tend to follow fixed experimental procedures mechanically, merely completing assigned tasks without deeper engagement. This rigid structure significantly limits their ability to develop practical problem-solving skills and hinders their capacity for innovation.

2.3. Incomplete Assessment System and Limited Evaluation of Learning Outcomes

Student learning assessment in the Big Data and Data Mining course primarily relies on final examination scores for evaluation. Although regular academic performance is also incorporated, the completion of homework assignments constitutes a substantial proportion thereof. This assessment method, which centers on the final exam and relatively neglects regular performance, is overly simplistic. It places excessive emphasis on outcomes while downplaying the learning process, prioritizing theoretical knowledge at the expense of practical skills. Such an evaluation approach fails to provide a comprehensive and objective measure of students' learning outcomes. Its assessment framework contains flaws, making it difficult to fully meet the needs for developing students' hands-on abilities and innovative thinking skills.

In response to these challenges, many educators from various universities have proposed and implemented innovative teaching reforms tailored to their institutional contexts. For example, Zhu Yi, Li Yun, and Qiang Jipeng, in their paper, propose a case-based approach to teaching, using case explanations to supplement instruction. They conduct teaching activities from two directions: classroom lectures and practical data set experiments. They also introduce the limitations of data mining methods in the context of specific project practices (Zhu, Li, & Qiang, 2021). Luo Yue, Chen Guozhu, and Mei Shuyu, in their paper, apply data mining techniques to student performance analysis, establishing a fuzzy comprehensive evaluation system and related rules to rank class performance and assess the correlation between subjects (Luo, Chen, & Mei, 2019). Zheng Yifeng, Zhou Yuping, Zhang Wenjie, and Wei Baoya, in their paper, focus on the reform of professional teaching models, exploring new talent cultivation modes from both course teaching and graduation project perspectives (Zheng, Zhou, Zhang, & Wei, 2023).

3. Exploration of Teaching Reform

Based on the current teaching situation at our university, this study explores reforms for the Big Data and Data Mining course to address the challenges in the existing teaching model. The reform initiatives focus on three key dimensions: instructional model, practical learning, and assessment system.

3.1. Reforming the Instructional Model

To address issues such as the rigidity of the instructional approach, insufficient teacher-student interaction, and lack of student motivation, this study explores an innovative blended teaching model that integrates online and offline learning. Specifically, we utilize course resources from the National University of Defense Technology, available on the China University MOOC platform.

As illustrated in **Figure 1**, the reform is organized into three key phases:

Pre-Class Phase: Instructors assign pre-study tasks and recommend online data mining courses from the China University MOOC platform as reference materials. Additionally, pre-study quizzes are designed to assess students' comprehension of the material. Students are expected to complete self-paced learning and take pre-study tests based on the assigned topics. Mid-Class Phase: Based on students' pre-study performance, instructors adjust the focus and strategies of in-class teaching to align with learning objectives. This phase follows a student-centered approach, incorporating problem-based tasks and discussions to enhance student engagement, deepen comprehension, and reinforce key concepts. Post-Class Phase: Instructors assign homework and provide supplementary reference materials. Students consolidate their in-class learning by completing assignments, further reinforcing their understanding of the subject. Additionally, students are encouraged to independently explore the reference materials to expand their knowledge, enhance their application skills, and foster creative thinking and practical abilities. By integrating pre-class, mid-class, and post-class learning in a blended format, this model emphasizes student autonomy and self-discipline, creating a structured and iterative learning process. This approach not only improves knowledge retention and application but also strengthens teacher-student interaction, enhances students' overall competency, and increases classroom efficiency, ultimately leading to deeper understanding and mastery of the course material.

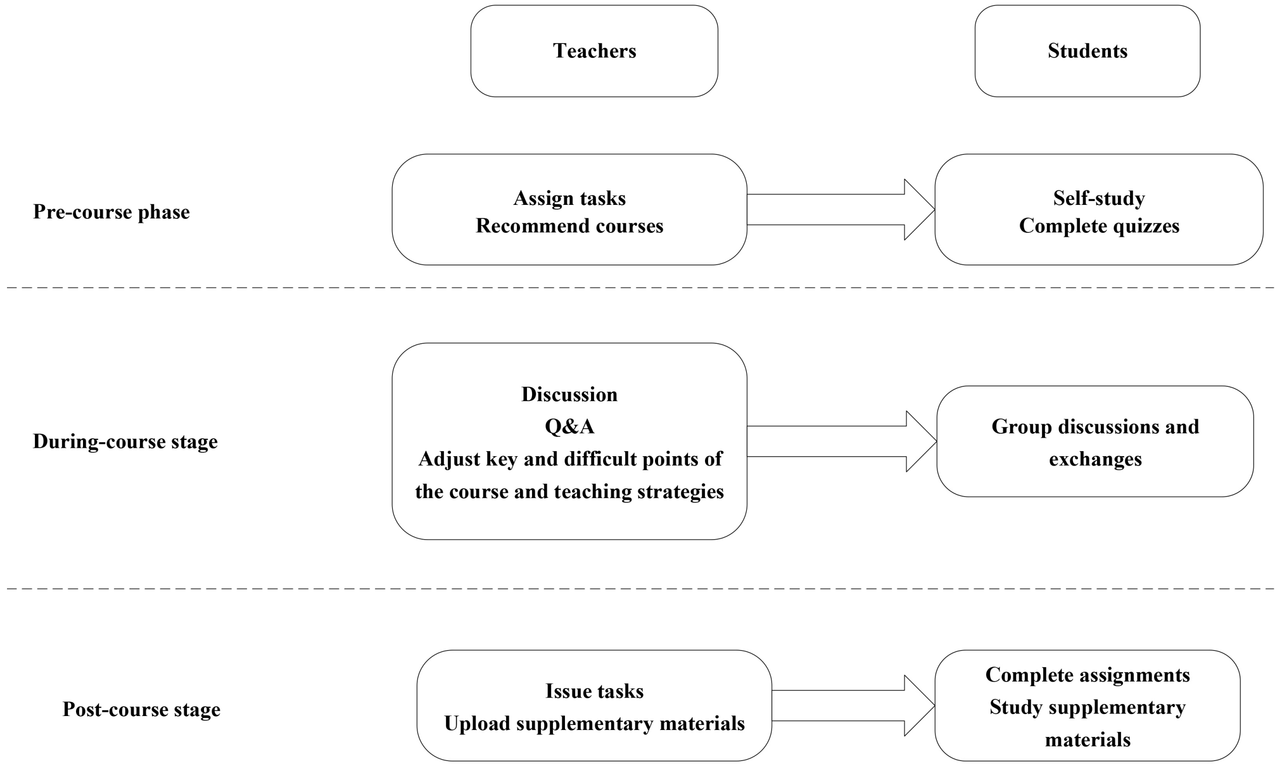

Figure 1. Instructional model workflow.

3.2. Reforming Practical Learning

To address the limitations in the practical learning environment for Big Data and Data Mining, this study proposes a phased approach to practice-based learning, as illustrated in Figure 2. Early Practical Phase: Students receive foundational training in Python programming, equipping them with the skills to implement key data mining algorithms, such as K-means clustering, decision trees, and agglomerative clustering. Mid-Practical Phase: Real-world case studies (e.g., location recommendation systems from data mining competitions) are integrated to bridge theoretical knowledge with practical applications. This approach helps students contextualize abstract concepts, transforming them into tangible problem-solving scenarios. Through hands-on engagement, students gain deeper insights into big data processing techniques and data mining algorithms. Advanced Practical Phase: Students tackle complex, hands-on projects, such as challenges from the Shence Cup University Algorithm Competition. These projects expose students to real-world data-driven problems, enhancing their problem-solving skills in big data applications (Xu & Zou, 2019). Through active participation, students learn to utilize programming languages such as Python and R to analyze large-scale datasets, uncover patterns, and extract meaningful insights to support decision-making. Moreover, the projects emphasize teamwork and communication. Through group discussions and collaborative tasks, students develop teamwork skills, problem-solving abilities, and critical thinking. Instructors guide students through problem analysis, solution design, experimental execution, and results evaluation, fostering their practical competencies and innovative thinking. This practical teaching model not only addresses the issue of an overemphasis on verification experiments and a lack of innovative experiments in practice teaching but also fosters the development of students' innovation abilities, enabling them to better adapt to the demands of a future data-driven society.

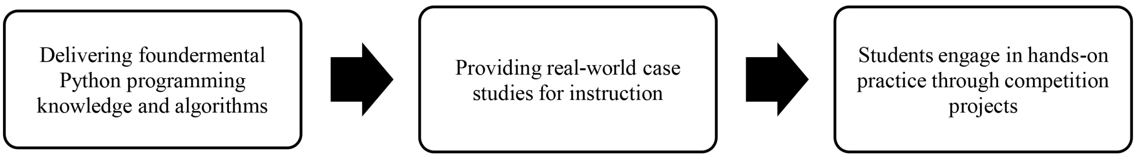

Figure 2. Process flow of practical teaching activities.

3.3. Exploration of Assessment System Reform

To address the inadequacies in the assessment system of the Big Data and Data Mining course and the limitations in evaluating student learning outcomes, this study adopts a competency-based approach, emphasizing dynamic monitoring of the learning process. A diversified assessment framework has been developed, incorporating both formative and comprehensive evaluations (Huang, Chen, & Bai, 2024). This system increases the weight of practical project assessments, requiring students to complete projects in groups, present their findings, and submit corresponding project reports. Additionally, online competitions are integrated into the assessment system, with scores assigned based on competition difficulty and student rankings. Regular assignments take various forms, including case studies and programming tasks. A learning progress tracking mechanism has also been established, where students actively engaging with the online learning platform receive additional credit. In terms of classroom performance evaluation, this study explores a quantitative assessment approach, incorporating regular quizzes and periodic tests. Furthermore, a peer evaluation mechanism is introduced after the completion of group projects, allowing students to assess each other's contributions. Additionally, the teaching team collaborates in the evaluation process, leveraging their expertise to ensure a comprehensive and accurate assessment.

4. Effectiveness of Teaching Reform

This teaching reform was implemented for 53 students from the 2021 cohort of the Electronic Information Science and Technology program at Inner Mongolia

University, following the proposed framework. Student participation in classroom activities was significantly improved, and their academic performance was systematically recorded, ensuring the effectiveness of the reform.

The final examination was conducted as a closed-book test, providing an objective measure of students' understanding and mastery of the course content. However, to compensate for the limitations of relying solely on a final exam, a more diverse composition of coursework grades was introduced. The coursework grades included factors such as class attendance, participation, regular homework assignments, and the completion and quality of group projects.

After a semester of teaching reform practice, the 53 students in the class have been divided into the following categories based on their usual grades: failing (1 student), passing (11 students), intermediate (11 students), good (27 students), and excellent (4 students). As illustrated in Figure 3, the standard deviations of the usual grades and the final examination grades of each marking section are relatively small, which indicates that the usual grades are basically proportional to the final grades. Regular performance scores indicated a substantial increase in student engagement, with more active classroom discussions and improved homework quality. This improvement can be attributed to the addition of group discussions and case analyses, where students collaborate to explore concepts, teach each other, and solve problems together. These activities not only enhanced their teamwork and cooperative skills but also deepened their understanding and application of knowledge. Additionally, the practical learning component significantly enhanced students' hands-on abilities by exposing them to real-world datasets and project-based learning. This experience improved their problem-solving skills.

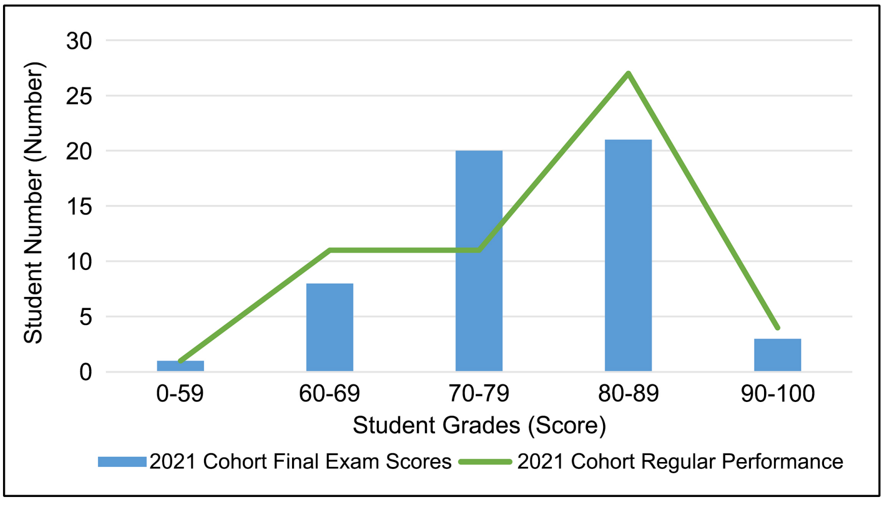

Figure 3. Comparison of 2021 cohort's regular performance and final exam scores.

Analyzed by a one-sample t-test, it was found that the performance of final grades, as one of the important indicators for testing the results of teaching reform, showed the same positive trend. As illustrated in Figure 4, the average final exam score increased by more than five points compared to the previous semester. The proportion of students scoring 90 and above rose from 2% to 6%, while the failure rate dropped significantly from 6% to 2%. These improvements demonstrate the success of the teaching reform in enhancing student learning outcomes.

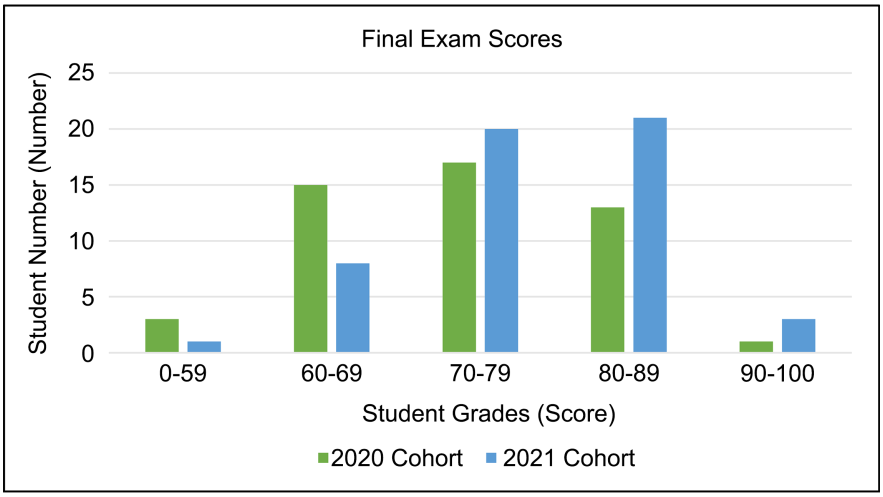

Figure 4. Comparison of final exam results.

Furthermore, we conducted a questionnaire survey to assess students' opinions and emotions regarding this reform. The results indicate that the vast majority of students held a positive attitude toward the teaching reform. They found the new instructional methods more engaging and intriguing, which effectively stimulated their interest and motivation for learning. Additionally, students widely reported that through case analysis and hands-on learning, they not only acquired specialized knowledge but also learned how to apply it to solve real-world problems. This has helped them better adapt to the demands of a data-driven society and has had a profound impact on their professional development.

Overall, the teaching reform implemented for the 53 students of the 2021 cohort in the Electronic Information Science and Technology program has shown promising initial results. The reform has not only improved students' academic performance and overall competencies but has also significantly enhanced their enthusiasm for learning while fostering their innovative thinking and creativity. Nevertheless, in view of the constraints imposed by teaching resources and the existence of a small number of students who do not adapt, the teaching reform of this course will continue.

5. Conclusion

In response to the talent demands within the context of "New Engineering Education," the teaching reform of the Big Data and Data Mining course not only enables students to gain a deeper understanding and mastery of theoretical knowledge and techniques but also significantly enhances their ability to solve practical problems.

Addressing the current state of the Big Data and Data Mining course, educators have implemented effective innovations in the course through three key aspects: the innovation of teaching models, the strengthening of practical teaching, and the improvement of the assessment system. These reforms have fostered interdisciplinary integration, enhanced students' innovation capacity, and developed their practical skills. Concurrently, the course incorporates real-time instruction with the utilization of cutting-edge big data technology. In addition, insights from relevant experts and industry changes are leveraged. These elements facilitate a more precise adaptation to the requirements of the big data era and the cultivation of highly sought-after application-oriented talents.

In future teaching, the university will also collaborate with enterprises to provide students with internship opportunities and industry-related projects, allowing them to apply the knowledge acquired in real work environments and enhancing their employability. Meanwhile, we must strengthen teacher training and build a stronger teaching team to improve faculty professionalism and instructional abilities, ensuring better guidance for students' learning and growth. Additionally, we aim to further deepen educational reform and explore more effective and practical teaching methods. We also plan to integrate the course with regional socioeconomic development, cultivating more high-quality, specialized big data professionals to meet the local demand. This integration will contribute to the digital modernization and transformation of the local economy and support the achievement of sustainable development goals.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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